

TECHNICAL DESCRIPTION

PSS®SINCAL Platform 21.0

Simulation software for analysis and planning of electric and pipe networks

siemens.com/pss-sincal

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PSS®SINCAL Platform

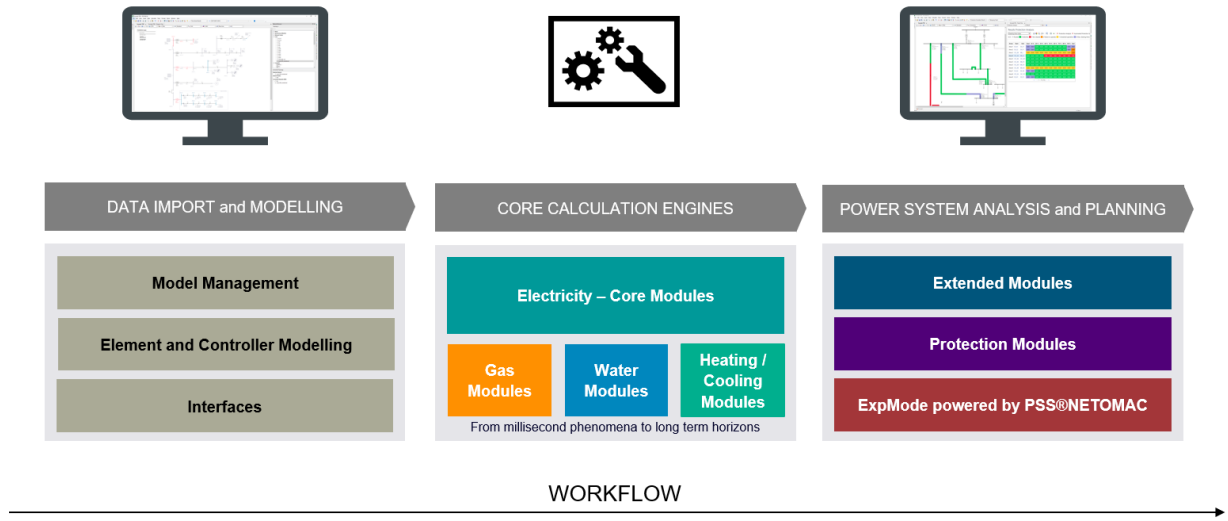


Figure 1: Workflow in PSS®SINCAL Platform from Data Input to Analysis

Overview

The programs of the PSS®SINCAL (**Si**emens **N**etwork **Cal**culation) Platform for network analysis and planning are designed for the calculation, visualization and evaluation of electrical networks and pipe networks.

There are currently two application programs available that use the same program components: PSS®SINCAL and PSS®NETOMAC. In addition to the graphical user interface of PSS®SINCAL, PSS®NETOMAC provides an additional interface for dynamic and transient calculations in expert mode.

Application areas

PSS®SINCAL is a product from practice with a large variety of calculation methods that have proven themselves internationally.

Problems from the following application areas are addressed:

- Energy supply in supra-regional or regional areas by distribution network operators and municipal utilities with electrical energy, district heating/cooling and gas
- Energy supply and generation in campus facilities, quarters and properties (e.g. hospitals) based on electrical energy, district heating/cooling or gas
- Planning of water supply networks in residential water engineering for transport networks or in the connection area of supply companies and support in the operational planning, planning and analysis of the fire water supply
- Energy supply and generation in industrial facilities (e.g. steelworks, paper, aluminum and chemical production plants as well as automobile and aerospace industry) based on electrical energy, district heating/cooling or gas
- Power generation and auxiliary networks of large power plants with special consideration of the mechanical components (turbine, drive train, generator) of a power plant
- Transmission and generation of energy in transport networks, transmission grids and interconnected networks by transmission network operators
- Integration of decentralized, renewable generation systems (DER) in the different voltage levels of the transmission and supply networks
- Traction power supply networks for the supply of traction units/trains along railway lines
- Studies by consulting offices for the use cases described
- Research on current and future questions of energy production and supply regarding control and regulation methods in complex networks, optimization of structures and operating modes as well as concepts for multimodal networks of different energy carriers,
- Training of engineers and planners with model-based simulation software

Analysis and planning tool

More than 50 years of experience in network planning, from the first load flow calculations to complex protection simulations and the observation of dynamic and transient processes are incorporated in the calculation methods for electrical networks. After the start of Siemens network calculations on mainframe computers in 1960, we became known as a center of expertise for electrical network planning. The calculation methods for pipe networks for heating/cooling, gas and water supply have also developed at the same time.

PSS®SINCAL offers a wide range of technical possibilities, a high level of quality as well as a modern user experience. This provides users with the necessary calculation and analysis tools to model, calculate and analyze networks of the different sectors based on the calculation results.

Offers for interfaces and integration projects

In addition to the manual application of PSS®SINCAL via the graphical user interface, the software architecture also allows the flexible integration of individual program components such as calculation methods into other programs and IT architectures. It is also possible to create and enhance network models with external applications as interfaces.

- Interfaces to geographic information systems (GIS), asset management systems, accounting systems and components of control centers
- Integration of software modules in turnkey projects for integrating PSS®SINCAL into the corporate IT environment

Offers for educational institutions, universities and research institutes

The training of engineers at academic institutions requires a comprehensive and easy-to-use software for network analysis and planning. The following three types of licenses are available:

- **Research** license for use in funded research projects
- **Education** license for training groups of students and pupils at institutes and schools
- **Student** license (free-of-charge) for the individual processing of dissertation and project work by students in further education establishments and in schools

Offers for training/courses

It is also possible to arrange customer-specific training and workshops with individual course contents in addition to courses with fixed contents for users of the basic functions.

- Training courses with defined training content on basic functions from the Siemens Power Academy offering
  - Basic courses on modeling and basic calculation methods as well as scripting at the Nuremberg site
  - Basic courses on modeling and basic calculation methods as well as scripting at other sites or in the customer's offices
- Customer-specific workshops and training on specific technical topics on request with technical experts

Support

- Product and user support are provided through various channels and can be combined and requested by the user accordingly.
- Hotline support and access to all updates and upgrades of the software
- Application support related to the individual technical questions of the user by experts in the specific fields
- User meetings in the regions with technical presentations, product news, workshops and exchange with product management and other users

License types

Various license types are available for optimal use in the company.

- Single user license (PC-bound)
- Dongle license
- Network license
  - Multi-user license
  - Floating license
  - Check-out options
- Use of network license in the company
  - Restricted to one site
  - Unrestricted site license within one country
- Leasing license for all license types
- Subscription license for all license types
- Installation on virtual machines (e.g. CITRIX support) for network license type together with subscription license

Languages

PSS®SINCAL currently supports the following languages:

- Chinese
- English
- German
- Russian
- Spanish
- Turkish

System requirements

Hardware requirements (recommended)

- CPU: x64, >= 2 GHz, MultiCore
- RAM: >= 16 GB (>= 32 GB)
- Hard drive space: >= 50 GB (>= 200 GB)
- Graphics card: >= 1920 x 1200, True Color

PSS®SINCAL provides software for 64-bit operating systems:

- Windows 10 and 11
- Windows Server 2016, Windows Server 2019, Windows Server 2022

Supported database systems:

- SQLite 3.x
- Microsoft Access (Support until October 2025)
- Oracle 18c, Oracle 19c, Oracle 21c
- SQL Server 2016, 2017, 2019, 2022

Modules – Electricity Networks

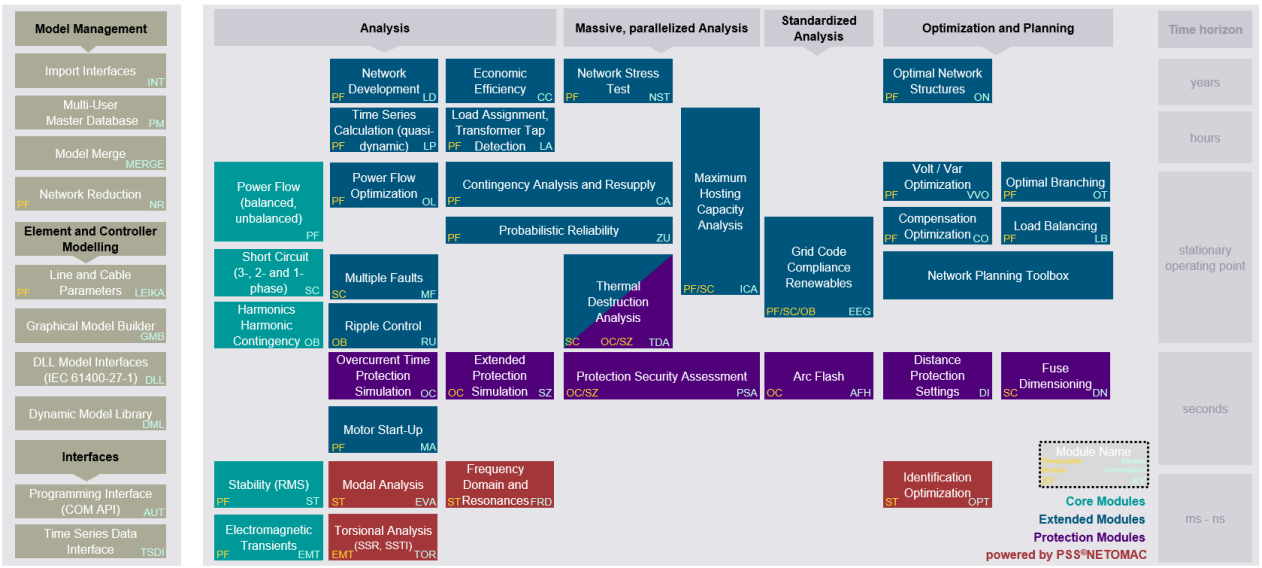


Figure 2: Overview on Modules for Electricity Networks in PSS®SINCAL Platform

Table 1: Overview on Modules for Electricity Networks in PSS®SINCAL Platform

Module Short Name	Module Name	Prerequisite Module
Electrical Networks		
Core Modules		
PSS®SINCAL - PF	Power flow (balanced, unbalanced)	
PSS®SINCAL - SC	Short circuit (1,2,3-phase)	
PSS®SINCAL - OB	Harmonics , Harmonic Contingency	
PSS®SINCAL - ST	Stability (RMS)	PF
PSS®SINCAL - EMT	Electromagnetic Transients (EMT)	PF
Protection Modules		
PSS®SINCAL - OC	Overcurrent-time protection simulation	
PSS®SINCAL - SZ	Extended protection simulation	OC
PSS®SINCAL - PSA	Protection Security Assessment	OC/SZ
PSS®SINCAL - AFH	Arc Flash Calculation	OC
PSS®SINCAL - DI	Distance protection setting calculation	
PSS®SINCAL - DN	Fuse Dimensioning	SC
Extended Modules - Analysis		
PSS®SINCAL - TDA	Thermal Destruction Analysis	SC-OC/SZ
PSS®SINCAL - LD	Network Development	PF
PSS®SINCAL - LP	Time Series Calculation / operating point	PF
PSS®SINCAL - OL	Power flow optimization	PF
PSS®SINCAL - MF	Multiple faults	SC
PSS®SINCAL - RU	Ripple control	OB
PSS®SINCAL - MA	Motor Start-Up	PF
PSS®SINCAL - CC	Economic Efficiency Calculation	
PSS®SINCAL - LA	Load assignment/ Transformer tap detection	PF
Extended Modules - Massive, parallelized Analysis		
PSS®SINCAL - NST	Network Stress Test	PF
PSS®SINCAL - CA	Contingency Analysis and Resupply	PF
PSS®SINCAL - ZU	Probabilistic Reliability Analysis	PF
PSS®SINCAL - ICA	Maximal Hosting Capacity Analysis	PF/SC
Extended Modules - Standardized Analysis		
PSS®SINCAL - EEG	Grid Code Compliance Renewables	PF/SC/OB
Extended Modules - Optimization and Planning		
PSS®SINCAL - ON	Optimal network structures	PF
PSS®SINCAL - VVO	Volt/Var Optimization	PF
PSS®SINCAL - CO	Compensation Optimization	PF
PSS®SINCAL - OT	Optimal branching	PF
PSS®SINCAL - LB	Load balancing	PF
powered by PSS®NETOMAC		
PSS®SINCAL - EVA	Eigenvalues / Modal Analysis (full)	ST
PSS®NETOMAC - TOR	Torsional Analysis (SSR,SSTI)	EMT
PSS®NETOMAC - FRD	Frequency Domain and Resonances	ST
PSS®NETOMAC - OPT	Identification and Optimization	ST
Element and Controller Management		
PSS®SINCAL - LEIKA	Line and Cable Parameters	PF
PSS®SINCAL - GMB	Graphical Model Builder	
PSS®SINCAL - DLL	DLL Model Interfaces (extern, IEC 61400-27-1)	
PSS®SINCAL - DML	Dynamic Model Library	
Model Management		
PSS®SINCAL - PSSE	PSS®E Import and Export	
PSS®SINCAL - INT	Import/Export UCTE/DVG/DGS/CMYDIST	
PSS®SINCAL - CIM	CIM 10,11,12,14,16 div. profiles	
PSS®SINCAL - INT	Excel Import	
PSS®SINCAL - GIS	ESRI ArcMap, ESRI Shape, Smallworld CIM15, MIF, Spatial Database, DBTune, Synergi	
PSS®SINCAL - PM	Multi-User Master Database	
PSS®SINCAL - MERGE	Model Merge	
PSS®SINCAL - NR	Network Reduction	PF
Interfaces		
PSS®SINCAL - AUT	Programming Interface (COM API)	
PSS®SINCAL - TSDI	Time Series Data Interface	

Modules – Pipe Networks

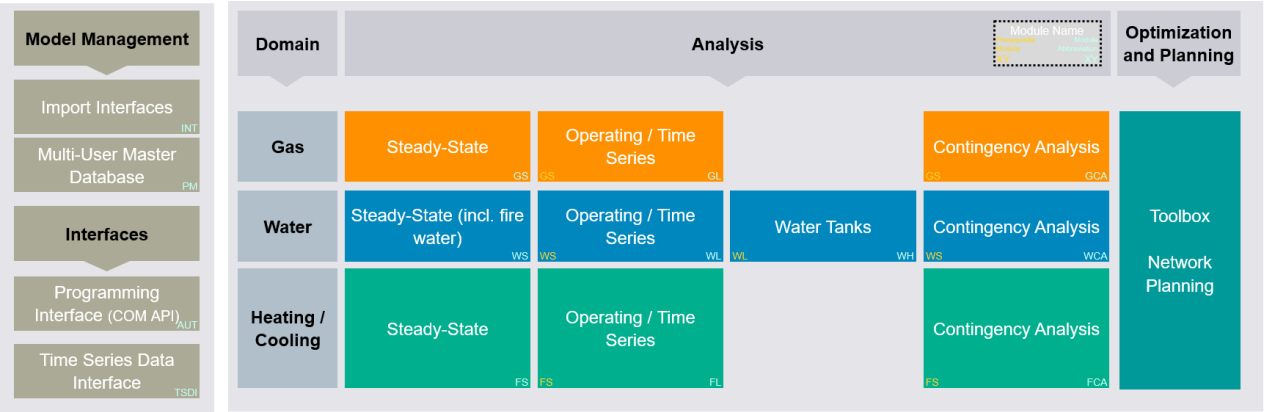


Figure 3: Overview on Modules for Pipe Networks in PSS®SINCAL Platform

Table 2: Overview on Modules for Pipe Networks in PSS®SINCAL Platform

Module Short Name	Module Name	Prerequisite Module
Pipe Networks		
Gas networks		
PSS®SINCAL - GS	Gas steady-state	
PSS®SINCAL - GCA	Gas Contingency Analysis	GS
PSS®SINCAL - GL	Gas Operating/Time Series	GS
Water networks		
PSS®SINCAL - WS	Water steady-state (incl. fire water)	
PSS®SINCAL - WCA	Water Contingency Analysis	WS
PSS®SINCAL - WL	Water Operating/Time Series	WS
PSS®SINCAL - WH	Water Tanks	WL
Heating / Cooling networks		
PSS®SINCAL - FS	Heating / Cooling steady-state	
PSS®SINCAL - FCA	Heating / Cooling Contingency Analysis	FS
PSS®SINCAL - FL	Heating / Cooling Operating/Time Series	FS
Model Management		
PSS®SINCAL - PM	Multi-User Master Database	
PSS®SINCAL - INT	Excel Import	
PSS®SINCAL - GIS	ESRI Shape for pipe networks	
Interfaces		
PSS®SINCAL - AUT	Programming Interface (COM API)	
PSS®SINCAL - TSDI	Time Series Data Interface	

PSS®SINCAL User Interface

(SINCAL GUI)

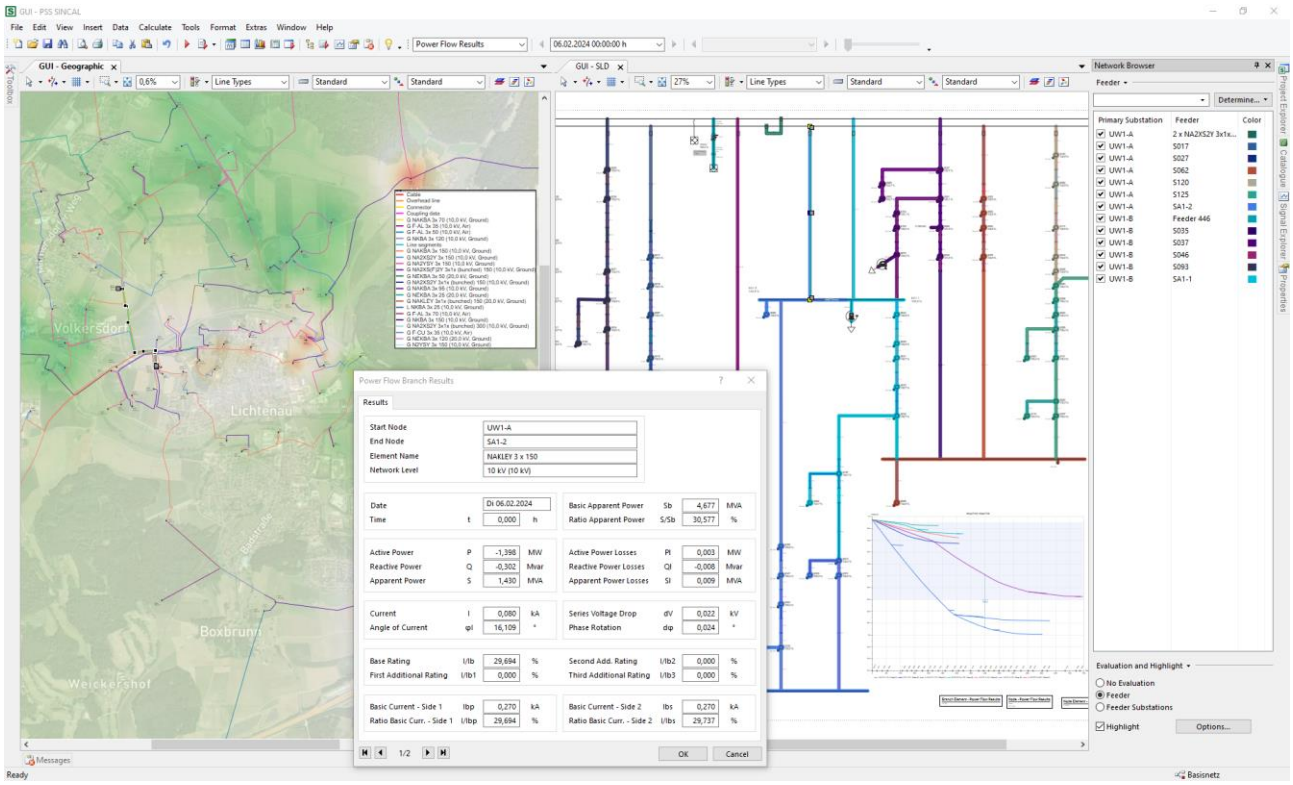


Figure 4: Graphical User Interface (GUI) of PSS®SINCAL

Overview

PSS®SINCAL has a flexible and modern graphical user interface. It offers users intuitive functions for the creation (modelling), editing and evaluation of networks. These functions can also be adapted to the requirements of user workflows. The various phases of a user project are supported here with clear and helpful tools.

The graphical user interface has the same structure and design for electrical networks and pipe networks (heating/cooling networks, gas networks, water networks).

The user interface allows efficient modeling and handling of input data and provides support for the use of the calculation and evaluation options of the simulation results in the network graphic, as well as in diagrams, tables and reports.

- Graphics editor for creating, editing and formatting network elements in the network graphic
- Geographic or schematic visualization of network models of any size (e.g. > 50’000 nodes) in the user interface and interaction similar to a GIS application
- Interactive, web-based overlay of online and offline background maps
- Excellent suitability for network documentation through high-quality graphics and integration of OLE (Object Linking and Embedding) objects
- Integrated network browser, tabular view, diagram and results view as well an integrated reporting tool (List & Label) to simplify the presentation of data and analyses
- Extensive visualization and evaluation functionalities as well as heat maps for input data and results for the rapid identification of network areas, feeders and weak points
- Maintenance of the network model for different tasks in multidimensional, synchronized views (schematic, geographical)
- Support of multidimensional network models (network levels, variants, scenarios, graphic layers, views)
- Comprehensive automation functions for the user interface via the COM interface with various programming languages (Python, VBScript, VBA, C++, C#, etc.)
- Use of the PSS®NETOMAC user interface in Expert mode (ExpMode) for the dynamics and transient engine

User interface

The user-definable graphical interface offers functions for importing and managing network models, the graphics editor, the tabular view, dialog boxes for controlling and starting calculations, diagram and results view as well as other tool windows and browsers.

- User-defined design of the toolbars and position of the views and the tool windows
  - Storage and management of different work environments (according to the project phase)
  - Export and import of workspace areas to secure and preserve custom program settings
  - Creation of user-defined toolbars with frequently used functions
  - Import of diagrams, table and page settings from other projects
- Workflow toolbar supports users by compactly providing most required functions in different use cases
- Fully context-sensitive integration of Help in the screen forms
- Direct switching to the user interface in Expert mode (ExpMode) for the PSS®NETOMAC dynamics and transient engine

Creating and importing network models

The basic requirement for performing calculations and creating studies is the generation and processing of a computable and consistent network model (see Model Management).

The graphical user interface is designed for the initial manual creation and editing of a network model by the user.

- Interactive manual modelling by the user (or automated) in the user interface as a network graphic with the graphics editor and the tabular view

Network models generated with the interfaces already supplied or externally developed can also be edited, extended and validated in the graphical user interface.

- Access in the user interface to the interfaces contained in the product for importing data sets using the supplied interfaces and adapters (see Model Management)
- Integration of functions for managing the network model in the graphical user interface
  - Support of multidimensional network models (variants, scenarios, network states)
  - Integration of the functions for managing and using the master database (PM module)

Editing the network model in the graphics editor

The graphics editor is used to edit and enter the network model with graphical representation as a network graphic. The network graphic is an individual geographical or schematic representation of the network model (or individual subareas) with its input and result data. In addition, the tabular view is also provided for entering and adapting the input data.

- Intuitive graphical Microsoft Windows application with browsers, screen forms, selection fields and lists as well as pop-up menus
- Creation and editing of network elements (nodes, branch elements and node elements) interactively in the network graphic by the user
  - Interactive insertion, positioning and connection of the individual network elements in the user interface
  - Input of the data via the element-specific input screen forms or the tabular view
  - Input screen forms with specific minimum and maximum values for physically meaningful input values of the elements
  - Step-by-step undo function and restoration of the last saved state of the network model
  - Search function in the network graphic
  - Interactive adaption of the network topology by changing the state of switches or of the element terminals with the switch mode
  - Support for the manual or automated generation of graphic representations of network elements
- Checking the input data during manual input regarding topology and technically specified value range
  - Verification of the topological data (e.g. unique node names)
  - Checking the technical values (e.g. for xd" of a generator)
  - Indication of invalid values or values entered outside the standard value range
- Creation and editing of graphic objects and graphics in the network graphic
  - Geometric shapes, freehand lines and text fields as well as highlighting and shading to structure and document the network graphic
  - Adaptive legends to document the annotation of elements with input and result data
  - Integration of active diagrams from the diagram view into the network graphic (automatic update after each calculation)
  - Annotation fields for the documentation of plans
  - Export of the graphic via a menu function to other applications for highly resolved documentation and presentation
  - Integration of SQL database queries in text fields for direct evaluation and graphic display of input and result data from the database

    - Linking graphical and text objects to any input data of the network model, accessible by double-click
- Support for the creation of the network graphic with grids, guidelines, ruler and zoom functions
- Multiple functions for selecting and editing the network elements and graphic objects as well as formatting the graphical representation of the input and result data of the network elements
    - Move, rotate, copy, paste, delete individual network elements or entire groups of elements directly in the network graphic
    - Selection of elements by type or user-defined filters
    - Selection of routes, elements supplied from the element, supply of the element or connected elements (based on last solved power flow)
    - Intuitive functions for formatting the graphical representation (e.g. colors, text types, line types)
    - User-defined annotation of the network elements in the network graphic with the input and result data
    - Free positioning of the annotations of the network elements
    - User-defined selection and display of units, decimal places and automatic unit switching
    - User-defined display and formatting of future or decommissioned elements
- Display of digitized plans or construction views with input data as background graphics
- Display of online or offline background maps from map providers
    - Interactive, web-based overlay of online background maps and possibility to download the required map sections for offline use
    - Support of the providers MapBox, CloudMade, Bing, OpenStreetMap®, Google Maps or generic interface
- Display of the (technical) network model or parts of this network model in any number of individual graphical views (e.g. as one geographical and one schematic view each)
    - Consideration of all elements in the calculation methods irrespective of their graphical representation in the network graphic
    - Schematic and geographical (with scale) views of the network graphic
    - Sheet line-free display in world coordinates
    - Views for drawing in scale mode or WYSIWYG mode (what you see is what you get)
    - Fully synchronized views and selecting of elements in the different views
    - Creation and management of any number of network graphics as views
    - Creation of positions in the views and linking of these positions to graphical elements
- Structured and individualized display of the network graphics through vertical and horizontal structuring with graphic layers and object types
- Evaluation and filter functions for the graphical display of input and result data by coloring the network graphic or the network elements with user-defined colors and value ranges
    - Evaluation functions for temporary coloring of network elements according to various criteria (e.g. operating state, energization, line type, network levels, network areas, object types, ...)
    - Filter functions for three state filter evaluation or evaluation with user-defined filter ranges and colors of input and result data specifically by element type and object type
    - Colored heat maps for the representation of input and result data
    - Full synchronization of the graphical coloring with the respective display of input or result data of the different calculations and calculation steps
- Linking of the topology with the graphical representation of the network model for network tracing, evaluation of network feeders etc.
- Linking graphical representation of the network model with simulation results in tabular view and signal explorer
- Automatic or user-defined generation of the network graphic or the graphical representation of individual elements and network areas
    - Schematic plans with substation layout
    - Function for manual updating of network elements in the views of the network graphic
    - Function for automatic updating of network elements according to different procedures in the views of the network graphic
    - Function for duplicating network graphics in different network views
- Printing or exporting the network graphic for documentation
- Linking and opening of external files (e.g. datasheets as *.pdf) in the input screen form of elements

Editing the network model in the tabular view

Besides the network graphic, the tabular view is also provided for entering and adapting the input data.

- Creation and manipulation of input data in input data tables and evaluation of results in result tables

    - Table with results of the individual result compilation
    - Integration of user-defined SQL views (full SQL syntax functionality) in the database for viewing in the tabular view
- Complete connection of the tabular view with the graphics editor and the element-specific input screen by selecting the graphic element in the network graphic from the pop-up menu of the tabular view
- Use of individual views as well as sorting and filtering functions for the tables
    - Creation and compilation of individual views with predefined filters and column selection
    - Text-based filter line for filtering and searching in the table
    - Selection-based or exclusionary filtering by type, input and result data
- Use of copy and paste of tables (or table sections) to or from Office applications (e.g. Excel)
    - Changing and manipulating a large amount of input data
    - Extraction of results for further evaluation and documentation
    - Column evaluation to determine total values, minimum values, maximum values of the average and standard deviation

Performing calculations and simulations

The calculations can be parameterized and started individually or as multiple calculations directly in the user interface.

- Dialog boxes for parameterization and control of the simulation process
    - Definition of calculation settings, reference values and sizes as well as output options
    - Definition of the scope of the results to be stored
    - Definition and management of plot definitions
- Dialog box for compiling and executing multiple calculations consisting of several individual calculations to be executed in succession
    - User-defined compilation of the calculation methods to be performed
    - User-defined selection of all variants and scenarios to be calculated
    - Automatic execution of all calculations in all selected variants and scenarios with just one click

Evaluation and presentation of results

Tabular view

The tabular view makes it possible to display the calculation results for the different calculation types in result tables. All functions of the tabular view are available for viewing and evaluating the result tables.

Diagram view

An extensive diagram system is provided for graphical representation of input data, results, or reference data from external sources.

- Diagrams with the compilation of time and value-based data series for different calculation methods
    - Input data based diagrams (e.g. for protection devices or profiles)
    - User-defined compilation of the displayed data series
    - Sorted representation of signals
    - y(x) diagrams for verification of characteristics and trajectories
    - Scaling, design, and labeling options
    - Displaying individual data points as point clouds
    - Assignment of additional information (time, frequency etc.) in characteristics
    - Options for integrating evaluation objects and using post-processing functions (e.g. calculation of mean or root mean square values)
    - Min/Max evaluation for the detection of minimum and maximum values in recorded signals as well as their maximum rates of change
    - Access to data points for exporting the data series
    - Evaluation of data series within a variable analysis window (e.g. Delta, 1/Delta)
    - Activation/Deactivation of shown signals
    - Highlighting signals of interest
    - Duplicating and importing diagram pages
    - Copy and delete several signals at once
    - Simultaneous changing of diagram properties
    - Link of time-series results to result view in network graphics
- Assistants for creating individual or multiple diagram pages based on pre-defined templates for specific input data and results (e.g. in the area of protection, motor start, harmonics)
- Simple function for comparing the data series of different variants in the diagrams
- Simple format editor for designing individual diagram pages. Templates can be exported and exchanged within different network models

Result browser

A separate, interactive result browser is available for displaying the calculation results of specific modules.

Result view

The interactive result view offers the view of user-defined result compilations as well as the tabular result dashboards from other modules.

- Interactive compilation of results (Result Cockpit) with the user's individual result view
  - Filter functions
  - Link to the network graphic
  - Export function for creating a report (*.pdf)
- Use case specific presentation of calculation results of different modules (TSDI, PSA, TDA, ...) and synchronized highlighting and coloring in the network graphic
- Display and Filtering of the calculation log messages

Report view

Reports are created with the fully integrated List & Label reporting tool.

- Standard reports are available for many modules / methods
- Creation and adaption of user-defined reports (e.g. individual protection setting data sheet, arc flash labels) and diagrams

Integration of user scripts and programs

The extensive APIs and open data structures of the PSS®SINCAL Platform offer the possibilities to write flexible user-defined scripts and programs (“plug-ins”).

Integration

Scripts and programs are developed by the user in external IDEs and the integration of the program files is supported by the UI of PSS®SINCAL.

- Project explorer to integrate, manage and link repositories containing the scripts and programs
- Direct execution with or without console from the file system structure of the project explorer
- Default interpreter settings (VBScript, Python)
- User defined toolbar buttons and shortcut keys to execute the linked scripts or programs

Interactive Window

The user defined scripts or programs may interact with the interactive window of the user interface. This enables user defined scripts and programs (e.g. starting complex simulation workflows, temporarily adapting model parameters, evaluating results, and much more) staying within the PSS®SINCAL Platform user interface context.

- Supporting the interactive debug mode for power flow solver
- User-defined, externally developed UI components (with user-defined HTML-based interface) to interact (supports input and output) with the process executing the user script / program

Additional functions and tool windows

In addition to the editors and options for evaluating results, tool windows are available for working with projects and the network models opened in the graphics editor.

- **Example explorer** to find and open the example networks
- **Project explorer** enables the efficient project organization of network models and user-defined files with input data and results
  - Project file (*.prj) for structuring the project with a user-defined directory structure
  - Linking of folders and files in the project from directories of the operating system
- **Network browser** with the display of the network topology in a tree structure and link
  - Linking of entries to both input data and results
  - List of neighbor elements connected to an element
  - Provision of the functions for graphical updating
  - Direct link to the corresponding help page
- **Toolbox** tool window with direct access to frequently used modeling and formatting functions
- **Signal Explorer** for organization of signals from steady-state and dynamic calculations, reference series, measurements, and other external data sources
  - Supporting diagram assistant for creating individual or multiple pages for calculation results of harmonics, protection coordination, motor start and other methods
  - Drag and drop of all available signals to user-defined diagrams
  - Loading and using external data sources of different formats as *.csv, *.res, *.out files and COMTRADE format (*.cfg or *.cff)
  - Linking results to network elements in network graphic
  - Multiple filter and selection for signal lists for efficient visualization and exporting
- **Properties tool** window for changing format properties of the selected network elements or views
- **Catalogs** for interactive creation and use of frequently used network elements and standard configurations (e.g. fields, switchgears, substations)
  - Individually designable catalogs for network elements and network element configurations

  - Drag and drop for creating and interactively inserting catalogs into the network graphic
  - Use as (permanent) clipboard for single elements or any complex element configuration
- **Message window** with information about the calculation, warnings and error messages as well as links to help and the tripping element in the protection coordination
- **Help menu** for topic-specific or structured presentation of the chapters of the program manuals

PSS®NETOMAC User Interface

(NETOMAC GUI)

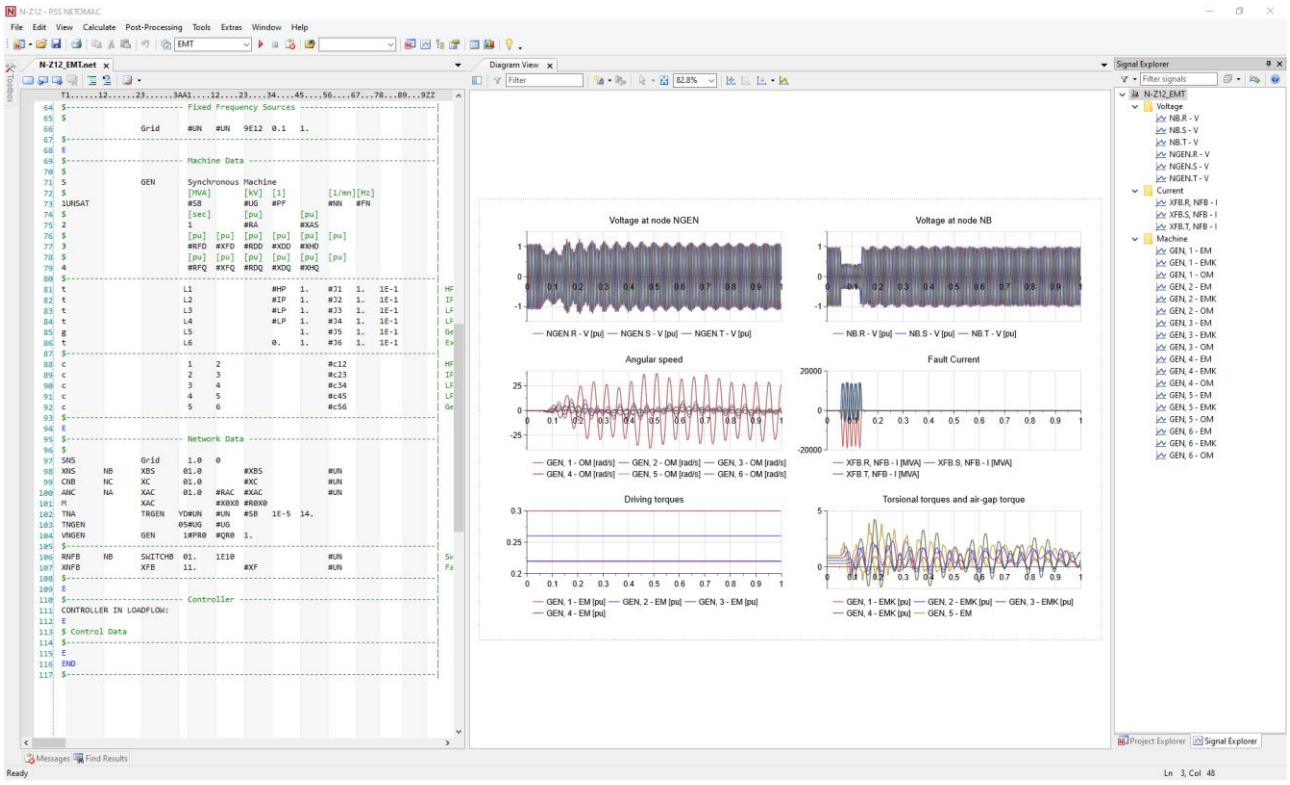


Figure 5: Graphical User Interface (GUI) of PSS®NETOMAC

Overview

The PSS®NETOMAC (NEtworkTOrsionMAchineControl) user interface is the native simulation environment of the PSS®SINCAL Platform for dynamic and transient calculations in expert mode (ExpMode). The customizable graphical user interface is designed for efficient use of the dynamic and transient engine in advanced calculations that require a high level of model detail. It combines the advantages of the high-performance PSS®NETOMAC engine with useful functions for handling, simulating and analyzing user-specific network models.

The engine has a modular structure for use in various user interfaces of the PSS®SINCAL Platform. The engine can be used directly in the PSS®SINCAL user interface for standard calculations of dynamic and transient processes in network planning and analysis as well as in protection analysis. For more extensive calculations, the user can use the expert mode (ExpMode) of the engine. The calculations can also be parameterized and executed with the help of the automation interface (e.g. using VBScript or Python).

The following modules of the PSS®SINCAL Platform are integrated in both the PSS®SINCAL and PSS®NETOMAC user interfaces and can be used extensively:

- Stability (RMS) (ST module)
- Electromagnetic transients (EMT module)

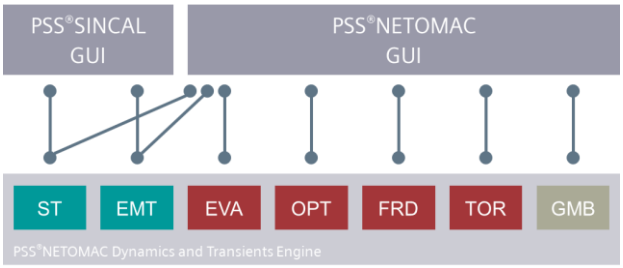


Figure 6: Module Integration in PSS®SINCAL Platform

PSS®SINCAL modules based on these, such as the protection simulation (SZ module), use the functions in the background of a calculation so that no direct access to it is necessary.

The following modules of the PSS®SINCAL Platform are integrated in the native user interface of the PSS®NETOMAC (ExpMode) dynamic and transient engine:

- Eigenvalue/modal analysis (EVA module)
- Identification and optimization (OPT module)
- Frequency domain (FRD module)
- Torsional analysis (TOR module)
- Graphical model builder (GMB module)

The two user interfaces allow the respective calculations as well as an efficient handling of the input data and

evaluation of the simulation results in diagrams and tables.

PSS®NETOMAC user interface

The user interface is designed to suit to the workflows of the users as well as the possibilities of the PSS®NETOMAC dynamic and transient engine. It supports the user in the most efficient use of the advanced modeling and simulation options. The various phases of a user project are supported here with clear and helpful tools.

- **Project Explorer** enables efficient project organization of input and result files
  - Organization of all input data of a project, which is available as ASCII files. In addition to the input data for the network model and the parameters for other models, these contain the essential settings for the simulation
  - Structuring and assignment of standard files according to the specifications of the PSS®NETOMAC engine, which are stored in the project file (*.nprj)
  - Automated renaming of project files and adaptation of the necessary file and diagram links
  - Deletion of results files from the results directories
  - Linking of result directories in which results of different formats are available (*.res, *.out, *.csv). If these are detected, they are provided as series in the signal explorer
  - Configurations allow the variable assignment of standard files depending on the configuration selection so that calculation options and model files can be changed quickly
  - Organization and execution of scripts
- When developing a network model, the user is supported with intuitive editors as well as functions of the dynamic and transient engine that are relevant for the task at hand
  - **Source Editor** supports the user with color-coded column orientation, line numbers, block selection, commenting, bookmarks and other functions
  - **Snippets** are predefined model calls, model parts and other code snippets that can be intuitively implemented in network and controller models
  - **Network Browser** displays the network topology read from the input data and the dependencies of the individual elements clearly in a tree structure. The entries are linked to both the input data and the results. Furthermore, the corresponding help page can be opened directly
  - **BOSL** (Block Oriented Simulation Language) offers the user a wide range of applications for the evaluation and control of simulations as well as for the programming of user-defined models such as excitation systems, governor controllers, variable admittances and many other model types. It contains many predefined functions that can be supplemented with FORTRAN statements. Excessive access to network model signals (e.g. all node voltages or all machine speeds in arrays) allows any type of models for controls, simulation control, evaluation etc.
  - **Graphical model builder** (GMB module) enables the user to graphically develop steady-state and dynamic models based on BOSL. Besides the integration of dynamic link library (DLL module), subsystems with FORTRAN syntax can also be defined
  - Block-related help link with reference to the input format of the respective blocks
  - Conditional **IFTHENELSE queries** can be used for a variable definition of parameters, variants, and the network model itself
- Various tools such as tables, diagrams and export functions are available to the user for evaluating the results of simulations
  - Any **input data** read in can be output in structured files, even after global and local constants have been resolved
  - The results of steady state calculations and modal analysis (EVA module) are displayed in **tables**. These contain useful filter functions and are linked to the network browser. Basic functions allow the calculation of minimum, maximum and average values in the columns
  - The **Signal Explorer** provides the user with the signals obtained from the result files contained in the result directories for evaluation. These can be easily converted into diagrams using drag and drop, copied to other applications or exported in various formats. The filter function and the multiple selection facilitate here the search for the necessary signals
  - If the results directory contains results in the form of *.res, *.out or *.csv files, these are also made available by the Signal Explorer for graphical evaluation
  - The **diagrams** for time- and value-based data series not only contain scaling, design and annotation options, but also options for incorporating evaluation objects and applying post-processing functions (e.g. calculation of mean values)
  - Many calculation methods create log files that contain intermediate steps and final results of a calculation process. These files can be opened directly with the **text editor** or displayed as a log file in the message window
  - In user-defined models, any ASCII character-based files can be created according to defined structures

- Post-processing functions allow efficient, automated processing of results
  - **Min/Max evaluation** for the detection of minimum and maximum values in recorded signals as well as their maximum rates of change
  - Evaluation of **flicker** in the results of time interval simulations according to the standards of UIE/IEC and IEC61000-4-15
  - Dialog boxes for parameterization and control of the simulation process
  - Definition of calculation settings, reference values and sizes as well as output options
  - Plot definition for user-defined recording of any signals contained in a model and definition of global evaluation functions
  - Simple and complex event definitions to simulate a wide variety of error conditions
  - Interactive dialog during various calculations for calculation control
- Tools for creating advanced input data, searching it, encrypting models and automatically searching the stability limit of dynamic network models
  - The **saturation characteristic curve** function enables characteristic curves for inductances and current transformers to be created and output in a suitable format
  - The **Stability Limit** tool determines the stability limit of a network model in conjunction with an abort model using an iterative procedure
  - By **encrypting** models, ASCII character-based models can be encrypted except for the header. The function of the models is retained while the structure is no longer visible
  - **Search function** in files, which are also restricted to certain columns, with a preview and link to the identified lines
- Functions for the import and export of network data, project and program settings
  - Native PSS®SINCAL - PSS®NETOMAC interface that combines the graphical design and management of the network model in PSS®SINCAL with the advanced modeling capabilities in PSS®NETOMAC
  - If the degree of model individualization is limited to individual network elements, these definitions can be used as diakoptics models in PSS®SINCAL
  - Export a project for distribution including all relevant project files in a *.zip file
  - Import of diagrams, table and page settings from other projects
  - Export and import of workspace settings to secure and preserve custom program settings
- Many additional functions for user-friendly handling and execution of dynamic or transient studies
  - Variable-dependent data input by evaluating IF THEN ELSE conditions
  - Efficient application of **parameter variations** through variant calculation, variant-specific diagram labels and result evaluation across variants.
  - Control of variant calculations through dependency relationships
  - Summary related to successful run for massive parameter variation calculations
  - User-defined **evaluation** of simulations in evaluation models with output in the log file or structured ASCII character-based files
  - Optional **real-time mode** for appropriate calculations
  - Use of global variables of the network model to label result diagrams
  - Possibility of **partitioning** network models to map networks of different frequencies including DC networks or for coupling between RMS (ST module) and EMT calculations (EMT module)
  - Functions for signal evaluation during the simulation process such as Fast Fourier Transformation (FFT) with window functions, Matrix Pencil method or determination of auto- and cross-correlations
  - The interpretation of FORTRAN statements by the engine provides a fast and intuitive way to individualize, influence and evaluate the network model according to the user's specifications and to export results

Architecture and Programming Interfaces (APIs)

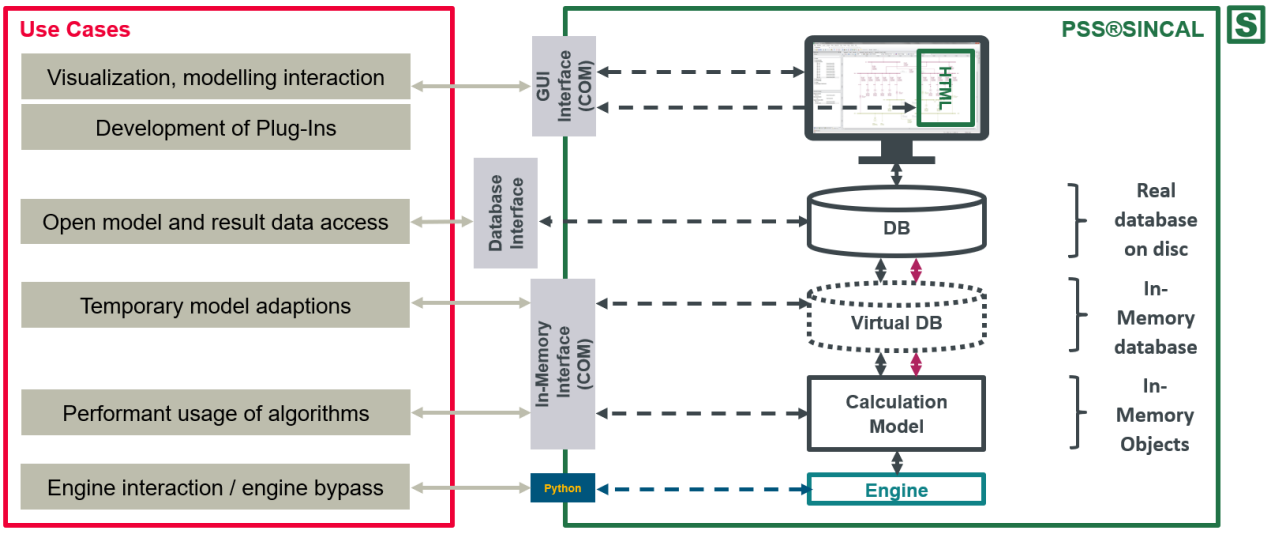


Figure 7: Programming Interfaces in PSS®SINCAL for Different Use Cases

Overview

The open and modular architecture of the PSS®SINCAL Platform enables the flexible integration of data management and calculation methods in IT environments and external programs.

- PSS®SINCAL is a "database application" with completely open data structure
- Management of all relevant input data, libraries and results in relational databases or readable files with read and write access
- Comprehensive programming possibilities via the COM interfaces (API) with standard programming languages (VBA, VBScript, C++, C#, Python, ...)
- Interfaces to the user interface, the virtual database and the in-memory calculation model based on COM technology and to the databases by native interfaces
- Access, modification, and extension of the stored or virtual network model (real or “virtual database”) via the API for automated network planning or model creation use cases
- Access to in-memory calculation model via the COM API and or a native Python API for powerful and high-performance applications

Databases

All data of the network model (input data, geo-referenced and schematic network graphics, simulation parameter and results) are available in relational databases with open structure. The complete PSS®SINCAL data model (including relations, attributes, units, limit values) is comprehensively documented.

- Local or central data storage through flexible, adaptable storage of the network model database on the user's hardware or on a server
  - Single-user system with local stored database (network model)
  - Multi-user mode with a central database (network model) on server
- Supported database systems:
  - SQLite 3.x
  - Microsoft Access (Support until October 2025)
  - Oracle 18c, Oracle 19c, Oracle 21c
  - SQL Server 2016, 2017, 2019, 2022
- Complete and flexible database management
  - Transition (and conversion) between different database formats at any time via the user interface
  - Compression function for the database to delete stored calculation results
- Complete transparency of network model data in open databases or *.xml file based model
  - Flexible read and write access to the database and *.xml files (e.g. switching states) with external applications
  - Documentation of tables and attributes in the PSS®SINCAL Help
  - External SQLite result databases for calculation methods with many results for user-defined post-processing and analysis of the data

    - Enables customer-specific or integrator-developed interfaces to GIS, EMS, SCADA, metering and protection data, ERP and other IT systems.
- Access to the database from the user interface via SQL queries and views in the network diagram and tabular view
    - SQL queries with full syntax regarding selection, linking and evaluation (e.g. mathematical or statistical functions in SQL) of data
    - Display externally generated, user-defined SQL database views in tabular view
    - Direct integration of SQL queries in text fields in the network graphic
- Time Series Data Interface (module TSDI) based on generic open external database to provide time series data as simulation input / start condition

Interfaces for programming languages and scripting

Interfaces are available for the automation of frequently recurring as well as very extensive workflows, the development and integration of user-defined calculation methods or the integration of calculation methods into external programs.

- Comprehensive programming possibilities for automation and simulation control with standard programming languages (VBA, VBScript, C++, C#, Python, ...) via the COM interfaces
- HTML based integration of own developed modules with input and output in the user interface
- Starting and controlling the PSS®SINCAL application from external programs
    - External server (with separate processes) or internal server (with the same process)
    - Enables customer-specific or integrator-developed implementations of user-defined calculation modules (e.g. with integrated HTML user interface)
- User interface API (COM based) for interaction with the graphical user interface and macro recorder
    - Calling user interface functions (such as selection, evaluation functions, feeder determination) via the interface
    - Full interaction between manual user input and function calls of the interface
    - Manipulation and extension (e.g. create new elements) of the network model (save “virtual” in-memory to network database on disc)
    - Functions to support automated graphic generation for missing graphical representation of elements
    - Macro recorder for recording workflows executed in the user interface and saving them as *.vbs or *.py scripts
- Calculation interface API (COM) for interaction with the modelling and calculation engine
    - Management of network data and result access in local „virtual” in-memory network database for performant and local (e.g. if central stored network model database) calculation solutions
    - Manipulation and extension (e.g. create new temporary elements) of the network model in the “virtual” in-memory network database
    - Direct access to manipulate the in-memory calculation model of the network between calculations for high-performant calculation solutions (without reload from database to memory necessary)
    - Use of the calculation methods in the background (as “engine”) for external programs (e.g. GIS system, SCADA system) by creating a temporary/virtual in memory network model, calculation, and retrieval of results without using the PSS®SINCAL user interface
    - Performant simulation based on snapshots of the network model and parallel processing
- Calculation interface API (Python) for interaction with the calculation engine
    - Access to the model parameters of the (for the chosen calculation method) contextualized model
    - Access to the model parameters and results within each calculation step
    - Access to result structures

Time Series Data Interface

(TSDI)

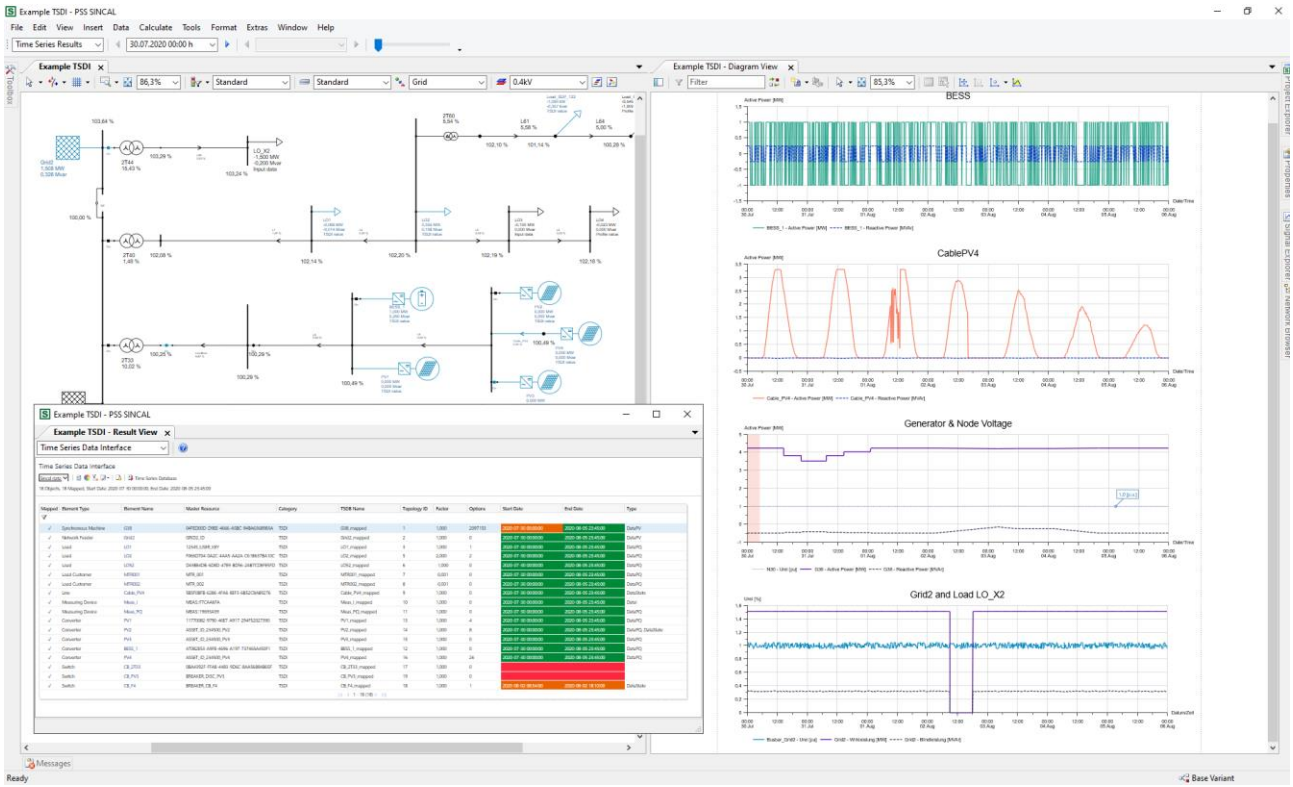


Figure 8: Linking to external time series date (via TSDI) and diagram results of time series calculation

Requirements

Time-stamped data in power systems and pipe networks can have its origin in measurements, forecasts, dispatches or can be derived from planned and unplanned events during operation like switching. These values can cover either past, current, or future periods. The integration of this data into the power system or pipe network simulation as input data, state or boundary conditions is addressing the following use cases:

- Leveraging the asset investment in metering devices/ smart meters and the available infeed data from DERs/IBRs for network and operational planning, (strategic) asset management and grid development strategy
- Strategic decision making for placement of additional measurement devices
- Integration of time series data (measured, forecasted, or scheduled values) for network and operational planning
  - Measured or estimated values: Post-operational analysis of power system or pipe network to validate planning assumptions (for example coincidence) and derive critical or typical points in time as new planning reference scenarios
  - Forecasted and scheduled values: Pre-operational analysis of power system or pipe network and starting point for model-based scenario evaluation and operational planning
  - More accurate planning assumptions (data driven derivation, locally with respect to real operation) than estimations or rough planning assumptions with high security reserves
- Gaining insight on the real utilization and voltage or pressure distribution over time and the residual flexibility of installed assets to minimize future asset invest
- Localize, optimize, and derive planning and operation imperatives based on simulated losses to reduce them strategically and identify potential locations causing non-technical losses
- Leveraging measurements as basis for application of extended methods (for example scaled power assignment in power systems) to obtain “virtual” measurement points for planning and operational planning use cases
- Enablement of network model validation and calibration (impedance or topology)

Solution

The time series data interface (TSDI) module of PSS®SINCAL offers an interface to an open generic time series database for all calculation methods based on time stamps or snapshots.

- Generic open time series database for the TSDI as target for data aggregation and pulling services from different data sources like MDM, SCADA or forecast databases
- Integration of time-stamped active power, reactive power, voltage, or status data and measured, or forecasted feeder currents for power system network models
- Integration of time-stamped consumed or infeed volume, pressure, and status data for pipe network models
- Pre-processing and substitution rules for invalid or bad-quality classified data before insertion into the calculation or simulation
- Full and flexible integration into existing workflows and modules

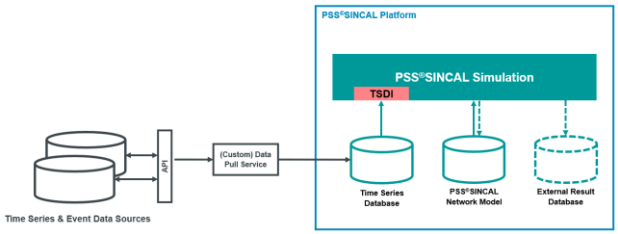


Figure 9: Architecture concept TSDI

Functionality

The TSDI offers several core features as listed below.

- Time series database decoupled from the network model database size and usage, aligned with the external result databases
  - Reduced size of the network model database by external storage of extensive time series input data
  - Reduced size of the network model database in combination with the optional external results databases for time series results
  - Benefits in working with network model databases and multi-user master databases (module PM) on remote servers
- Generic open time series database (SQLite) with mapping based on unique IDs (MRIDs) to the different element types of a network model
  - Mapping based on MRIDs of elements supported by interactive mapping table in the user interface
  - Use a specific database for each snapshot or use one database with multiple snapshot entries
- Generic open time series database for the TSDI independent from time series data source
  - Data pull and aggregation services collecting and preparing time series data use the defined generic data format of the database as target
  - Preparation of time series data from different sources (MDM, SCADA, DER measurement databases, ...) performed independently from simulation
- Consideration of status value for each time step for all types of elements (in service/out of service) and breakers (connected / disconnected)
- Consideration of (phase specific) signal values for each time step for active, reactive power, current or voltage provided according to power flow type of elements of balanced symmetric and unbalanced asymmetric electrical networks
  - Active and reactive power constant (P-Q-Type)
  - Full integration of data into element control structure and signal flow (for example volt-var control)
  - Active power and bus voltage set point (P-V-Type)
  - Bus voltage reference for slacks (V-phi-Type)
  - Full support of phase-specific signal values mapped to symmetric and asymmetric modelled circuit
- Consideration of signal value for each time step for pressure or volume according to flow type of elements in pipe networks (gas, heat/cooling, water)
- Integrated pre-processing and substitution rules for invalid or bad-quality classified data before insertion into the calculation
  - Global and individual option flags for each data point to handle missing data or bad quality data
  - Quality flag for each signal for each time step
  - Consideration of input data and cyclical profiles for unmapped data points, missing data or bad-quality data
- Performant time series simulation of a period or stationary power flow/hydraulic calculation for selected point in time (snapshot)
- Alignment of the two concepts of time-stamped input data on the one hand and recurrent profiles on the other hand
  - Avoid usage of profiles (without time step) for long and time-stamped data
  - Usage of profiles only for recurring behavior
  - Use time step referenced data as input values and in results according to the set view date and period for calculations and simulations
- Time-stamped snapshot as initial condition for power flow for dynamic and EMT simulations (modules ST and EMT)

Results and evaluation options

The result and evaluation workflows with the usage of the TSDI are fully integrated into the other modules and additional support is provided by the mapping table to validate and adapt the mapping.

- Full integration into workflows of other modules (for example modules TS, PF, LA or GS, GL) with respect to modeling, parameter setting, simulation and result evaluation
- Visualization of mapping between time series database data points and the network model elements in an interactive tabular view with visualization capabilities in the network graphic
    - Mapping table to validate the mapping based on the detected MRIDs before the simulation
    - Adaption of pre-processing/substitution options and factors with the mapping table
    - Visualization of the mapped elements in the network graphic

Solution Context

In the solution context (workflow and architecture of several systems for power system simulation and operation) the TSDI module offers further support.

- Enablement of use cases (for example like Redispatch 2.0) by offering the open and generic data model definition for time series data independently from an installation of PSS®SINCAL itself
- Engineering support in the solution design, implementation, and maintenance as well for the integration into the IT-landscape is offered on project basis by a solution team

Model Management

Overview

PSS®SINCAL offers functions for the creation, management, structuring and further development of a network model and the associated network graphic(s). The data collected to describe the network model is available without restriction for use and transfer to other applications.

- Import and export interfaces for common network data set formats and user-definable Excel import
- Support of multidimensional models in relation to the network model (network levels, variants, scenarios) and the network graphic (views, graphic layers)
- Integrated functions for creating, managing and calculating variants, scenarios and network states
- Temporary integration of externally stored network models as "include networks"
- Integrated functions for creating, managing and using element libraries by means of standard databases and catalogs
- Integrated function for central administration of the network model in the network as a master database (repository) with version control and user roles

Creation and editing of network models

The first step for the later network analysis and calculation is the generation and processing of a calculable and consistent network model from the available source data sets. Various procedures are available for this purpose.

- Modeling completely in the user interface (see user interface)
- Manual or automated extension and refinement of an imported network model in the user interface
- Import of data records using the supplied import interfaces/adapters for data formats of other network calculation programs
  - PSS®E (*.raw, *.seq, *.dyr, *.iec, *.har, *.drw, *.loc) version 27, 29, 30, 31, 32, 33, 34
  - DGS exchange format
  - DVG exchange format
  - CYMDIST exchange format (5.0, 7.2, 8.0, 9.0)
  - PSS®U, PSS®ADEPT, PSS®VIPER
  - PSS®Engine HUB file
  - DINIS
- Import of data records using the supplied import interfaces/adapters for standard data formats
  - CIM (based on IEC 61970-301) in the versions 10, 12, 14, 16 (*.xml-based)
  - CIM 12 adapted for Spectrum Power 5 (without graphic)
  - Profiles: CIM standard (CIM10), CIM for planning (CIM12), CIM for ENTSO-E (CIM14) and CGMES 2.4.15 (CIM16)
  - UCTE ASCII file format
- Import of tabular data sets using the supplied configurable Excel import interface
  - Flexible import adapter with user-defined configuration capability for the mapping of tabular columns to the element parameters
  - Individual and interactive configuration by the user in the user interface to assign the tabular data
  - Mode “Test” to test the configuration
  - Mode “Import” to read in network elements, protection devices, additional objects, network graphic and format, data series and characteristics
  - Mode “Update” to read in and overwrite existing parameter values (e.g., load values, protection settings)
  - Identification modes supported: Name, Topology, MRID
- Import of PSS®SINCAL specific network model data sets based on open *.xml files (sincase)
  - Network topology data and element data
  - Network state (switching state, operating state)
  - Parameter (settings) of protection devices
- Import of PSS®SINCAL specific data sets from network data sets or other sources
  - Network graphic and graphical objects (OLE)
  - Data series, profiles and characteristics from other PSS®SINCAL network models
  - Copy and paste from other open projects with automatic back-documentation of alphanumeric networks or external systems
  - Import/export a project including all relevant project files, models and standard type equipment databases (*.sinx) for archiving
- Import library (Python) for pandapower network models (network topology, elements, and graphics) on request
- Generation of the network model by an external interface from the data set of a network calculation software, a geographic information system (GIS) or the network model management of a control system
  - Standard interfaces to GIS systems for user-specific adaptation for Intergraph G/Technology, ESRI ArcMap, ESRI Shape, MapInfo®, AutoCAD® and GE SmallWorld™ (NRM)
  - Individual interfaces of integrators

- Update and merging of different PSS®SINCAL network models with conflict handling (MERGE module)
- Import and export of protection data and protection setting values
  - Import of protection data via Excel interface for protection data and settings that are available in a digital format
  - Import from and export to Gridscale X Protection Data Manager (PDM). In addition to exchanging protection settings, it is also possible to create the protection model based on the import function in PSS®SINCAL
  - Import from and export to protection device configuration files via Gridscale X Protection Data Manager
  - Export of protection data via the protection settings report for documentation purposes and the setting of protection devices in the field

Separate modeling of network graphic and model

PSS®SINCAL allows separate modeling of the network graphic and the network model, and thus also a multiple view of the same network model (e.g. schematic, geographic, by voltage level, network areas) in any number of network graphics.

All elements of the network model are included in the calculation, even if they do not have a graphical characteristic (as a graphic object) in the network graphic. In this case, the results are still available (for example, in the tabular view).

- Structuring of the network graphic with flexible concepts to reflect vertical, horizontal, grouped structure concepts of a power system in the network graphic views
  - Modeling of any number of graphical views (schematic or geographical) of the network graphic
  - Definable zoom positions in views
  - Linking (hyperlinks) of graphical objects with views/positions
  - Graphic layers (vertical)
  - Object types (horizontal) for individual typing and annotation of network graphic elements
  - Graphical network element groups for free combination of network elements
  - Graphical element containers for the clearly arranged representation of complex layouts with many elements
- Import of graphic files into the network graphic and export of network graphic or diagrams into graphic files for documentation
  - Import: DXF, SID, SHP, PIC, SVG
  - Export: BMP, PSP, GIF, JPG, PRN, PNG, PRT, PCL, TIF, DWG, WMF, EMF, DXF, EPS

Network model structure and management

Extensive concepts are available for structuring the network model in order to refine the modeling in relation to the real existing network and its state over its lifetime.

Structuring of the network model

- Network levels (vertical structuring) for displaying the voltage levels of a network
- Network areas (vertical and horizontal structuring) for hierarchical structuring of the network into areas and subordinate areas
- Network zones (horizontal) for free structuring of the network in zones
- Network element groups (partly with function reference, e.g. failure) for free combination of network elements

Timestamp and observation time

- Use of date-related element states for modeling the time-dependent network state (commissioning, decommissioning and maintenance)
  - Simulation is based on a selected time stamp, for which the valid network state is determined
  - Date-related scenario files

Variants

- Variants to support planning tasks
  - Hierarchical structure (tree structure) with any number of variants and sub-variants
  - Inheritance of the changes from the higher-level variants to the subvariants
  - Switch to each individual variant for display and evaluation
  - Possibility to compare different scenarios (input data, results, diagrams etc.)
- Variant management for organizing the variants in a tree structure
  - Variant comparison with option to create a scenario file from differences
  - Create, delete variants and overwrite the base variant
- Display of minimum, maximum and average values of all calculated variants in the network graphic
- Display of variant-specific results in the diagrams

Scenarios

- Flexibly combinable scenarios from individual file-based network states, input values and parameters in the network browser
  - Creation of external scenario files (*.xml)

  - Free and multiple combination of the scenario files to scenarios
  - Import of switching state and operating state files written by 3rd party applications (mapping via MRIDs)
  - New network elements in scenario files (not stored in network model database)
  - Network element data update
  - Calculation settings
  - Flexible arrangement of the scenario files as work packages along the timeline with timestamps
- Free arrangement of work packages or other changes to the network using the scenarios along the time axis
- Combination of scenarios with variants using the multiple calculation in the user interface or the scripting interface

Include networks

- Integration of externally stored and maintained PSS®SINCAL network models (e.g. subordinate voltage levels of substations) as include networks
  - Allows separate data storage, modeling and calculation in the individual network models
  - Management and assignment of link nodes in the user interface
  - Modeling of boundary injections and equivalent loads for the separate analysis of the individual network models
- Temporary merging of the linked network models into a common network model for the calculation

Data model (Database)

- Automatic update of the network model in the version specific data model during opening (or by API) in a new PSS®SINCAL version with guaranteed conversion compatibility. (No backward compatibility after conversion.)
- Direct read and write access to the input data and results in the database possible (see architecture)
- Free database attributes for entering and managing additional data (e.g. transformer filling medium, mapping IDs of GIS, SCADA or MDM systems, UUIDs for CIM)
- Database compression to delete stored result data

Standard type databases and catalogs

The functions for creating, managing and integrating standard type databases are provided for the management and maintenance of libraries for equipment (e.g. lines, cables, protection devices).

- Extensive standard type databases supplied for lines and cables with predefined standard types based on cable manuals and standards
- Create, extend and manage custom libraries as standard type databases with user-defined or customized types
  - Management of the standard type databases in the user interface
  - Standard type databases open for external access
  - Unrestricted distribution of standard type databases on one server or as file on a central storage to allow access for all users
- Creation and use of user-defined catalogs with frequently used network elements

Multi-User Master Database

The master database function (PM module) makes it possible to implement central management of the network model in the network as a master database (repository) with version control and restrict access and management rights by users based on different roles. By that, a multi-user project management with parallel access of authorized users (user rights) to the same master network model (incl. management and error management) can be supported as a process.

Workflow management

In addition to the options for managing the network model in the graphical user interface, extended functions for workflow management are available on request.

Export of data sets

The following formats are available for the transfer of single or complete data sets as well as results to external programs:

- CIM (based on IEC 61970-301) in the versions 10, 12, 14, 16
  - Profiles: CIM standard (CIM10), CIM for planning (CIM12), CIM for ENTSO-E (CIM14) and CGMES 2.4.15 (CIM16)
- PSS®NETOMAC data sets
  - Network sets containing network data and calls of dynamic models
  - Simulation results as readable *.plt or *.dat/*.cfg/.cff (COMTRADE) files
- PSS®E (*.raw) version 32, 33, 34
- DGS exchange format
- DVG exchange format
- CYMDIST exchange format
- UCTE ASCII file format

Geographic Information Systems (GIS) – Interfaces

Geographic Information Systems (GIS) are often used as data platform for geographic models of power systems. Continuous workflows and data streams between these platforms and the PSS®SINCAL platform for grid simulation used in the grid planning and grid operation departments are important. To gain the maximum value from the data (e.g. geographical data, line and cable types) collected in the GIS a proper and customizable conversion of the model to a PSS®SINCAL network model is crucial to enable the various calculation and analysis modules.

Solution

Around the PSS®SINCAL Platform, several standard interfaces with various options to configure or extend the model import and conversion process are offered:

Smallworld GIS – PSS®SINCAL Interface

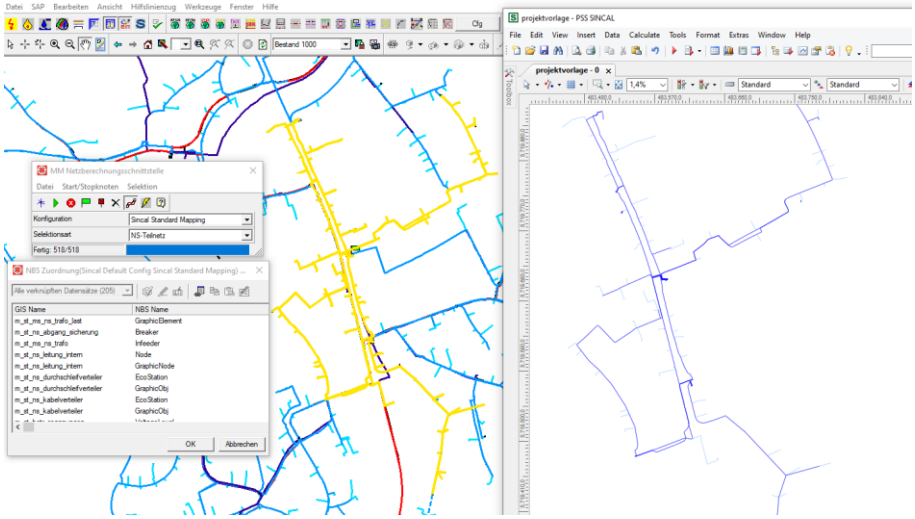


Figure 10: Smallworld GIS – PSS®SINCAL Interface

MIF - PSS®SINCAL Interface

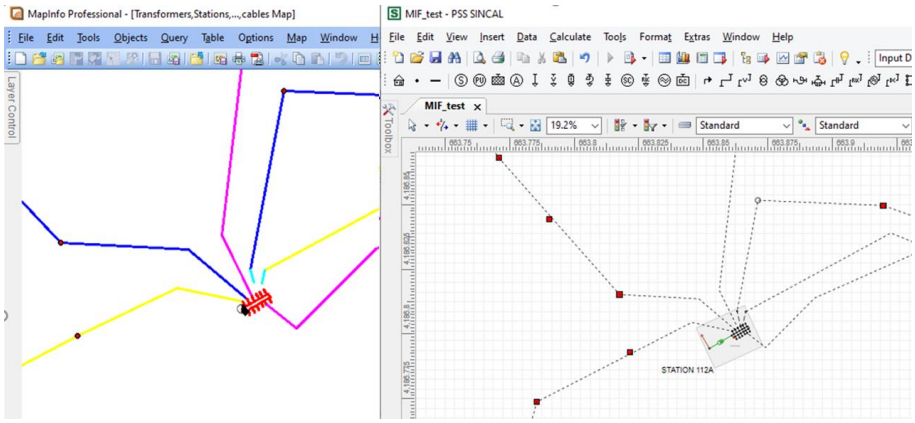


Figure 11: MIF - PSS®SINCAL Interface

ESRI ArcMap – PSS®SINCAL Interface

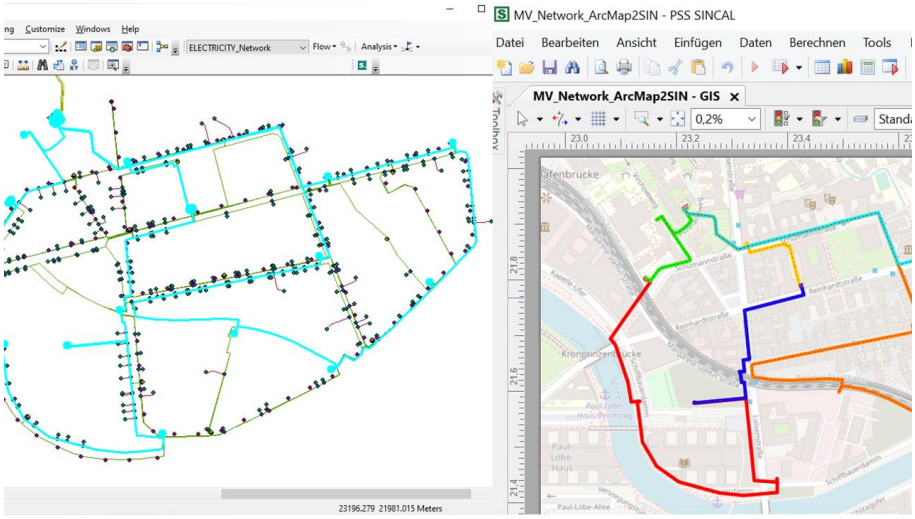


Figure 12: ESRI ArcMap – PSS®SINCAL Interface

ESRI ArcGIS Pro Utility Network (UN) JSON – PSS®SINCAL Interface

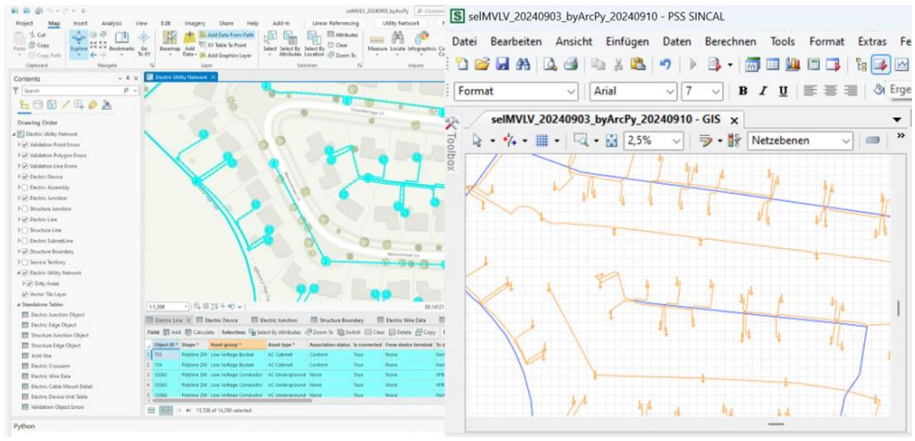


Figure 13: ESRI ArcGIS Pro UN JSON – PSS®SINCAL Interface

ESRI Shape – PSS®SINCAL Interface (Electrical)

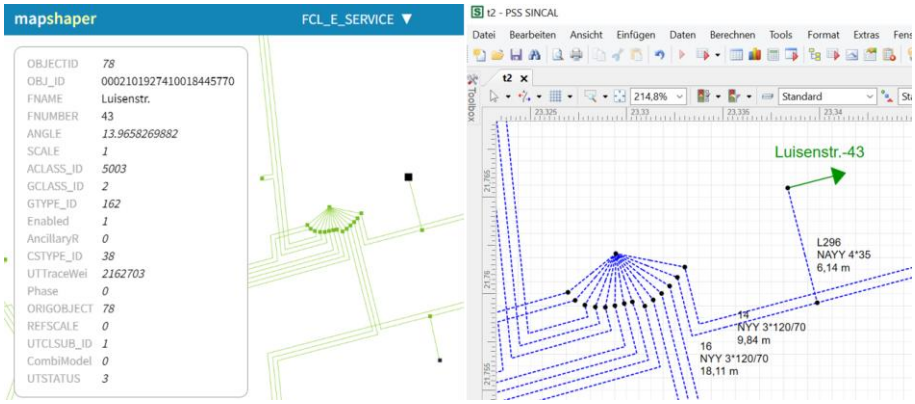


Figure 14: ESRI Shape – PSS®SINCAL Interface (Electrical)

ESRI Shape – PSS®SINCAL Interface (Pipe)

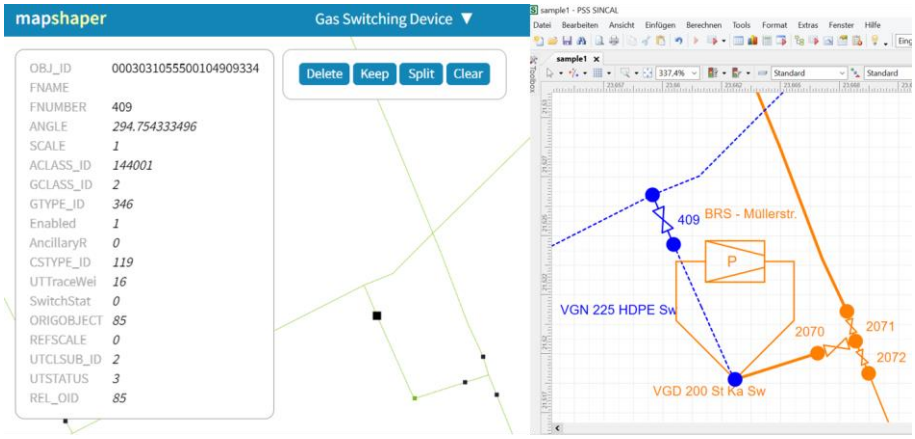


Figure 15: ESRI Shape – PSS®SINCAL Interface (Pipe)

Spatial Database – PSS®SINCAL Interface

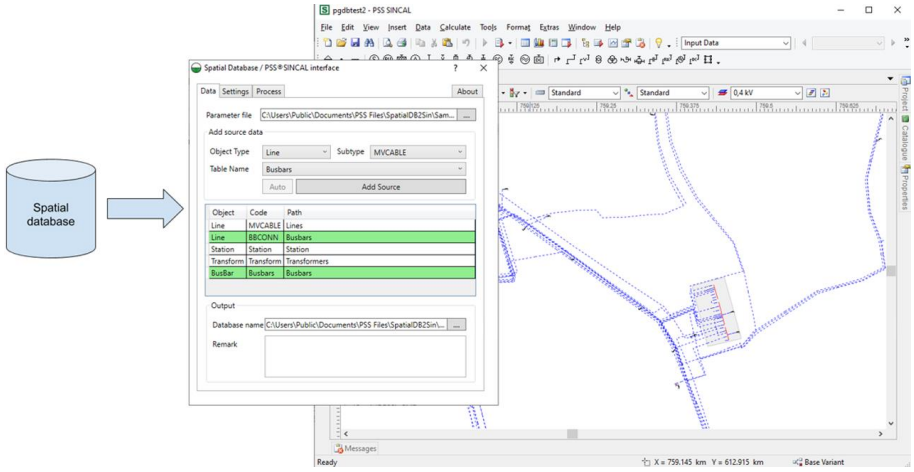


Figure 16: Spatial Database – PSS®SINCAL Interface

Smallworld CIM15 – PSS®SINCAL Interface

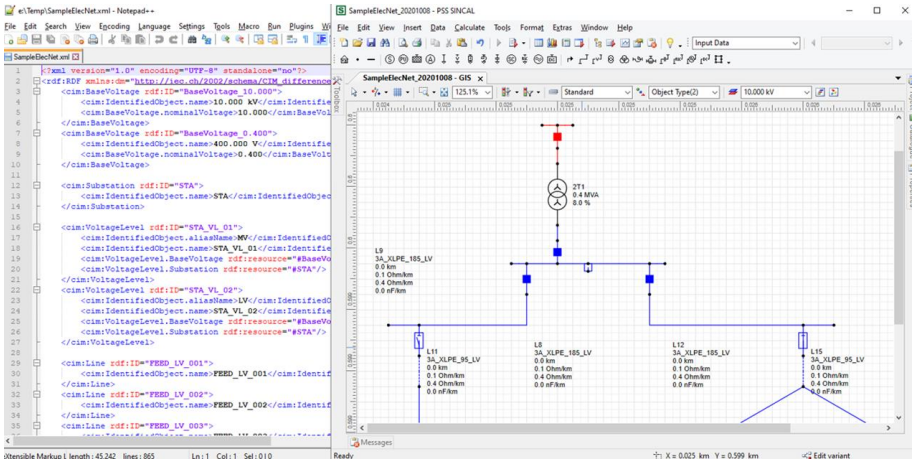


Figure 17: Smallworld CIM15 – PSS®SINCAL Interface

Synergi – PSS®SINCAL Interface

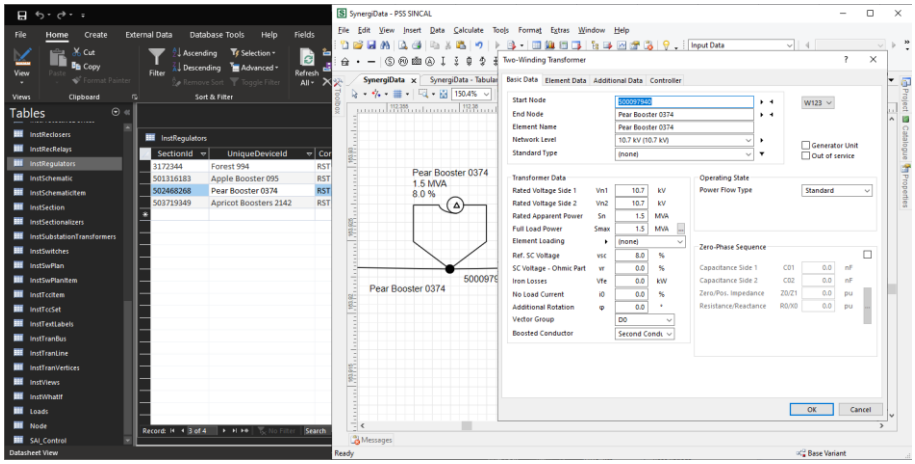


Figure 18: Synergi – PSS®SINCAL Interface

TSDB Manager (Electrical)

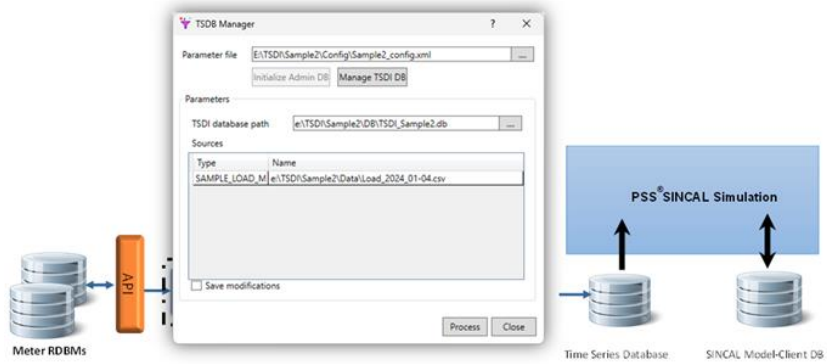


Figure 19: TSDB Manager

Detailed information about the interfaces can be found in this document from page 155 in chapter Model Management – GIS Interfaces.

Network Model Tuner

(DBTune)

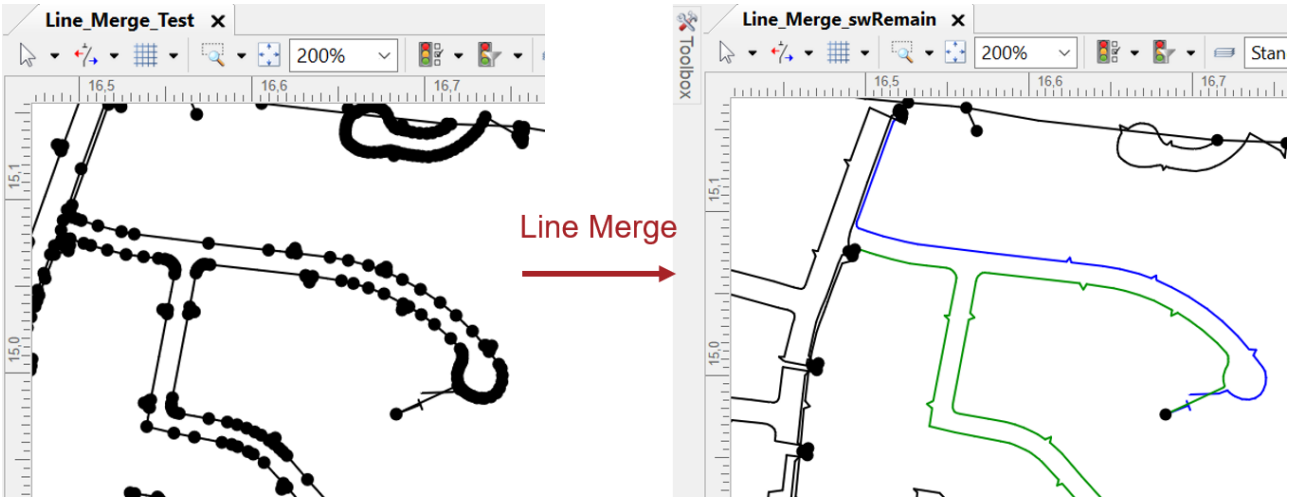


Figure 20: Network Model Tuner

Requirements

The base of the successful network calculation in PSS®SINCAL is the appropriate network model in the database.

The network model can be created by:

- Standard GIS – PSS®SINCAL interface
- PSS®SINCAL import functions
- PSS®SINCAL Excel import
- PSS®SINCAL user modelling via the UI
- Other import or interface solutions

Imported data structures may not be optimal in PSS®SINCAL, because of the different data management and modelling conventions of the source system. In this case the network model in PSS®SINCAL can be optimized.

Solution

The database tuning module (DBTune) for PSS®SINCAL optimizes the PSS®SINCAL network model to enable visualization and performance optimization of the model handling by PSS®SINCAL.

- Tuned network model equivalent to the source network model
- Network model tuning with an optimization of the structure/topology of the network (e.g. merging lines)
- Graphic representation tuning with an optimization of the network graphic (e.g. smoothing of lines) without affecting the network structure/topology
- Flexible combination of the tuning functions according to the user specific requirements

Functions

The tuning rules are defined in the parameter file (*.xml).

The current version of the application supports the following functionalities:

- Merge lines with similar type
- Merge lines at the marked node connection only
- Merge lines with same name
- Merge lines without an opened terminal
- Merge lines without an added breaker or protection device
- Deletion of orphan lines
- Tune node annotation text position
- Tune branch annotation text position
- Set branch symbol at the longest segment
- User defined default values for the graphical element representation
- Line smoothing with angle limit to drop the line's buckle positions, which differs less than the straight direction based on the angle limit

The application can have plug-ins to extend the functionality.

The application can work on the base or active variant of the PSS®SINCAL database.

Results and evaluation options

The result of the automated tuning is a PSS®SINCAL network model containing the updated database.

- Database system SQLite or MS Access
- Optional error and/or log file creation with error messages indicating serious functional problems and warning messages for not serious problems
- Optional log file creation with:
  - Information about the software and hardware environment of the application
  - GUI parameters
  - Summary information about internal processes
  - Summary information about the updated elements
  - Number of errors and warnings
  - Process duration

Multi-User Master Database

(PM)

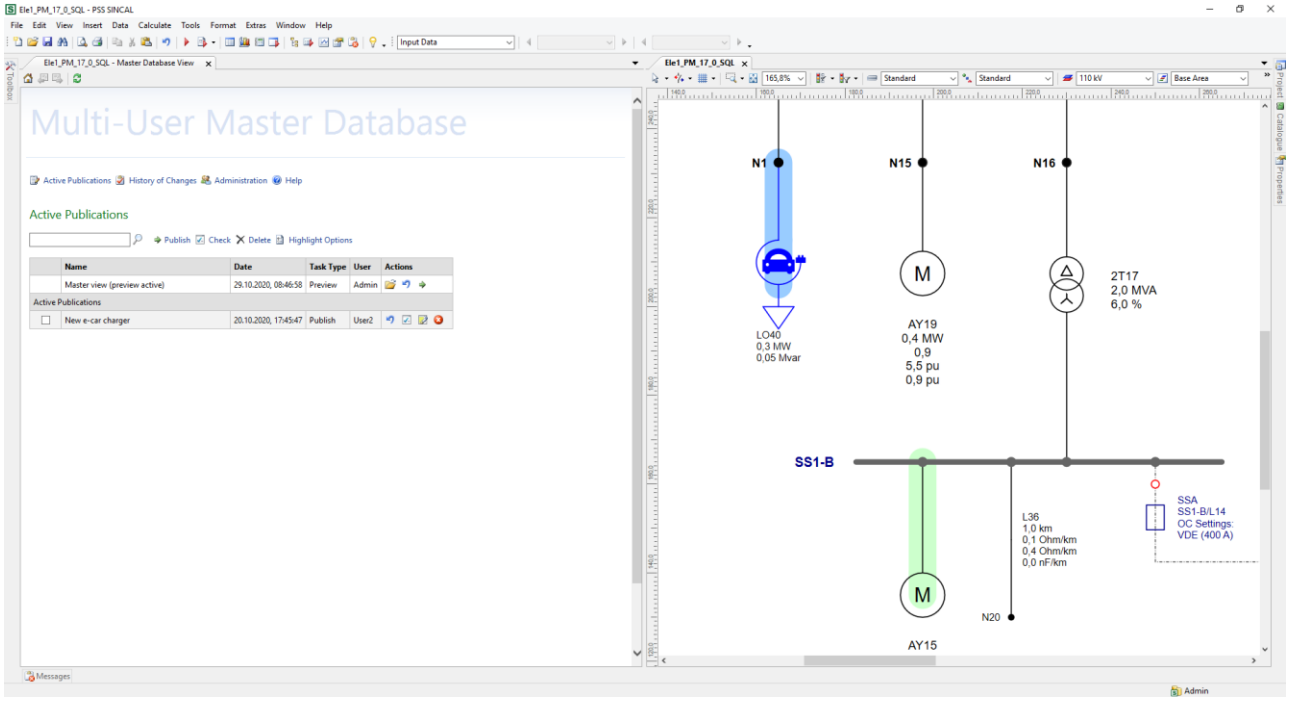


Figure 21: Multi-User Master Database

Requirements

When working with multiple users or teams on complex network models, certain requirements must be fulfilled in order to manage a common network model to track the changes of individual users and keep the network model consistent.

- Mapping of corporate processes with different roles and their access rights to a network model for modelling and release
- Consistent network model for synchronization (and possibly also reduction) of work steps (e.g. to support project management)
- Central storage of the network model on a network server as a repository for the individual users
- Update or reset to a previous state of the central network model based on changes made by individual users by version control
- Tracking and documentation of changes

Solution

- The module multi-user master database (PM) in PSS®SINCAL enables you to work on a network model that is synchronized and distributed across different locations and workstations.
- Creation of a central network model in a master database on one server (repository) from a previously locally existing network model
- User management for the administration of different user roles with appropriate access rights
- Connection of decentralized users (clients) to the master database, local editing and subsequent publication of the changes made
- Central administration (version control) of the master database by an administrator with functions for synchronization and conflict management in a graphical interface

Functions

The module offers the following functions to enable different users with different roles to work together:

- Global master network model in a central master database (repository) on a server
  - Initial conversion of an existing network model into a master database (repository)
  - Support of the database systems SQL Server and Oracle for the master database
- Integrated graphical user interface for managing and executing the module's functions
- Creation of user roles (administrator, power user, user, viewer with read access) to manage access rights to the master database
- Initial assignment of user name and password by administrator in user administration section. Later change of user password by administrator possible or individually by user

- Connection of decentralized users (clients) to the master database, preview and update to copy the current master network model to a local network model
  - Editing the network model in local user databases
  - Database system of the local database adjustable by user (Microsoft Access, SQLite, SQL Server and Oracle)
  - Sending the changes made locally for publication in the central master network model
  - Updating the local network model after changes in the master network model
  - Automatic information of users about changes in the master network model when opening client networks with option to apply them
- Central administration of the master database by user roles administrator or power user with defined functions for synchronization and conflict management
  - Review and approval or rejection of changes requested by users
  - Assignment of markers (labels) and optional resetting of the network model to a selected state
- Documentation of the changes

Results and evaluation options

- User-defined graphical management view for the administrator of a master database
  - Management of the accesses and authorizations
  - Change management functions
- Change history with documented history of the individual changes
- Preview of changes in the network model in the network graphic

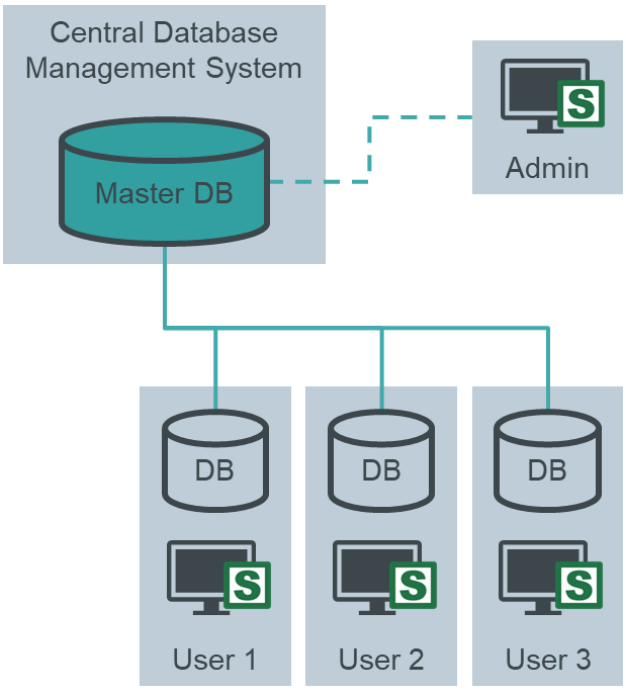


Figure 22: Central master database connected with local user database

Model Merge

(MERGE, MERGEFlow)

Requirements

The modeling of networks is based on the output data set for a basic model, which is obtained by conversion or an import from external data sources (e.g. SCADA, GIS) or another network data set (e.g. CIM). If this initial data set changes, a new conversion or import is necessary to update the base model. At the same time, however, extensions to the model (e.g. additional model attributes and extensions, protection data, models and parameters) that have been made in PSS®SINCAL in the meantime should be retained.

- Updating a network model based on changes in the output data set without losing the additional elements modeled in PSS®SINCAL
- Separate processing of models and their regular merging into a new basic model after processing
- Incremental update based on the changed, added or removed elements of the other data source
- Avoidance of time-consuming, manual synchronization of network models

Solution

The Model Merge module (MERGE) in PSS®SINCAL enables two network models to be merged with minimal user intervention.

- Performant and automatic merging of two network models with conflict handling
- Maintaining the consistency of the simulation model
- Individual configuration of the process and marking of changes in the network graphic
- Supports electrical, gas, heat/cooling and water network models

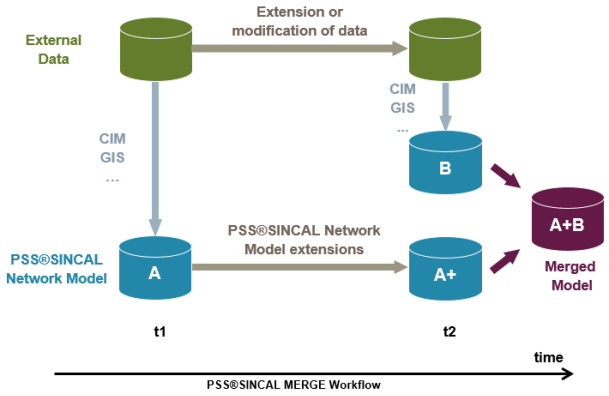


Figure 23: Example workflow using the MERGE module

Functions

The module offers the following functions for merging two network models.

- Support of all network models available in file-based database systems (Microsoft Access, SQLite and SQL Server Express)
- Configuration and start of the merging process in a form-based user interface
- Open configuration file with the rules for merging the network models
  - Configuration file in open *.xml format
  - User-defined modification of the rules
- Merging the base variant or an active subvariant
- Conflict handling for new, modified and omitted network elements
- Options for color coding of new, modified or omitted network elements
- Consideration of the standard databases for network elements and protection devices
- Matching of the network models based on the unique identification of the individual network elements

Results and evaluation options

The following models and results are available after the merge.

- New network model based on the merged network models
  - Network element groups for modified elements
  - Possibility to delete network elements based on their assignment to groups
- Output of additional files to document the process
  - Simple and detailed log file
  - Difference file with the differences of the elements in the two networks in *.xml format
  - File listing the errors that occurred during the merge (e.g. conflicts that could not be resolved)
- Tabular evaluation of the changes made to the various network elements in the user interface of the Model Merger module
- Graphical evaluation of changes in the network graphic in PSS®SINCAL by color-coding of the elements

Electrical Networks – Modelling

Network Model (electrical)

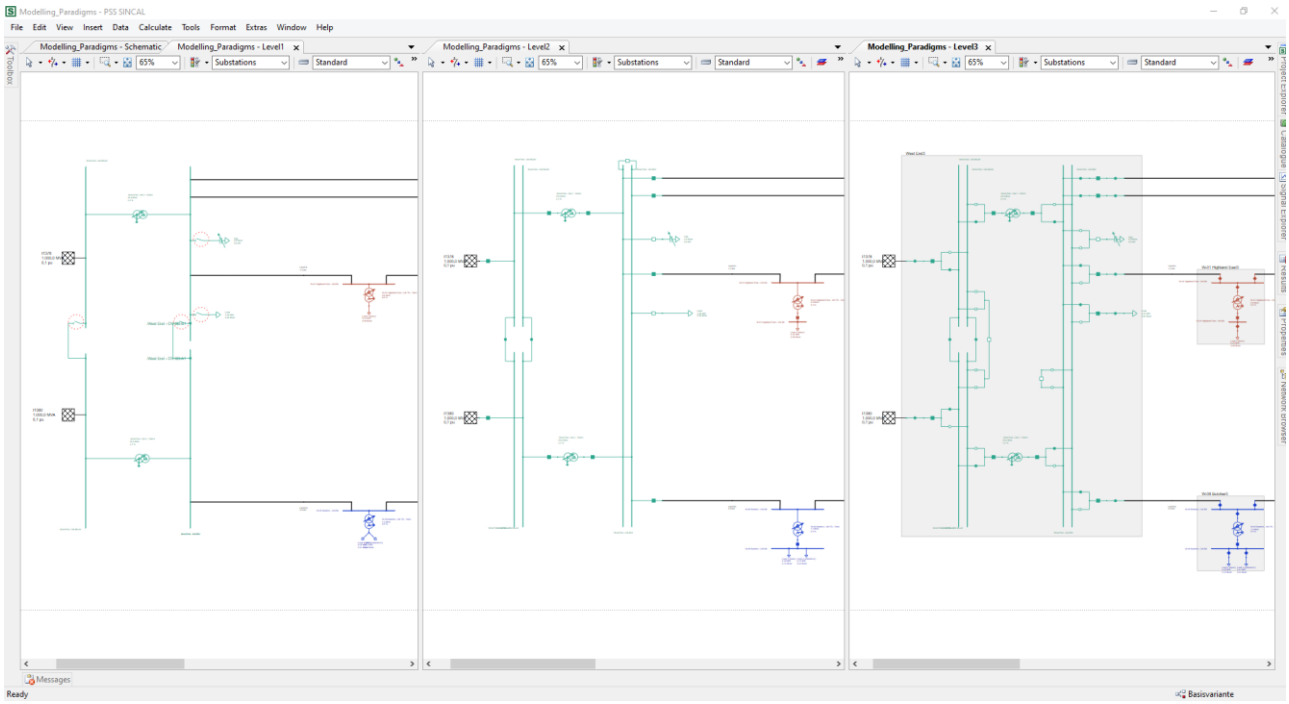


Figure 24: Modelling concepts – from bus branch models via a combined approach to full node-breaker models

Network model (electrical)

Each element only needs to be inserted once in the network model and only the mathematical model varies depending on the used calculation method. For example, lines can have a PI equivalent circuit or wave equations, loads and asynchronous machines adapt a method specific behavior. For the harmonic calculation, the dependence of the impedance on the frequency is considered.

- No fixed limitation of the number of buses / nodes (calculation of networks in connection with GIS systems with more than 100,000 nodes)
- Modular network model for gradual extension and refinement for the parameters used in the respective calculation methods
- Modeling of 3-phase symmetrical and asymmetrical systems, coupling data and 2-phase traction current systems
  - Modeling of symmetrical 3-phase systems
  - Modeling of asymmetrical polyphase networks (e.g., four-conductor or SWER networks)
  - Modeling 2-phase systems (180° phase difference) for traction power supply networks
  - Modelling of line coupling based on the 0-sequence system
  - Modeling with transposed systems with complete (coupling) matrices
  - Consideration of line couplings between active and switched off (and grounded) sections
  - Import of the determined (coupling) matrices for lines (module LEIKA)
- Definition of the dynamic, quasi-dynamic or inter-model communication behavior using models (macros) from the model library (DML) or user-defined models
  - Use of models from the model library (DML) of PSS®SINCAL/PSS®NETOMAC
  - Use of user-defined models (*.mac) based on BOSL code and models created with the graphical model builder (GMB) (*.xmac)
  - Use of interfaces to pre-compiled DLLs (DLL module)
  - Modelling of signal flow between different models/ controllers to reflect overlaying communication infrastructure functionality (e.g. park controller)
- Modeling of equipment based on the available nameplate values
  - Input of data with physical units based on the data given on the nameplate, data sheet or test report
  - Automatic conversion of the input data for the calculation methods
- Modeling of overhead lines and cables based on individual, synchronized segments
- Use of standard type databases for the modeling of equipment

- Support of different modeling paradigms for the representation of networks with simplified or detailed models of substations and switchgear within bays
  - Bus-Branch model with simplified representation of the (sub-)stations as busbars/nodes and implicit modeling of the switches and protection devices based on the switchable terminals of the elements (e.g., lines and generators)
  - Bus-Branch-Breaker model with simplified representation of the (sub-)stations as busbars/nodes and explicit modelling of circuit-breakers and the related protection devices
  - Node-Breaker model with detailed representation of the substation and the outgoing feeder panels (bays) with explicit modelled circuit breakers, disconnectors, load breakers and combinations
  - Protection devices, fuses and measuring equipment like CTs and VTs (with optional representation in the network graphic)
  - Unlimited capabilities for a combination of the modelling paradigms depending on the use case of the planning or simulation task (e.g., inserting of lines according to the bus-branch approach in a detailed node-breaker model without representation of switchgear or bay for early power flow studies)
  - Assignment of busbars / nodes and elements to stations supported in all three paradigms
  - Assignment of bays to stations supported in the two more detailed approaches once switches are modelled explicitly
- Different types of nodes, lines, generators and decentral energy resources (DER) based on available types for easier differentiation (e.g. branches as lines, cables or connectors)
- Switch element to model single- or multi-phase switching capabilities of established equipment types and combinations (like Power circuit-breaker, Disconnector, Load breaker, ...) and representation of earthing disconnectors
- Load and Load container model with various input data format modes and relation to a selected coincidence factor characteristic
- Modeling of individual equipment based on the combination of individual RLC elements to circuits
- Generic element with unlimited, freely definable connections to the network for the integration of highly detailed modeled resources in the network
  - Connection of extended models (e.g. multiple HVDC connection)
  - "Black box" principle
- "Co-simulation" with other software programs by diakoptic simulation of network areas (e.g. simulation of one network area with the dynamic network calculation engine and the other network area in parallel with the power flow calculation)
- User-defined network models with an unlimited degree of freedom in ASCII-based files for application in calculations of transient phenomena

Network Reduction

(NR)

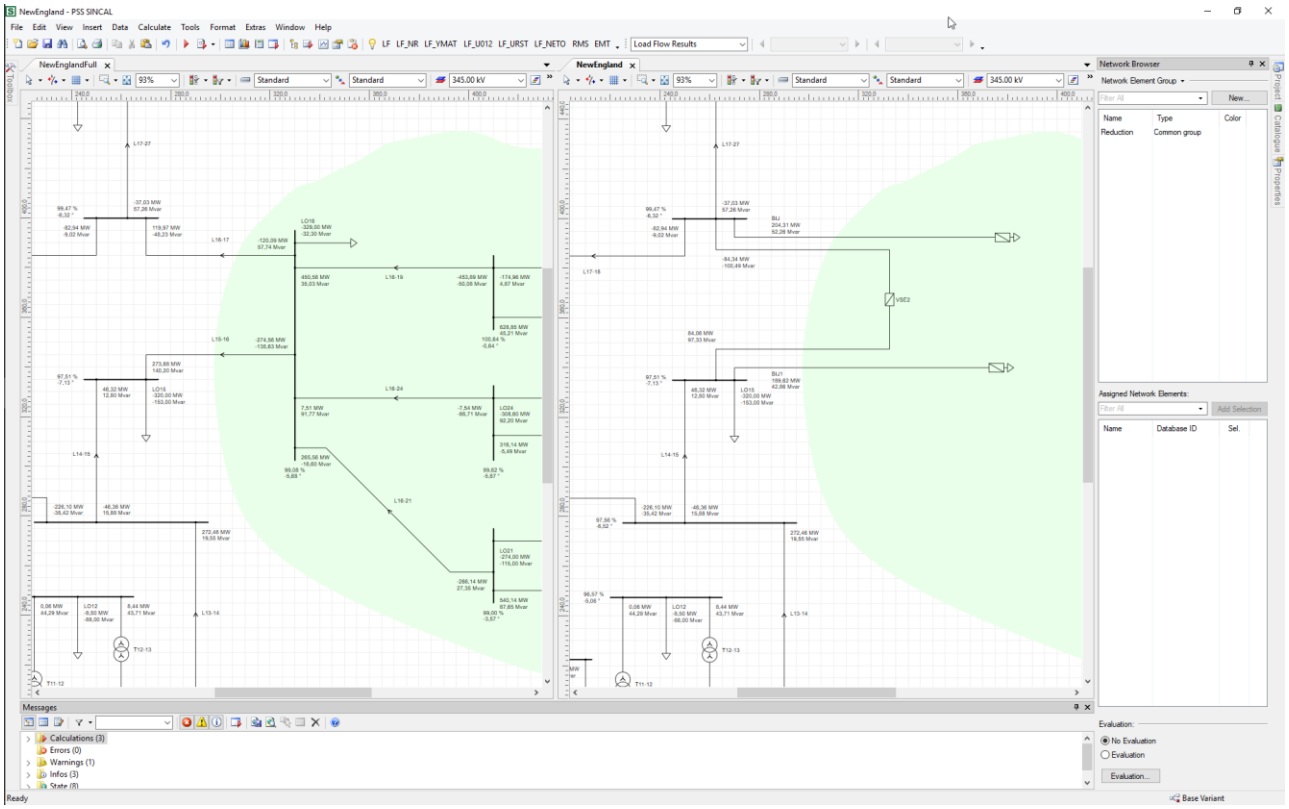


Figure 25: Application of Steady-State Network Reduction

Requirements

The consideration of interactions between the users own and neighboring network areas, i.e. the area of observation and the influencing conditions, may for cooperative collaboration be subject to restrictions regarding data protection and computing capacity. While on the on hand this particularly involves the protection of information of critical infrastructure or intellectual property, on the other hand it involves the optimization of the model by reducing it regarding a specific purpose of analysis. In both cases, the aim is to obtain the same behavior in a reduced model at the defined boundary nodes as in the complete model:

- Reduction of defined network areas in the network model to equivalent partial models
- Enabling the transfer of reduced network data to third parties with defined boundary nodes
- Identical behavior of reduced and complete network model at the boundary nodes regarding power flow calculation and short circuit data (3-, 2- and 1-phase)
- Reduction of the network model to save computing capacity for applications such as real-time simulation

Solution

Based on the basic module for power flow calculation, the PSS®SINCAL Platform offers the network reduction (NR) module, an effective tool for reducing definable areas in network models. The network area is selected graphically, by network element groups or other selection criteria. As a result, the equivalent elements are implemented directly in the users network model or optionally in an additional include network model.

- Static reduction method based on the Ward and Extended Ward method
- Consideration of power flow calculation and short circuit data as reference
- Use of boundary injections and equivalent branches at and between the boundary nodes, for the reduction of the network area in line with the results
- Simple selection of the reduction area by polygons, network element groups or a reduction file

Process options and result

The static network reduction uses the modeling and calculation principles of the power flow (PF) basic module to reduce a defined network area for steady-state analyses. At the defined boundary nodes, the reduced area, consisting of boundary injections and equivalent branches, behaves like the complete model for steady-state calculations. The procedure contains various options to meet user-specific requirements regarding the target network after network reduction.

- Determination of the shape of the target network after network reduction regarding splitting and use
  - Determined equivalent elements can be implemented directly into the original network model
  - Split network models can be created based on the include networks principle. The user defines how the original elements are processed, whether they are deleted or deactivated
- Various options for defining and selecting a network area to be reduced
  - User-defined, graphical polygon definition of any shape directly in the network graphic
  - Assignment of selected network elements to a network element group and their selection
  - Definition of an XML-based reduction file with information on the elements to be reduced and the elements to be retained in the format of the NMM module
  - Provision of the methods in the COM object for automated network reduction
  - Option to invert the selection
- Extended options to model the equivalent elements at the boundary nodes of the network area to be reduced
- Optional use of the Extended Ward method for extended simulation of boundary injections with user-defined settings for modeling type (reactance, impedance), maximum impedance and power-frequency characteristic
- Consideration of short-circuit data for 3-, 2- and 1-phase faults
- Optional ignoring of shunt impedances of lines, transformers and other passive shunt elements in the positive and negative phase sequences
- Setting of the modeling type (reactance, impedance) of the equivalent branches between the boundary nodes and specification of the maximum impedance

Line and Cable Parameters

(LEIKA)

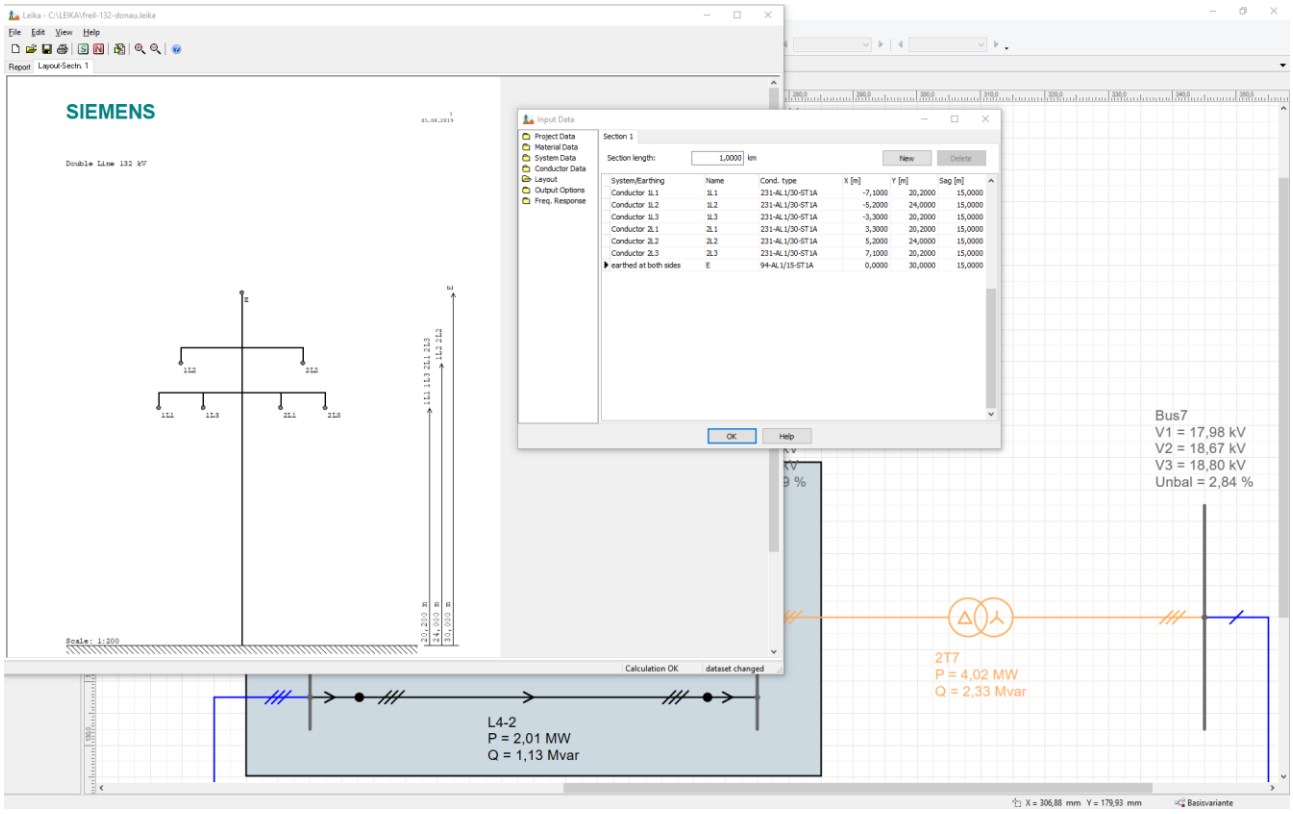


Figure 26: Determining Line and Cable Parameters from Geometric Conditions by LEIKA

Requirements

Analytical studies of system behavior, which depend on accurate modeling of overhead lines and cables, require the corresponding input data in the form of complex equivalent circuit diagrams and frequency-dependent elements. The planning and operating process provides the user with the information in the physical characteristic values of the conductors, insulators and insulation materials, as well as the geometric arrangement. It is necessary to convert the physics into an electrical equivalent circuit diagram for the different calculation types of the PSS®SINCAL Platform.

- Determination of parameters for single- and multi-phase systems with or without ground return from the geometric arrangement and material characteristics (conductors, insulation, shield etc.)
- Modeling of parallel systems and their mutual interaction through couplings
- Individual consideration of cable structure and arrangement with conductors, shields and armoring

Solution

The calculation of electrical parameters of overhead lines and cables (LEIKA) from geometrical arrangements and material characteristic values is made possible by the PSS®SINCAL Platform. The determined parameters serve as input data for power flow, short circuit, influence calculation and other calculation methods.

- Consideration of any arrangement and types of conductors and single cables
- Overhead lines are calculated with any number of parallel systems of different voltages and any number of ground cables
- Calculation of cables with concentric shields or metal sheaths or armor, additional common sheaths around a three-phase system and parallel ground conductors
- Line and cable characteristic values can be calculated at operating frequency and at higher frequencies up to several kHz
- Output of coupling data for PSS®SINCAL and for the expert mode (Exp Mod) in PSS®NETOMAC

Input data and function

The essential input data for the calculation of the characteristics of overhead lines and cables are given by the material characteristic values and the geometrical arrangement of the transmission system.

- Project data with basic frequency as well as the specific ground resistance, which affects the zero impedances or ground return line

- Predefined and user-defined extendable material constants of conductors
  - Specific resistance at a reference temperature of 20°C
  - Temperature coefficient for deviations from the reference temperature
  - Relative permeability of the conductor material
- Predefined and user-defined extendable constants of insulation materials
  - Relative dielectric constant for calculating the capacitances
- Use of material constants to define conductor types or cables/cable shields that can be used in an arrangement
  - Selection of the respective conductor material and the armoring material for cables. A database included in the delivery already contains the characteristic values of the most frequently used overhead lines
  - Definition of conductor and armor cross-sections
  - Consideration of the conductor temperature
  - Definition of multiple conductors with their arrangements and the appropriate clearances
  - Optional consideration of the DC resistance value. If this is not known, it is calculated from cross section, specific resistance and a twisting factor (stranding)
- Definition of any number of parallel systems of different voltages and any number of conductors and ground cables as a template for defining the arrangement
  - 3-, 2- and 1-phase system definition
  - Free input of conductor voltages for calculating the boundary field intensity
  - Free input of conductor currents for calculating induced currents and voltages
- Definition of the arrangement of the transmission systems for defined sections of the transmission route
  - Input of the respective section length
  - Definition of conductor arrangements in coordinates
  - Consideration of the sag of conductors
- Input for calculating the characteristic values at frequencies other than the nominal frequency

Results and output options

The results of the calculation for the electrical characteristic values from the input of geometric arrangements and material parameters are available in the results log and a graphical representation of the defined sections.

- Log in report form with the specification of all input data and user-defined results in different output formats of the values
  - Impedances and admittances before and after elimination of grounded conductors for conductor sizes and symmetrical components
  - Inductive and capacitive asymmetries
  - Wave resistance, natural power and charging power
  - Induced currents, voltages and boundary field intensities based on the specifications in system data
  - Internal impedances and current displacement
- Output of the section definition including all systems as graphics with specification of all geometric distances
- The results are exported as inductive and capacitive coupling matrices for PSS®SINCAL as well as for the expert mode (Exp Mod) in the PSS®NETOMAC transient engine and can be used directly with analytical studies
- Generation of standard types for lines or cables in local PSS®SINCAL databases

Graphical Model Builder
(GMB)

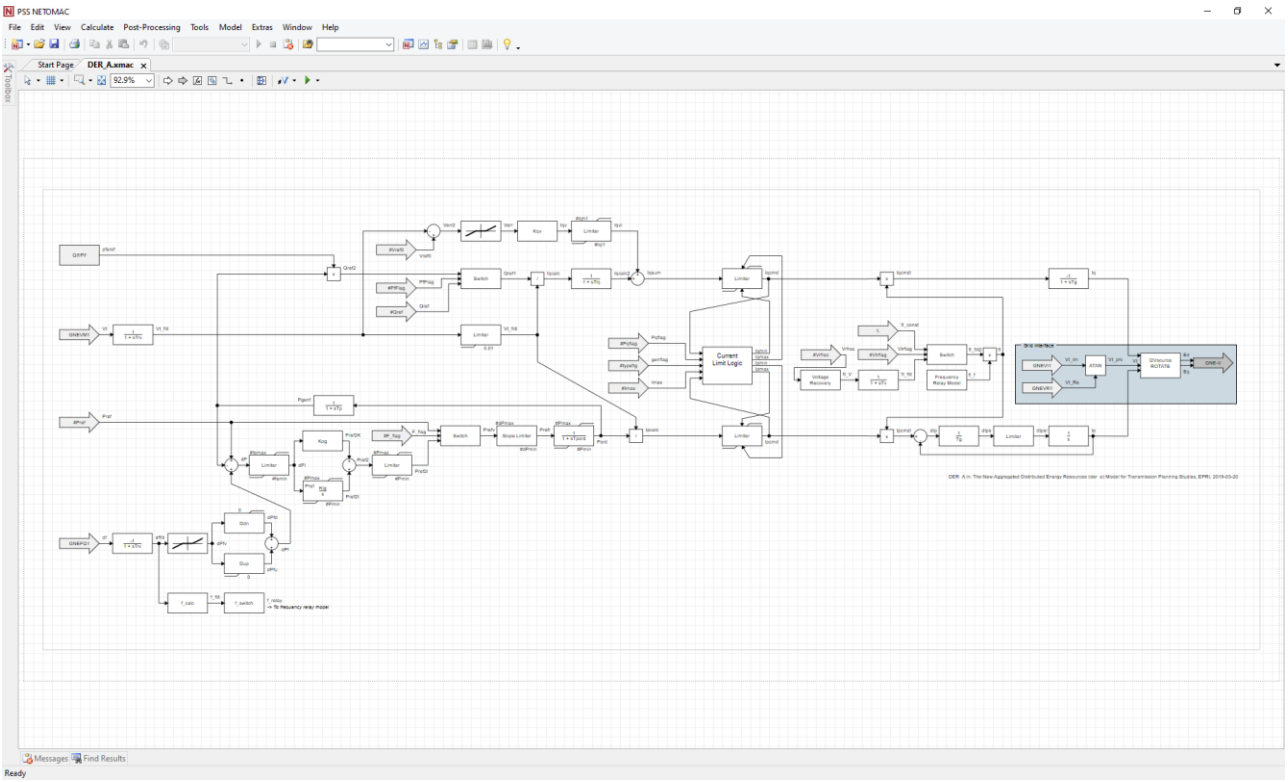


Figure 27: Development of User-Defined Models for Steady-State and Dynamic Analysis in Graphical Model Builder (GMB)

Requirements

An intuitive and efficient model editor is required if user-defined models of equipment, control devices or simulation controls are to be used, for which the behavior cannot be simulated by the standard models in the delivered model library.

- Possibility of modeling for user-defined models for control devices in generating and transmission systems for different calculation types as well as individual influencing of load and branch element behavior depending on various variables and network signals
- Pre-defined functions and block diagrams for the simulation of controlling devices with the option to implement your own code
- Simplified integration of external DLLs that contain vendor-specific algorithms and model behavior
- Encryption of models to protect intellectual property
- Use of created dynamic models in different products of the PSS®Suite

Solution

The graphical model builder (GMB) in the PSS®SINCAL Platform contains an intuitive user interface for user-defined modeling. The block oriented GMB is fully integrated in the native GUI of the PSS®NETOMAC dynamics engine and can be used in all simulation programs of the PSS®Suite via a provided interface without compilation or other third-party software.

- Intuitive operating and modeling concept as well as automatic plausibility check during modeling
- More than 30 different model types for generation and transmission systems as well as for controlling individual network elements and simulation
- Creation of user-defined models for use in different calculation types
- Over 100 predefined function blocks and the possibility of implementing user-defined code in a FORTRAN syntax
- Pre-defined templates for typical block diagrams and option to create user-defined template library
- Connection of external DLLs (DLL module) as subsystems of a model
- Output of selected signals during the runtime of the model in predefined file structure

- Test environment for the created models with analysis possibility directly in the block diagram of the model as well as in diagrams
- Possibility of model encryption

Functionality

The large functional range of the graphical model builder is the result of its complete integration in the PSS®NETOMAC dynamics engine and is made available to the programs of the PSS®Suite. The functionality of the graphical model builder is based on the BOSL (Block-Oriented Simulation Language) native programming language, which is considered in various calculation types.

- Consideration of the created models in the different calculation types of the PSS®SINCAL Platform as well as in other programs of the PSS®Suite
  - Depending on model type in power flow and time series power flow calculation, stability, electromagnetic transients, eigenvalue calculation, active frequency response
  - Automatic linearization of the model blocks in the corresponding calculation types, e.g. eigenvalue analysis or active frequency response
  - Interoperability of models in PSS®SINCAL, PSS®NETOMAC and PSS®E
  - Different model types for generation and transmission systems as well as for controlling individual network elements and the simulation itself
  - Control devices for machines such as speed/power controllers, excitation systems, underexcitation and overexcitation as well as stator current limiters, compensators, power system stabilizer
  - Control devices of the doubly fed asynchronous machine
  - Effect on node and branch elements such as loads by control algorithms in generic controllers or transformer tap changers
  - Simulation of converter-based systems like photovoltaic systems, wind turbines, batteries and other storage systems, HVDC, FACTS by generic elements (power, admittance, voltage and current) as well as by converter control in the EMT simulation
  - Modeling of protection functions
  - Simulation of the signal exchange between different models for centralized or decentralized operation coordination
  - Creation of global models for the detailed evaluation of simulations with the possibility of exporting information (*.csv, *.txt etc.) as well as the output of warnings and fault messages during the simulation runtime
  - Definition of global functions that can be used in a modular way in other models
  - Definition of target functions and secondary conditions in the optimization
  - Control of variant calculation in the expert mode of the dynamics engine
- Predefined input and function blocks and the possibility of implementing user-defined code in a FORTRAN syntax
  - Electrical and mechanical input variables from models of machines
  - Input variables of the network, directly at the terminal of a plant or at remote nodes and branches, for different phases or in symmetrical components, depending on the calculation method
  - Input variables from results, files and parameters in the simulation
  - Transfer functions such as proportional gain, integrator, 1st and 2nd order delay element, dead time, high-pass filter, phase compensation, PID and PI controller and others as well as freely definable transfer functions
  - Non-linear functions such as various dead bands, dead zone, insensitivity, saturation, 1- and 2-dimensional functions also from external files, size and rate limiters, hysteresis and others
  - Other functions for logical calculations, generation of random numbers, for the iterative initialization of models or switching of branches in the network model
  - Mathematical functions that are automatically considered correctly in the linearization for certain calculation types
  - Implementation of separate functions with separate code in a FORTRAN syntax
  - Calculation with complex numbers in the user-defined functions
  - Generation of information, warning and error messages directly within the message window of the using program
  - Connection of dynamic link library (DLL) within models through the standardized interface according to IEC61400-27-1 and the external DLL interface (DLL module)
- Different initialization options depending on the model type and accuracy requirements
  - Efficient forward initialization according to Regula Falsi for models of machine control devices that are only active within the time or modal domain

- Presetting of essential state variables for all model types. All other variables can be initialized based on these
- Initialization of models together with the power flow iterations, if the models are already active

User interface

The GMB offers an intuitive and adaptable concept. The layout of a model can be designed according to the requirements of the user, irrespective of its functionality.

- Targeted support of the user in the model building phase
  - Definition of described, constant parameters with their default, minimum, maximum and debug values
  - Copy parameter lists to and paste from external data sources
  - Warning if important parameters are not set
  - Overwrite default and debug parameters into each other
  - Calculation of parameter dependent constants before simulation
  - Check of parameter values with output of warnings if necessary
  - Simple copying and reusing of model parts in different models
  - Intelligent signal routing and connection of blocks
  - Adjustable prefix for variables that are automatically assigned when new blocks are inserted
  - Automatic identification of the sequential processing of models
  - Efficient search for used parameters and variables in the model
  - Plausibility check during model creation
  - Automatic creation of raw/dyr records for PSS®E models
- Options for a user-defined and efficient layout of models
  - All visible blocks can be modified in their layout regarding size, colors, labeling, etc.
  - Graphical objects for structuring and visual adaptation of models such as predefined and free graphical objects, text fields and frames in which the view can be enlarged if required, highlighting of model areas and integration of graphics in standard format
  - Functions for fast alignment and distribution of points and objects
  - Adjustable grids and guidelines for optical alignment of models
  - Selection and appropriate adaption of blocks based on properties
- Encryption of models
  - Visibility is limited to the inputs and the output of the model
  - Delivery of the dynamic model for use in the PSS®Suite while retaining the intellectual property rights of the model developer

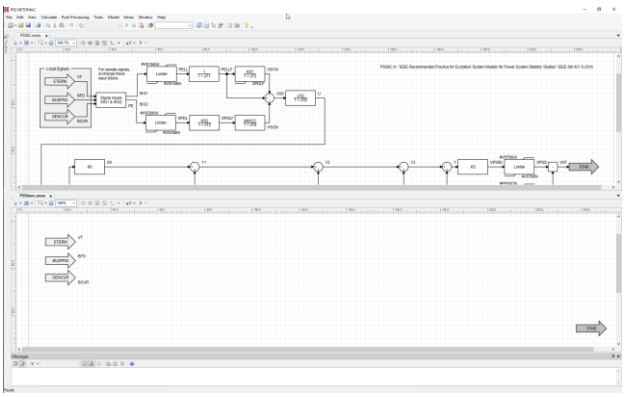


Figure 28: Encryption of GMB Models

Functional check of the modeling

- Test environment for the created models with advanced analysis and display options
  - Definition of debug parameters deviating from the default values directly in parameter dialogue
  - Automatic background check of model functionality during test execution
  - Check the model initialization according to the user's specifications in the debug parameters
  - Simulation of open loop tests with step and sinusoidal excitation in all model variables
  - Possibility of calculating closed-loop tests with an appropriate network model
  - Variable-based display of results from initialization, open and closed-loop tests directly in the model editor for each initialization or time step
  - Intuitive and easy to use diagrams with evaluation and display options for the test results
  - Export of test results to other applications via copy & paste
  - Any signal can be written out from user-defined models in ASCII character-based formats according to a defined structure
  - Signal export as MATLAB (level 4), COMTRADE, PLT, CSV

DLL Model Interfaces
(DLL)

Requirements

When creating and maintaining user-defined models of equipment, control devices or simulation controls in the model builder (GMB module), the integration of program parts and blocks developed as DLLs as subsystems is also useful in order to address the following requirements:

- Functional extension of models with complex data types and structures as well as functions that are not natively available in GMB
- Development, use and distribution of user-defined function blocks in C, C++ or other programming languages
- Coupling of internal input or output signals of the controllers with other applications running in parallel (if necessary, synchronously)
- Protection of intellectual property in the form of subsystem design or implementation
- Standardized interface for the use of subsystems in different software environments
- Development and testing of control functions in a "Software in the Loop (SiL)" environment

Solution

The two interfaces of the DLL model interface (DLL) module, as part of the PSS®NETOMAC dynamics engine, extend the simulation of models created with the graphical model builder (GMB) by integrating user-defined subsystems as a dynamic link library (DLL).

- Integration of external, already compiled DLLs as model subsystems in models created with the GMB
- IEC DLL interface, standardized to IEC 61400-27-1 F
- EXTERN DLL interface of the PSS®SINCAL Platform with simplified definition
- Use of the interface in the LF, LP, ST, EMT calculation methods

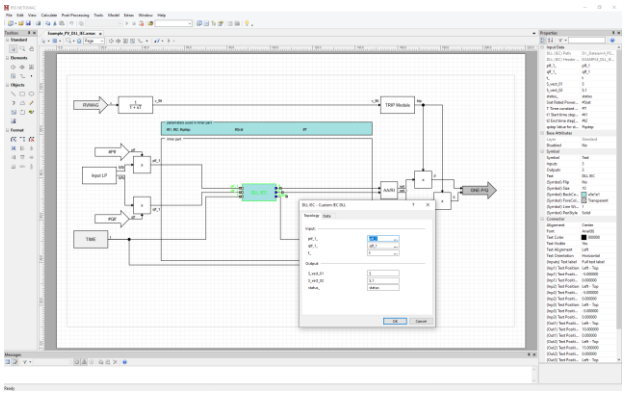


Figure 29: Implementation of a DLL in a GMB Model

Functionality

Both interfaces can be directly integrated as graphical function blocks in the model builder (GMB), connected to the other blocks and parameterized.

- Transfer of the calculation type of the PSS®SINCAL Platform performed in the network model as well as in other programs of the PSS®Suite to the DLL
  - Depending on model type in power flow, time series power flow calculation and time domain simulation
  - Use of interoperable models in PSS®SINCAL, PSS®NETOMAC and PSS®E
  - Implementation of user-defined behaviors for the different calculation types and programs by model developer
- IEC DLL interface, standardized to IEC 61400-27-1, Annex F
  - Annex F: Generic software interface for use of models in different software environments (ESE interface)
  - Specific function for the modes: Power flow, initialization and integration as well as simulation end
  - Parameter check and error messages
  - Handling of the model with a fixed (model-specific) time step or optionally with a time step synchronized to the simulation time step
  - Exchange of scalars and vectors
- EXTERN DLL interface of the PSS®SINCAL Platform with simplified definition
  - Lean interface without predefined functions for the different modes
  - Handling of the model with a synchronized time step in relation to the simulation time step or with the sampling rate of the higher-level controller
  - ExpMode: text-based connection of DLL

Results and evaluation options

Results and evaluations are provided in the same way as for all models in the user interface and the GMB, depending on the calculation method

Dynamic Model Library
(DML)

Requirements

To analyze the dynamic behavior of electrical power systems, standard models are defined by different standardization committees (IEC, VDE, IEEE etc.), which must be treated uniformly in different simulation programs and can be individualized only by changing parameters. While the classical standardization of dynamic models primarily addresses control devices for conventional generation units, type 2 generation units are gaining in importance and require the consideration of their models in dynamic simulation.

Solution

The PSS®SINCAL Platform contains a library of dynamic models (DML) for different network elements and calculation types that can be connected to the respective network model by the user.

The following dynamic models are included in the global library of the platform:

- Models of synchronous machines and their controllers according to IEC61970-302, IEEE421.5, IEEE PES-TR1 and other standards and guidelines.
- Inherent models, which are used by default in PSS®SINCAL in the absence of user-defined dynamic models on the network elements, to simulate the basic dynamics of the network elements
- Generic models for representation of dynamic behavior of loads, general shunt and serial branches and distributed generation plants. These can be used both as the equivalent of the complex behavior and as a starting point for the creation of user-defined, dynamic models
  - Variable power (GNE-P/Q)
  - Variable shunt admittance (GNE-Y)
  - Variable serial admittance (GNE-Y4)
  - Current injection (GNE-I)
  - Voltage injection (GNE-V)
  - Simple storage model with node voltage control
  - Simple storage model with branch loading control
- Models of machine control devices
  - according to the IEEE, IEC (CIM CGMES) standards, the PSS®E definition and other specifications
  - Excitation systems, compensators, limiters, power system stabilizer, speed/power governors
- Generic inverter-based models
  - Distributed energy resources according to WECC, EPRI (e.g. DER_A, PVD1, BESS, PV)

The following dynamic models are contained in the user library in the Documents folder of the user:

- Flexible AC transmission systems (FACTS) models for power flow and stability calculations:
  - Static var compensator (SVC)
  - STATCOM (SVC Plus)
  - Mechanically switched capacitors (MSC)
  - Thyristor controlled series capacitor (TCSC)
- Simple three-phase photovoltaic model
- Dynamic models of wind turbines with different generator concepts
  - Asynchronous machine with squirrel-cage rotor (SCIG)
  - Doubly fed asynchronous machine (DFIG)
  - Synchronous machine with full converter (FCSG)

Electrical Networks – Core Modules

Power Flow

(PF)

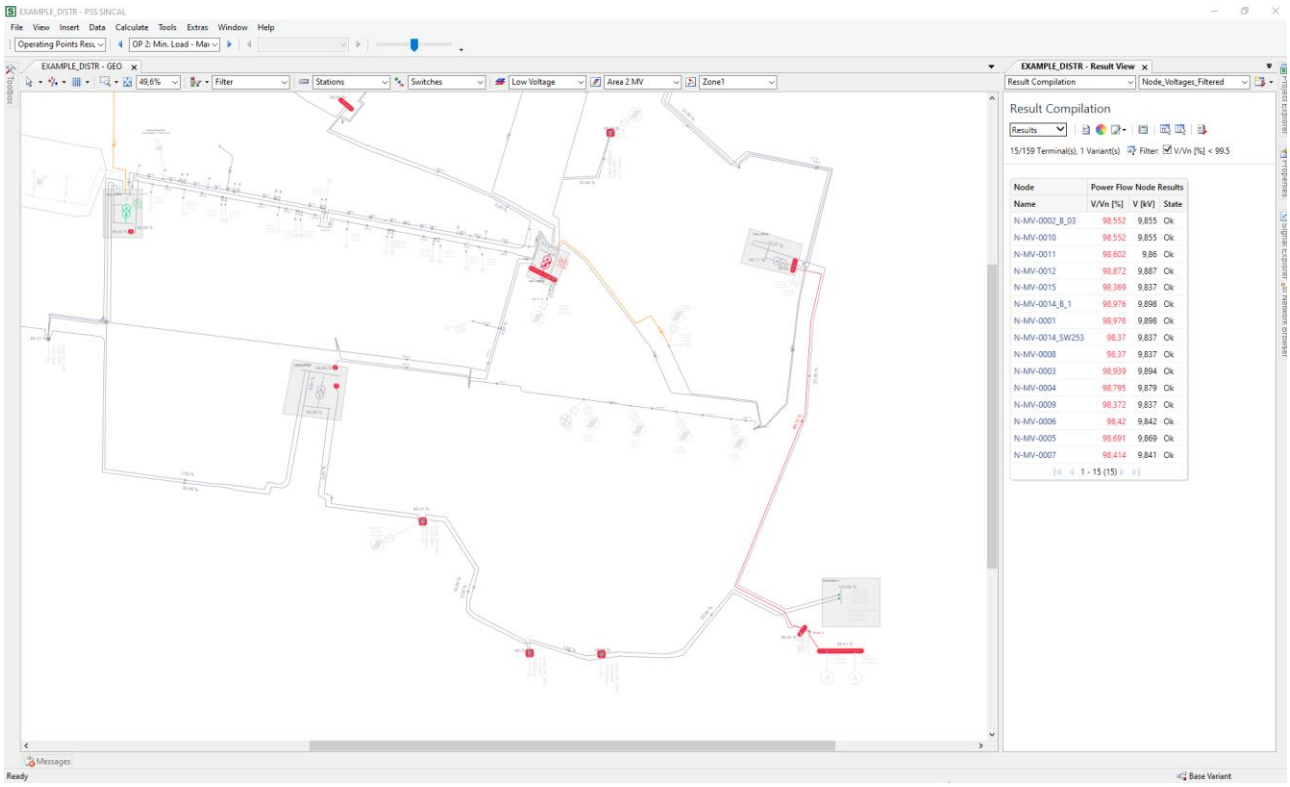


Figure 30: Power flow results in network graphic (with colored evaluation of the utilization) and tabular view

Requirements

The power flow in the network and the voltages and currents in the network are useful for solving the following tasks in the planning, design and operational management of electrical transmission, distribution and industrial networks as well as for other types of networks operated with alternating current (micro-grids, networks on ships and traction power supply):

- Planning of new networks and network areas as well as the analysis and restructuring of existing networks
- Determination of the balanced or unbalanced voltages at all nodes in a symmetrical or asymmetrical network
- Compliance with regulatory requirements of the permissible minimum and maximum operating voltages
- Determination of the balanced or unbalanced equipment utilization (loading) in a symmetrical or asymmetrical network
- Checking and planning of switching operations and switching configurations
- Optimization of the settings of controllable and adjustable equipment (e.g. tap position for transformers, capacitors)
- Integrated analysis of transmission and distribution networks
- Validated network model based on measurement results
- Identification of elements with high losses for the analysis of inefficient transmission or distribution

Solution

The module (PF) of PSS®SINCAL offers the user fast and robust methods for calculating the load flow/power flow in electrical networks, considering a high modeling depth for elements and controlled elements.

- Robust methods (e.g. Newton-Raphson, current iteration) for calculating the distribution of currents, voltages and power in symmetrical and asymmetrical three-phase systems (as well as 4-wire systems)
- Simulation of controlled elements with regulators such as transformers, capacitors and reactors or the individual control of network elements depending on any variables (e.g. voltage, current, power) in the entire network model
- Support of complex load modeling, user-defined models, phase shifters and asymmetrical transformers as well as simulation of temperature dependencies
- Visualization of weak points in the network based on the results for voltage and utilization

Modeling

The modeling of the (controlled) elements for the power flow calculation is based on standard elements and controllers and can be refined by the user as required.

- Modeling of symmetrical and asymmetrical systems as well as multi-phase / polyphase systems
  - Specification of the phases for the 1-phase or 2-phase network elements: Loads, generators, transformers (also with center tapping), lines, etc.
  - Specification of positive, negative and zero-phase sequence data
  - Detailed simulation of the grounding on busbars (or nodes) and neutral points of transformers
  - Support of the modeling of 4-wire systems with neutral conductor
  - Support of the input of lines with coupling matrices, also for switched-off sections
  - Simulation of phase shifters and asymmetrical transformers
- Support of complex load types and integration of user-defined models for loads
  - Default types for representing load as PQ or Impedance
  - User-defined BOSL Models (module GMB) based on a power or current interface at the connection node
  - Input formats for power or current values
  - Input formats for annual energy balance values with internal auto-conversion to power based on time or user-defined characteristic
  - Referencing coincidence factor characteristics
- Modeling of the transformer tapping / taps and the controller (regulators, phase shifters, OLTC, etc.)
  - Modelling of different functions as the manual setting, the voltage dependent control (optional with impedance-based correction of the measurement), control based on the power flow or current
  - Separate functionality of the control depending on the flow direction (forward / backward)
- Modelling of the taps / steps and the controllers of shunt capacitors and reactors
- Standard controllers for generation unit elements (converter, synchronous machine, asynchronous machine) with predefined or individual control characteristics for Q(V), Q(P), cosPhi(V), cosPhi(P), P(V)
  - Voltage dependent active and reactive power control P(V) / volt-watt, Q(V) / volt-var, cosPhi(V) / volt-power factor
  - Active power dependent reactive power control Q(P)
  - predefined or individual characteristics for the different controllers
  - Prioritization of reactive or active power
  - Signal for voltage measurement at local connection node or remote network node of choice
- Absolute and voltage dependent limits for active and reactive power (capability curves)
- Extended functional modelling of controlled equipment like converters (bidirectional), inverters, battery electric storage systems (BESS) or energy management systems (e.g. charging infrastructure)
  - Simplified energy storage model with linear charging / discharging behavior
  - Combination of the pre-defined elements and highly-detailed user defined models (GMB based on BOSL)
- Integration of user-defined models for network elements and user-defined controllers (GMB) that exceed the functions of standard controllers
- Network model independent global models (GMB) for representing communication systems
- Modeling of Leader/Follower control concepts for parallel or subordinate network elements with setpoints from a superimposed controller.
- Modelling of individual utilization of lines, cables and transformers depending on the ambient temperature of the network area

Calculation

Established methods are available for the calculation of the power flow.

- Robust methods to solve the power flow problem
  - Algorithms: Admittance matrix (current iteration) for symmetrical and asymmetrical networks, Newton-Raphson
  - Automatic use of the solution method for asymmetrical network models when using 2- or 1-phase network elements
  - Interactive and step-by-step control of power flow iterations by the user in case of convergence problems
  - Start value determination and specification (flat start, individually or based on calculation results) for the power flow
  - Adaptation of the network feeders and generators to a slack a PV-, PQ- or I-type if necessary
  - Use and presentation of power flow results to initialize dynamic simulations (for RMS and EMT in PSS®NETOMAC)
  - Use of the power flow results in other calculation modules of PSS®SINCAL, such as short circuit,

multiple faults, motor start-up, protection coordination

- Fully integrated calculation of different voltage levels
  - Consideration of any number of voltage levels
  - Input of the rated voltage of the network level as LL or LE
- Support of network configurations with multiple and distributed slacks
- Simultaneous calculation of several networks isolated from each other
- Multiple slacks in a network
- Option to form island networks in isolated network areas by converting generators into slacks
- Determination of the optimal distribution of the network feeders according to the user-defined limit values for power and frequency statics
- Calculation of load factor and transmission loss factor (TLF) at the nodes
- Control of generator supplies and tap positions while maintaining user-defined voltage bands or power flows
- Control using the signals for voltage and power at local and remote nodes and branches of the network model
- Voltage and current-dependent shedding of loads, generators, converters
- Consideration of the temperature dependence of lines and transformers for maximum utilization
- Consideration of transfer capacities (max. import and export powers) between network areas
- Automatic group formation of loads with same coincidence characteristics, derivation of coincidence factor and application by adaption of the power values
- Simulation of snapshots with time series data located in an open and generic external database (e.g. metering or forecasting data) with the time series data interface (module TSDI) without additional transfer of input data

Power Flow based functions and tools

The following additional functions and tools based on power flow calculations are already available to the user with the module.

- Simulations of user-defined operating points and scenarios
- Automated calculation of PV and QV curves to assess voltage stability using diagrams
- Determination of connection points for loads within a user-defined radius in geographical networks
- Equipment sizing of lines and transformers (network planning tools)
- Automatic feeder evaluation and documentation and determination of the transfer reserve after switching operations

Results and evaluation options

The program provides the following options for evaluating the results.

- Compilation of the achieved accuracy of the power flow and iterations as well as extended calculation log with results of the individual iterations
- Complete results of the (balanced or unbalanced) power flow calculation for evaluation in graphics, tables and databases as well as in reports
  - Number and identification of nodes with voltages outside the user-defined voltage bands
  - Utilizations (loading) of elements
  - Number and identification of branch elements above the utilization limit
  - Tap position of the transformers
  - Network and subnetwork losses
  - Determination of isolated (without supply) or non-supplied subnetworks
  - Color-based filters for node and branch results to visualize the results
  - Heat maps for selected results, such as voltage deviation
  - User-defined scope, type and format of the annotations of the network graphic with results
  - Selection of the supply or the supplied elements based on the power flow result
- Prepared results for the entire network and for the network areas
  - Display of supplied areas in the network graphic
  - Cumulative supply and consumption as well as the respective balance of active and reactive power
  - Detailed balance results for active and reactive power as well as losses by element type
  - Subnetwork losses
  - Transfer of powers between network areas
- Evaluation possibilities in diagrams
  - Voltage profiles along selected feeders/routes or all feeders of a substation
  - PV and QV curves
- Evaluation options in reports
- Direct access to the database with external applications for further evaluations

Short Circuit

(SC)

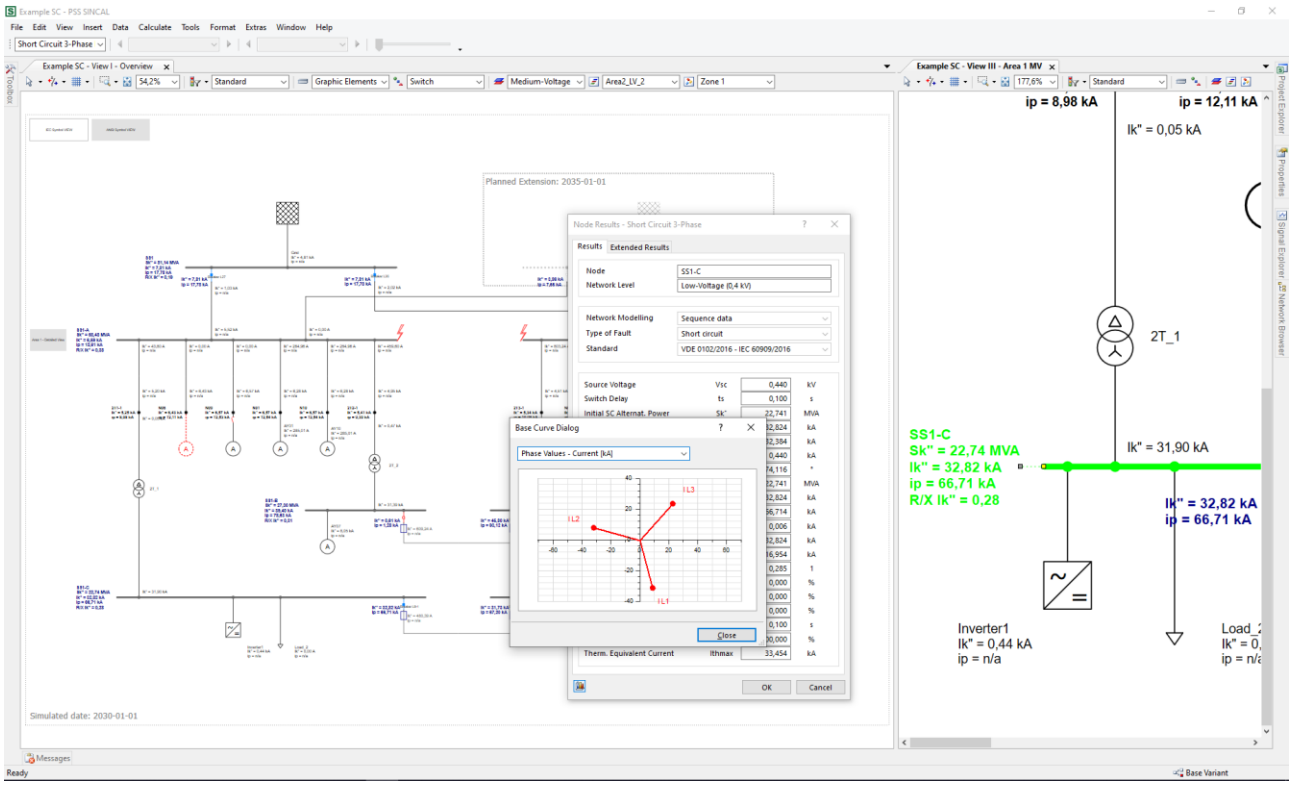


Figure 31: Short circuit calculation results in an industrial network

Requirements

The calculation of short-circuits in networks during planning and operation to assess the load on the equipment must be carried out according to standardized procedures. The results obtained in this way are also required as a basis for further analysis (e.g. protection concept, arc flash evaluation).

In addition to the short-circuit calculation based on conventional generation, guidelines and standards increasingly require the consideration of converter-based generation.

- Dimensioning of the equipment according to the expected thermal and mechanical stress in case of short circuits (maximum short circuit currents)
- Determination of the protection setting based on the short-circuit results (minimum short-circuit currents)
- Arc flash evaluation based on the short-circuit results
- Calculation of short circuits under initial load
- Calculation of the short-circuit current contribution of converter-based generation plants

Solution

The short circuit calculation (SC) module in PSS®SINCAL allows the calculation of short circuits according to standardized procedures and standards. The calculation and its results are then available to be used by other modules.

- Modeling of the network elements for the short circuit calculation according to the listed standardized procedures and standards
- Calculation methods:
  - IEC 60909/VDE 0102 (2016, 2001, 1990)
  - IEC 61363 (1998)
  - IEEE C37 (2016, 1990)
  - G74
  - G74 Issue 2
  - GOST R 52735 (2007), 28249 (1993)
- Short circuit calculation of balanced and unbalanced faults in asymmetrical networks with simulation of individual phases (instead of symmetrical components) and fault impedance
- Calculation of short-circuit currents for 3-, 2- and 1-phase faults with and without earth connection
- Calculation of short-circuit currents of converter-based generation plants in the positive and negative sequence system based on Dynamic Voltage Support
- Calculation of short-circuit currents with initial load based on the power flow results

- Determination of the maximum switch off time up to thermal destruction of lines and transformers
- Visualization of the exceeding of permissible short circuit currents of equipment in the network graphic

Modeling

The network elements are modeled according to the listed standardized procedures and standards. Extensive possibilities are available for the connection of the network conductors, and if necessary, of the ground/earth as a starting point for the short-circuit calculation.

- Symmetrical and asymmetrical modeling of the network for the different fault circuits
- Input of additional data to simulate the connection of neutral conductor and earth
- Input of a fault resistance by means of ground transition and arc impedance at the fault location
  - Entry of additional data for all network nodes or via the network level for all nodes of the network level
  - Individual input of additional data for each node
- Flexible modeling of the neutral point grounding of transformers
- Consideration of the transformer vector groups with unbalanced (asymmetric) faults
- Setting of the short circuit contribution of converters
- Modeling of the Dynamic Voltage Support for converter-based generation plants via setting a characteristic for the control of the short circuit contribution in the positive and negative sequence system
- Modeling of a power unit as a single element or as a combination of separate generator and transformer elements identified as a block

Calculation

The short-circuit calculation follows the listed standardized procedures in the treatment of the individual equipment and the calculation steps.

- Short-circuit calculation according to standardized procedures and after initial load with the power flow results (superposition principle)
- Calculation of short-circuit currents for 3-, 2- and 1-phase faults with and without earth connection
- IEC 60909/VDE 0102 (2016, 2001, 1990)
  - Maximum/minimum or user-defined calculation
  - Support of all methods according to IEC 60909 for the calculation of the peak short circuit current (uniform ratio R/X, ratio R/X at short circuit point, equivalent frequency procedure for equivalent impedance)
- IEC 61363 (1998)
- IEEE C37 (2016, 1990)
- G74
- G74 Issue 2
- GOST R 52735 (2007), 28249 (1993)
  - Calculation based on the approximated approach with a voltage source at the fault location
- Calculation of voltage support of converter-based generation plants by injection of a reactive currents in the positive sequence and/or negative sequence system
- Calculation of the thermally equivalent short circuit current from the initial short-circuit current and calculation of the maximum switch off time for lines and transformers
- Checking the short-circuit current capability of the busbars for initial and peak short-circuit current
- Calculation of the short circuit at a selected fault location with complete current and voltage distribution in the network
  - Calculation of the total values of the currents at the fault location
  - Calculation of the contributions over the branches leading to the fault location and the voltage profiles along these branches
- Simultaneous calculation of the short circuit at all network nodes of the entire network or for selected network levels in one calculation run
  - User-defined restriction of the calculation to individual network levels possible
  - Calculation at all open line ends

Results and evaluation options

The program provides the following options for evaluating the results.

- Complete results of the short circuit calculation according to the listed standardized procedure and standards for evaluation in graphics, tables and databases as well as in reports
- Detailed numerical calculation results and graphical representation in vector diagrams (conductors L1, L2, L3 as well as symmetrical components)
    - Screen forms with node and branch results
    - Vector diagrams (magnitude and phase) for currents and voltages
- Creation of diagrams for the plot of the node results Ik", Sk" and ip along user-defined routes in the network
- User-defined visualization of the exceeding of permissible short circuit currents of equipment in the network graphic
- Determination of the maximum switch off time up to thermal destruction of lines and transformers

Harmonics/Harmonic Contingency (OB)

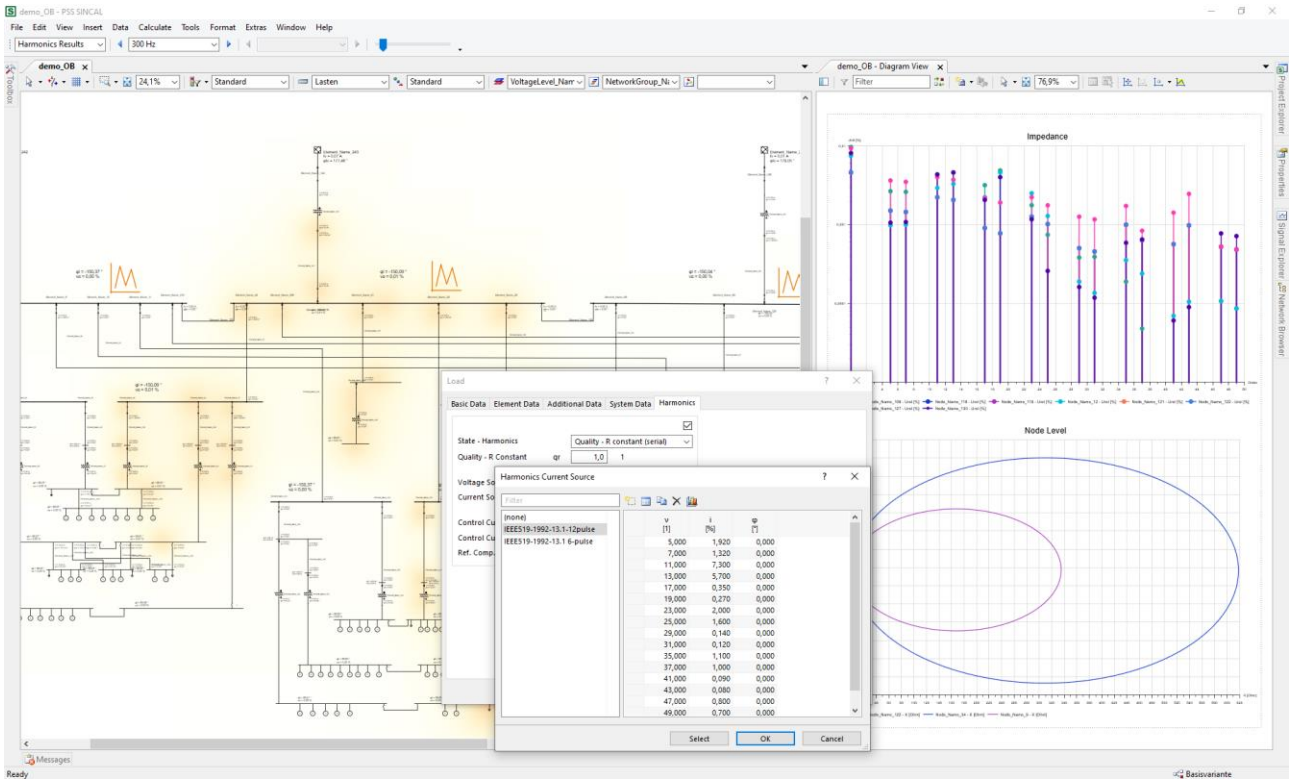


Figure 32: Input of harmonic emissions and calculated frequency dependent network impedance and levels

Requirements

When planning and designing electrical networks, it is also useful to observe the frequency-dependent behavior of equipment and the resonance or damping of the harmonics emitted by individual devices:

- Determination and analysis of the frequency-dependent behavior of the network and the resonance frequencies for the current network state
- Automatic execution of the analysis for a high (combinatoric) number of network states (switchovers, maintenance) or depending on all possible positions of controllable elements (e.g. capacitors) in order to include all network configurations in the analysis
- Compliance with regulatory requirements for voltage quality of the permissible minimum and maximum harmonics and distortions of the voltage in the network
- Prevention of harmonics visible in the lighting (flicker)
- Protection of equipment (e.g. capacitors) against damage or destruction by voltages and currents of higher frequencies
- Selection of the vector group of transformers for targeted suppression of individual harmonics (e.g. 5th and 7th for YY0 and YY1)
- Design and placement of filters
- Reduction of network areas (boundary networks) as resonance networks, considering the frequency-dependent behavior and the switching states and tap positions of controllable elements (e.g. reconnected filters)
- Integration of the measured behavior of subnetworks that were not simulated in detail in the network model

Solution

The module (OB) in PSS®SINCAL offers the user the calculation of frequency responses in static network configurations as well as in combinatorial configurations in harmonic contingency calculation and the calculation of harmonics distribution limit. Furthermore, a functionality for filter design is available.

- Extension of the network model with frequency-dependent model behavior
- Modeling of active and passive resonance networks
- Extensive options for modeling sources with harmonic emission
- Calculation of frequency responses for static states as well as harmonic contingency calculation (malfunction calculation for harmonics)
  - Evaluation of the results for voltages and currents in relation to the limit values from standards IEEE 519

(TIF and IT), THFF and EDC, NY x UNY and NY x INY, IEC 61000-2-4 class 1, 2, or 3

- Evaluation of the results for voltages and currents in relation to user-defined limits

- Graphical display of gain levels over frequency, frequency response locus, impedance areas and harmonic levels in diagrams
- Function for detecting resonance points and for filter design of filter groups

Modeling

The modeling of the frequency dependence of the network elements is based on a topological model as an additional modeling dimension.

- Modeling the lines with wave equations to determine the impedances of the fundamental frequency of the network
- Modeling of the frequency-dependent behavior of the network elements with quality factors for the X/R ratio, with the CIGRE models or freely definable frequency-dependent behavior
  - Quality factor for constant resistance
  - Quality factor for constant ratio of X/R
  - Support of different CIGRE models for specific network elements
  - Freely definable frequency-dependent characteristic curve for R, X and C for detailed modeling of skin and proximity effect
  - Frequency blocking behavior
- Consideration of the fully asymmetrical network model (based on the network model for short circuit calculations)
  - Consideration of the vector group and zero system data for transformers
  - Consideration of asymmetrical elements and sources
  - Consideration of the correct sequencing of the harmonics
- Modeling of resonance networks on shunt or serial elements for the frequency-dependent simulation of reduced, adjacent network areas
  - Passive resonance networks as shunts with resonance characteristic curves for the individual harmonics
  - Active resonance networks as branches with resonance areas for the individual harmonics
  - Determination of the resonance characteristic curves or areas with a combinatorial calculation carried out in advance in the network area to be reduced
  - Transfer of measured network distortions
- Modeling of balanced and unbalanced current and voltage sources with even and odd harmonics as well as interharmonics at any network node
- Modeling of filters using the provided filter models for different filter configurations and types
  - RLC filter serial, parallel
  - High-pass filter
  - Creation of user-defined filters (administration in catalogs possible)
- Modeling of the PCC (Point of Common Coupling) configuration of network elements
- Create analyses for frequency responses at nodes or between nodes (along a route) in the network
  - User-defined range for minimum and maximum frequency
  - User definable step size of the frequency in the analysis area

Calculation

For the calculation, several steps are available which, individually or in combination, lead to the necessary results for different requirements. The frequency responses for defined nodes are determined based on the determination of the frequency dependence of the model. Excited with the supplied harmonic currents and voltages, the harmonics distribution limits for the analyzed frequencies are determined and the distortion characteristics are calculated. Based on the frequency responses, the levels and the permissible/specified maximum levels, the filter design can be started. The creation of resonance characteristic curves and areas for the simulation of subnetworks as resonance networks or as a basis for a more detailed network analysis is carried out by the harmonic contingency calculation. The frequency dependence is determined considering all (automatically generated) combinatorial cases in the network area.

- Calculation of the frequency response at the user-defined nodes and routes
  - Automatic adjustment of the step size or constant step size
  - Calculation of the frequency response locus for the respective analyses
  - Determination of the parallel and series resonances for the frequency response
  - Automatic determination of the suitable impedances from the resonance areas that simulate active or passive resonance networks
  - Options for the consideration of resonance networks, loads and voltage angles
- Calculation of the even and odd harmonic components and the interharmonics of voltage and current in the (a)symmetrical network model

- Calculation of the distortion factors
  - THD (total harmonic distortion)
  - TDD (total demand distortion)
  - Arithmetic total of the harmonic voltages
- Evaluation of the voltages and currents in relation to the limit values from the selected standard or user-defined limit values
  - IEEE 519: TIF (telephone influence factor) and IT
  - THFF (telephone high frequency factor) and EDC
  - NY x UNY and NY x INY
  - IEC 61000-2-4 class 1, 2, or 3
  - User-defined limit values
- Harmonic contingency calculation considering the possible combinatoric states (caused by element failures) in the network and the steps of controlled network elements (e.g. capacitors) to determine resonance characteristic curves or resonance areas
  - Single or combined failure (e.g. connection and disconnection of a capacitor) of the elements
  - Optional consideration of the additional combinatorics resulting from the positions of the controllers
  - Implementation for selected harmonic numbers or ranges
- Automated filter analysis and design based on the determined harmonic distortions for all frequencies and for all nodes of a network level
  - Analysis of the frequency responses of all nodes of the network level and the distortion levels for all supplied frequencies
  - Selection of compensation method (high pass R or C, serial or parallel)
  - Selection of a minimum deviation of the levels reduced by the filters from the selected limit value
  - Definition of the maximum number of filters to be placed in the filter bank
  - Group of filter elements as calculation result
  - If required, automatic creation of the filter group in the network model

Results and evaluation options

The program provides the following options for evaluating the results.

Diagram view

- Display of the frequency-dependent network impedance (frequency response) and the angle of the network impedance
  - Frequency response from the perspective of a node or between two nodes in the network
  - User definable overlays of frequency responses of different nodes
- Display of the frequency resonance locus (X-R) in the complex plane
- Graphical evaluation of the harmonic levels at nodes and in the network levels according to the selected limit values of the standard or user-defined limit values
  - Display of the limit values
  - Display of the harmonic levels
  - Display of the THD
- Results of the harmonic contingency calculation: Diagrams for the resulting frequency responses and areas separately for harmonic numbers or together
  - Display of the frequency responses of all combinations
  - Display of the impedance area of all combinations for one frequency each (transferred as one area each of a resonance network) or for all frequencies (as a basis for the filter sizing or the verification of switching flexibility)

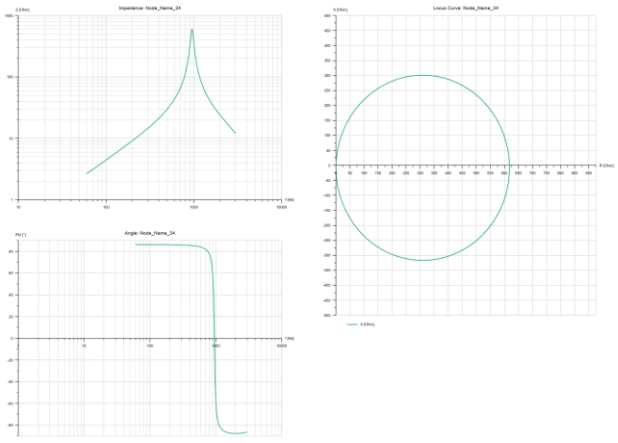


Figure 33: Result of harmonic calculation showing impedance, angle depending on frequencies and locus curve

Network graphic

- Graphical display of the harmonic levels at all nodes and network levels as well as appropriate filter functions for color-coded evaluation
  - Display of the total values or each individual frequency analyzed
  - Display of node and branch results in result screen form
  - Embedding of interactive diagrams (frequency response, distortion level)

Other results

- Full range of results in tabular view
- Log with the determined serial and parallel resonances (in message window and log database)
- Display of the elements determined in the filter design in the result browser
- Evaluation options in reports
- Direct export of diagram values in list form to Office products (e.g. Excel)
- Direct access to the database with external applications for further evaluations

Stability (RMS)

(ST)

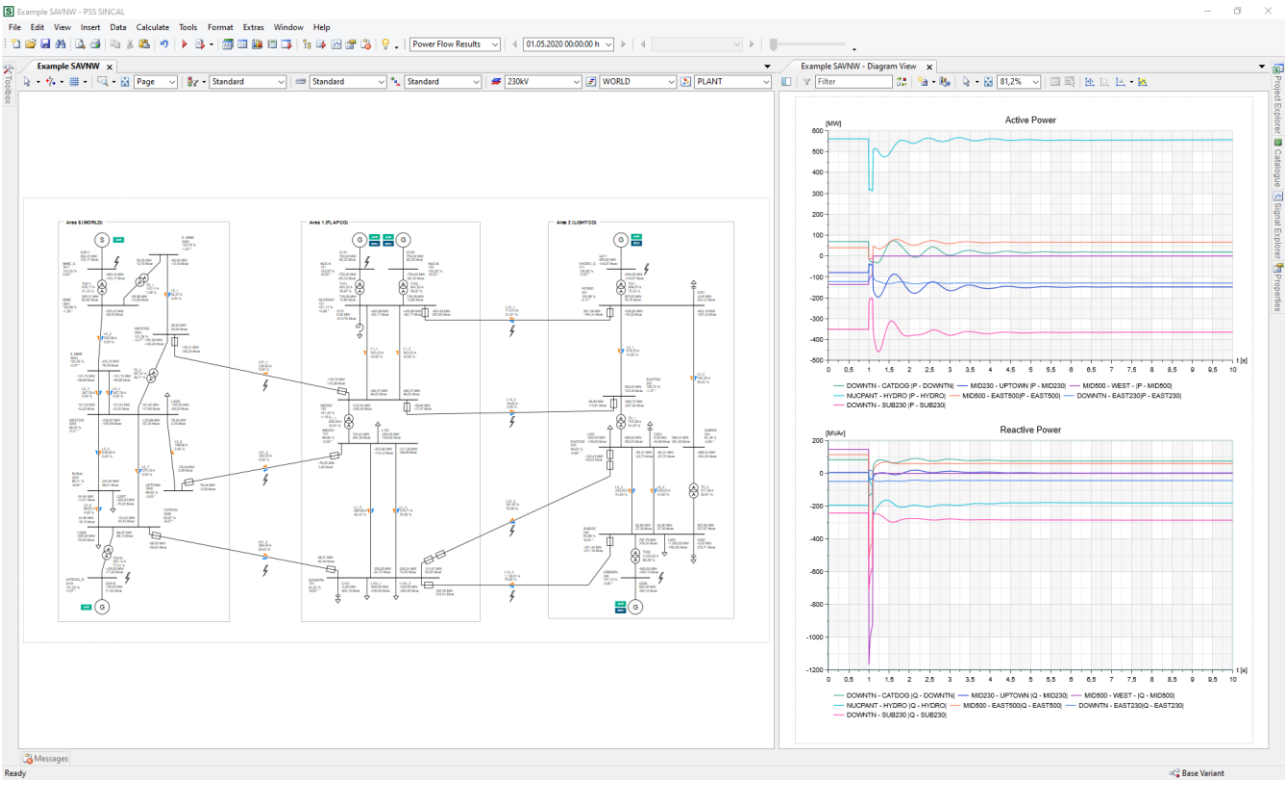


Figure 34: Analysis of Power System Dynamics by Stability Simulation

Requirements

The planning and operational management of complex energy systems require analysis methods in the time domain, so that not only stationary conditions but also dynamic processes that occur in between are included in the assessment of the network state. If the dynamics of the network are shifted to the network levels subordinate to the transmission network, the complexity of the demands on the operators of such systems increases.

- Time domain analysis for compliance with the classical stability concept according to IEEE regarding voltage, frequency and rotor angle stability
- Interactions in the electrical power system to and between converter-based systems
- Analysis of transients and stresses in the transmission and distribution network in case of symmetrical / balanced and asymmetrical / unbalanced events (e.g. short-circuits, start-up processes, equipment malfunctions)
- Consideration of the influence of different types of generating plants with their control and communication devices
- Verification of the protection concept in case of mutually dependent fault sequences in time domain

Solution

The PSS®SINCAL Platform with its dynamics engine PSS®NETOMAC offers the user in this module (ST) the possibility to use it for the most basic applications directly in the PSS®SINCAL GUI, as well as in the expert mode (ExpMode) to use the native user interface of the engine for advanced calculations. The expert allows users from PSS®SINCAL the usage of feature only available in PSS®NETOMAC and additionally supports in identifying dynamic modelling issues.

- Time domain simulation based on phasors (RMS) for symmetrical and asymmetrical networks with symmetrical and asymmetrical fault conditions, loads and power generation
- Use of proven and successfully validated dynamic models and simulation methods of the PSS®NETOMAC dynamics engine
- Consideration of the protection device behavior during transients in the time domain simulation and in protection coordination
- Analysis of Fault-Ride-Through behavior of electrical assets by imposing voltage or frequency characteristics

Modeling

With the classical focus on electromechanical transients, established models of machines and their standardized controller models are provided. But also, the modern converter based generating plants are considered by the modeling possibilities and the provision of generic models (DML module).

- Modeling of the dynamic behavior of machines (synchronous and asynchronous machines) by means of differential equations
  - Synchronous machines are modeled with the 5th order (dq) Park model without considering the stator field dynamics
  - Depending on the configuration, asynchronous machines can be modeled with single and double squirrel cage, resistive or fed rotor windings. The models are suitable for the analysis of transient and steady-state operating conditions
  - The equipment models are parameterized with original data (impedances) or derived values for various operating ranges (subtransient, transient, synchronous) for the dq system
  - Reference of the rotor angle to terminal voltage, center of inertia (COI) or to the rotor angle of certain machines or infeeders
  - ExpMode: Individual wiring and control of the rotor windings of asynchronous machines
- Simulation of multi-phase or single-phase network topology with complex impedances
  - Basic frequency model with dynamic phasors of all network variables (voltages and currents)
  - Symmetrical and asymmetrical network models
  - ExpMode: Use of the symmetrical components for asymmetrical calculations as well as simple influencing in the negative and positive phase sequence by generators and loads
  - Consideration of user-defined models for network elements as well as for control and communication devices for different types of generating and transmission systems
  - Model library with machine control devices according to standards (IEEE, IEC (CIM CGMES), etc.) and generic models of type 2 generation (DML module)
  - Simple connection and parameterization of models directly in the database or with automation
  - Use of the native ASCII character-based format of the PSS®NETOMAC dynamic engine for extended topological definition of individual node and branch elements
  - Intuitive creation and analysis of user-defined models in the graphical model builder (GMB module) and easy connection to the node and branch elements in the network model
  - Implementation of dynamic link library (DLL) within user-defined models through the standardized interface according to IEC61400-27-1 and the external DLL interface (DLL module)
  - ExpMode: Combined RMS/EMT hybrid simulation to simulate DC link circuits and to co-simulate subnetworks
  - ExpMode: Real-time simulation mode for training simulators in connection with control center platforms
- Any definable events and their sequences in the time domain on busbars, nodes and branch elements at freely definable times as well as clearing of fault conditions
  - Short-circuit observations for 3-, 2- and 1-phase busbar faults with or without earth connection
  - 3-, 2- and 1-phase line interruptions also in combination with different earth faults
  - Individual fault clearing based on defined specifications and designed protection concept
  - Definable disconnection and reconnection of node and branch elements (transformers, lines, loads etc.)
  - Start-up and switch-off processes of machines
  - Modeling of user-defined load shedding
  - Fault clearing by modeled protection devices

Calculation

The extended topology modeling, the robust simulation method and the DLL interfaces enable a wide range of applications in the field of dynamic simulation.

- Precise and fast initialization of the dynamic models contained in the network model, so that the simulation can start in the steady-state condition
- Robust and high-performance simulation engine based on a predictor-corrector method
  - Stable short-term and long-term simulation, so that different time horizons and phenomena can be observed
  - ExpMode: Simplified parameter variation calculation with nested structure and control options
  - ExpMode: optional dynamic adaption of simulation time step during time domain simulation
  - ExpMode: Transition between EMT (EMT module) and RMS simulation methods and switching of model orders

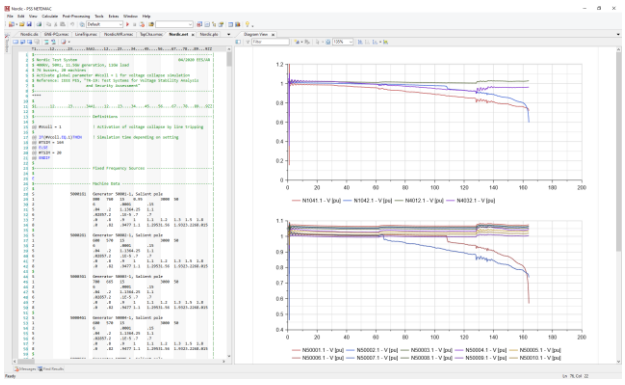


Figure 35: Stability Simulation in Expert Mode

Results and evaluation options

The program provides the following options for evaluating the results.

- All signals of the simulation can be made available as results:
  - Voltage RMS values, angles and frequencies of all nodes contained in the network model
  - Current RMS values and angles through all branches included in the network model
  - Active and reactive power of all node and branch elements
  - Impedance or admittance at the branch elements
  - Machine model internal variables for the rotor windings in the d and q axis
  - Mechanical variables of the machines such as speed, rotor angle (related to different references) and slip
  - All internal signals of dynamic models
- Extended evaluation options of the dynamic simulation
  - Automated determination of the critical fault clearing time (CFCT) by defining the initial fault duration and stability conditions
  - Evaluation of variations in generation and loads in the time domain
  - Individual evaluation options in element controllers with the possibility of exporting information (csv, txt etc.) as well as the output of warnings and fault messages during the simulation runtime
  - ExpMode: Identification of system information from the time domain signals using FFT, Prony or Matrix Pencil methods
  - ExpMode: Possibility of displaying characteristics in x-y diagrams
- Diagrams for the evaluation of the time domain simulation
  - Intuitive and easy to use diagrams with basic evaluation and display options
  - Comparison of results from variant and scenario calculations
  - ExpMode: Simple creation of individual and collected variant diagrams and variable annotations
- Export the results to frequently used formats
  - Export of any displayed signals via copy & paste
  - Export as COMTRADE or PLT files
  - Any signal can be written out from user-defined models in ASCII character-based formats according to a defined structure

Electromagnetic Transients
(EMT)

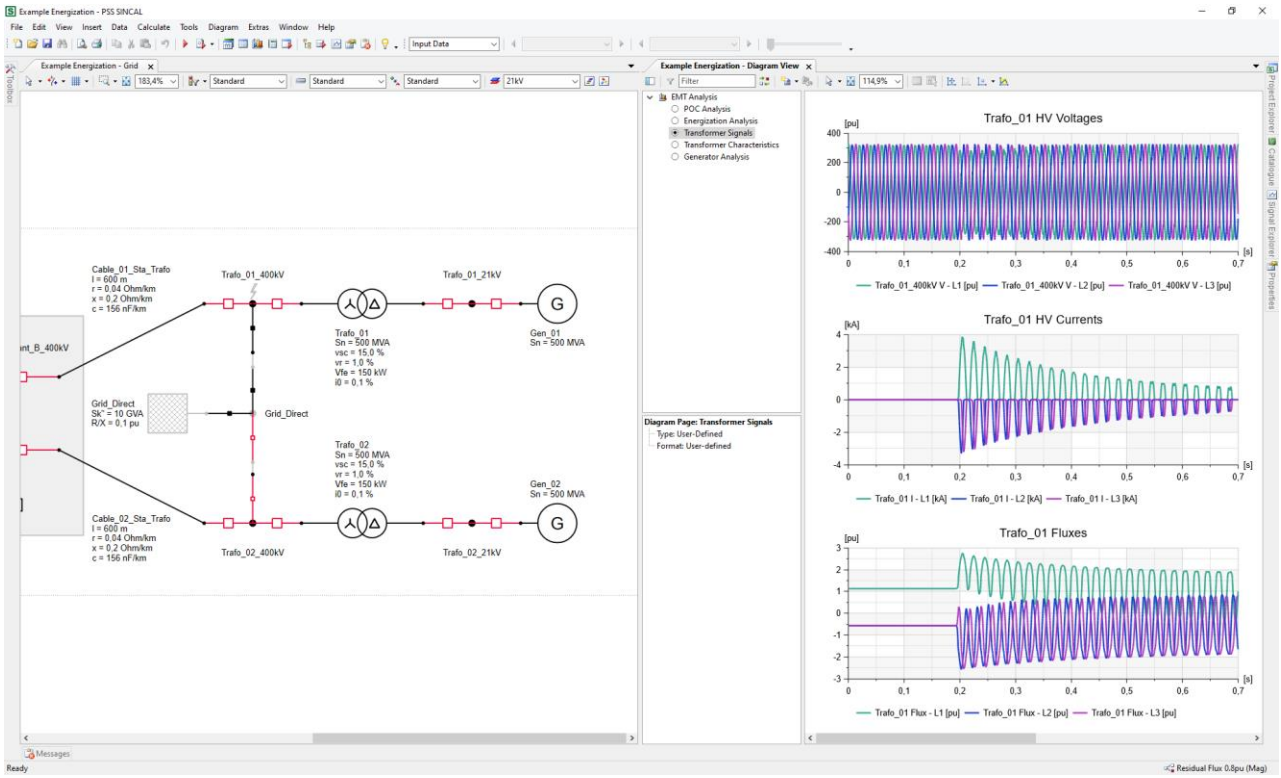


Figure 36: Analysis of Transients by Electromagnetic Transients (EMT) Simulation

Requirements

The dimensioning of equipment in electrical power systems requires the determination of their electrical and mechanical stresses that can occur during operation of these systems as a result of switching operations and faults. Depending on the components, the potential physical phenomena, occurring in different frequency ranges, have to be analyzed and appropriate counter-measures taken in the sizing and protection concepts if limits are violated.

- Analysis of insulation coordination regarding temporary overvoltages (TOV) or those caused by switching operations (SOV) or lightning strikes (LOV)
- Evaluation of very fast transient overvoltages (VFTO)
- Analysis of the effects of switching on and switching off of lines, transformers, electrical machines and inductive loads
- Determination of the stresses on circuit breakers during switching operations
- Analysis of transient voltage recovery (TRV)
- Studies on the connection of converter-based electrical generation and transmission systems such as HVDC, FACTS, wind and photovoltaic systems
- Analysis of subsynchronous resonances (SSR) and interactions (SSTI) with machine drive trains (additionally, module TOR is needed)

Solution

The PSS®SINCAL Platform with its PSS®NETOMAC transient engine offers the user in this module (EMT) the possibility to use it for most basic applications directly in the PSS®SINCAL GUI, as well as in expert mode (ExpMode) to use the native user interface of the engine for advanced calculations.

The transient engine offers a very high degree of freedom for modeling and simulation control in addition to the precise and reliable internal dynamic models of equipment.

- Time domain simulation based on instantaneous values for symmetrical and asymmetrical networks with symmetrical and asymmetrical fault conditions, loads and generation
- Initialization of network model by power flow
- Use of proven and successfully validated dynamic models and simulation methods of the PSS®NETOMAC transient engine
- User-friendly and simple control of the calculation and evaluation of results

Modeling

In the analysis of electromagnetic transients, the greatest modeling depth for network elements is used throughout the program in order to adequately represent the transients from a few Hz to the range of several MHz. In addition to the extended models of machines and their control devices, network element models based on differential equations are also used, which can be extended if necessary, by non-linear characteristics or their approximated frequency behavior. User-defined models of other equipment can be implemented at different depths of detail.

- Modeling of the dynamic behavior of machines (synchronous and asynchronous machines) by means of differential equations
  - Synchronous machines are modeled with the 7th order (dq) Park model while taking the stator field dynamics into account
  - Depending on the configuration, asynchronous machines can be modeled with single and double squirrel cage, short-circuited, resistive or fed rotor windings
  - The equipment models are parameterized with original data (impedances) or derived values for various operating ranges (subtransient, transient, synchronous) for the dq system
  - ExpMode: Individual wiring and control of the rotor windings of asynchronous machines
  - ExpMode: Reference of the rotor angle to terminal voltage, center of inertia (COI) or to the rotor angle of certain machines
- Multi-phase or single-phase and modular network topology modeling
  - Symmetrical and asymmetrical network models
  - Single or 3-phase input of the network model
  - Input of resistive, capacitive and inductive coupling data for nodes and branch elements
  - Modularly expandable models in order to consider EMT-specific features
- Consideration of different EMT-specific models for components
  - Implementation of non-linear characteristics (e.g. saturation) for otherwise linearly treated network elements
  - Frequency-dependent modeling of lines and cables with concentrated or distributed (based on the wave equation) parameters
  - For concentrated parameters there is the possibility of modular model chains of Pi and T elements
  - For distributed parameters, simple and Marti model or the Universal Line Model (ULM) can be used
  - Use of the native ASCII character-based format of the PSS®NETOMAC transient engine for extended topological definition of individual node and branch elements
  - User-defined modeling of network elements to simulate any kind of equipment behavior
  - Voltage and current sources for pulse excitation
  - Surge arresters and spark gaps
  - Individual components of power electronics such as diodes, thyristors, GTOs etc.
  - PWM ignition pulse generation for thyristor-based converter models
  - Resonances with drive trains of machines (TOR module)
  - Extended models for current and voltage transformers
  - ExpMode: Use of hysteresis curves
  - ExpMode: Combined RMS/EMT hybrid simulation to simulate DC link circuits and to co-simulate subnetworks (ST module)
- User-defined models for control and communication equipment for various types of generation and transmission systems
  - Intuitive creation and analysis of user-defined models in the graphical model builder (GMB module) and easy connection to the node and branch elements in the network model
- Any definable events and their sequences in the time domain on busbars, node and branch elements as well as clearing of fault conditions
  - Definition of conditions regarding time and voltage query when a fault occurs as well as time and break-off current when the fault is cleared
  - Short-circuit observations for 3-, 2- and 1-phase busbar faults with or without earth connection
  - 3-, 2- and 1-phase line interruptions also in combination with different earth faults
  - Individual fault clearing based on defined specifications
  - Definable disconnection and reconnection of node and branch elements (transformers, lines, loads etc.)
  - Start-up and switch off processes of machines
  - ExpMode: Consideration of arc reverse voltages
  - ExpMode: Consideration of simple or individual recovery strength during the switching operation
  - ExpMode: Determination of synchronous machine synchronization conditions regarding voltage, phase position and frequency

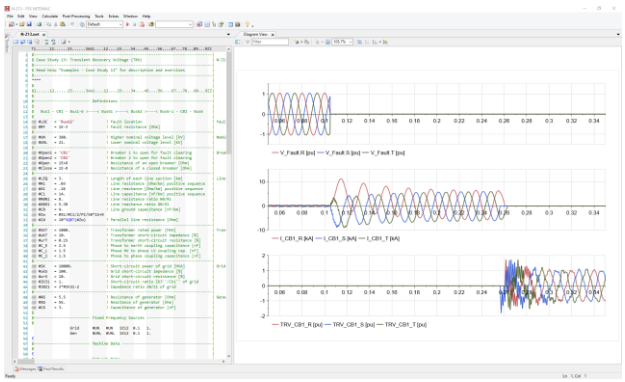


Figure 37: EMT Simulation in Expert Mode

Calculation

The modularly expandable topology modeling as well as the high performance and robust simulation method enables efficient and in-depth analysis of electromagnetic phenomena in the instantaneous values domain.
The transient engine allows even the simulation of large network models.

- Precise and fast initialization of the network model, so that the simulation can start in the steady-state condition
- Robust and high-performance simulation engine based on the difference admittance method
  - ExpMode: Possibility of switching the simulation time step during the simulation
  - ExpMode: Intuitive parameter variation calculation with nested structure and control options
  - ExpMode: Transition between EMT and RMS simulation methods and switching of model orders
- Simulation of the influence between AC and DC systems in the event of a fault

Results and evaluation options

The program provides the following options for evaluating the results.

- All signals of the simulation can be made available as results:
  - Instantaneous values, as well as their calculated magnitudes, angles and frequencies of all node voltages and voltage differences contained in the network model
  - Instantaneous values as well as their magnitudes and angles of all branch currents contained in the network model
  - Calculated active and reactive power of all node and branch elements
  - Impedance or admittance at the branch elements
  - Voltage, energy, flux and current values in non-linear network elements
  - Machine model internal electrical values for the rotor and stator windings in the d and q axis
  - Mechanical variables of the machines such as speed, rotor angle and slip
  - All internal signals of user-defined models
- Advanced evaluation options of the transient simulation
  - Individual evaluation options of all signals of the simulation in global models with the possibility of exporting information (*.csv, *.txt etc.) as well as the output of warnings and fault messages during the simulation runtime
  - ExpMode: Identification of system information from the time domain signals using FFT, Prony or Matrix Pencil methods
  - ExpMode: Possibility of displaying characteristics in x-y diagrams
- Diagrams for the evaluation of the time domain simulation
  - Intuitive and easy to use diagrams with basic evaluation and display options
  - Comparison of results from variant and scenario calculations
  - ExpMode: Simple creation of individual and collected variant diagrams and variable annotations
- Export the results to frequently used formats
  - Export of any displayed signals via copy & paste
  - Export as COMTRADE and PLT files
  - COMTRADE Export can be linked to protection locations and instrument transformers
  - Any signal can be written out from user-defined models in ASCII character-based formats according to a defined structure

Electrical Networks – Extended Modules

Thermal Destruction Analysis

(TDA)

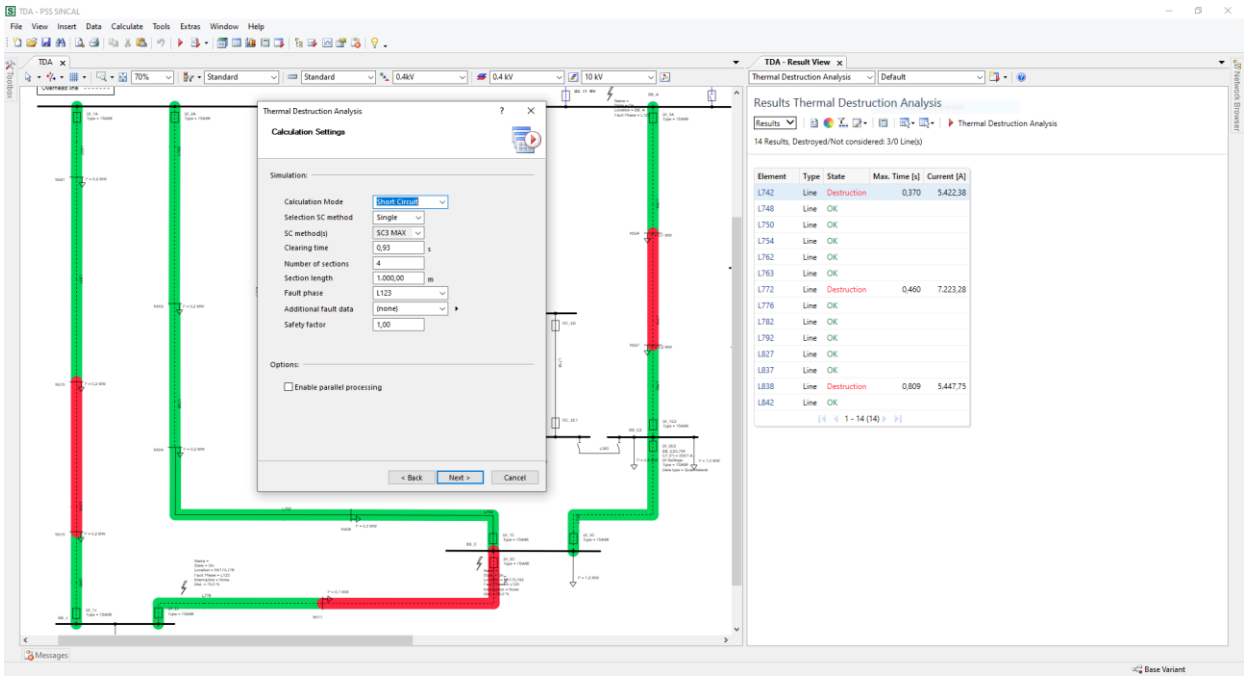


Figure 38: Thermal Destruction Analysis - Destroyed network elements in the result view and in the network graphic

Requirements

The operating equipment of the network must be designed to be thermally short-circuit-proof. This requires a check for thermal destruction. For this purpose, the occurring short-circuit currents must first be determined for all possible fault locations in the network, possibly also for different fault types. From the occurring short-circuit currents and the short-circuit current capability of the equipment, the maximum permissible fault times can be calculated. These maximum fault times must be higher than the fault clearing times of the protection system to ensure that the equipment get not thermally destroyed. This test is very time-consuming when performed manually, so a time-efficient solution is desirable.

Taking into account the tripping behavior of the network protection, there are further requirements.

In meshed networks, the changing short-circuit currents during stepwise fault clearings must be considered.

If inverse tripping characteristics are used (e. g. inverse time OC, reclosers, fuses...), all fault types must be calculated, since here the 1-phase short-circuit current can represent the biggest thermal stress for the equipment at high tripping times.

Solution

The thermal destruction analysis in PSS®SINCAL enables both, the network planning, and the protection department to perform an automated check for thermal destruction for all lines,transformers, busbars and breakers in the network.

While in the protection department a model of the network protection is usually available, it isn't in the network planning. Therefore, there are different modes for the check for thermal destruction:

Short circuit mode

The protection systems aren't modeled in the network to be analyzed. The thermal short circuit withstand capability of the equipment is therefore checked for a predefined maximum fault time. This maximum fault time should correspond to the maximum fault clearing time of the network protection.

Protection mode

Protection systems are modeled for the network. The thermal short circuit withstand capability of equipment the lines and transformers is therefore checked considering the tripping behavior of the protection systems.

As a result, the user receives a clear representation of all equipment that gets thermally destroyed. With this, measures regarding network protection or network expansion can be determined to restore the thermal short-circuit withstand capability. These measures can then be tested directly with the thermal destruction analysis.

- Automated check for thermal destruction for all lines, transformers, busbars and breakers in the network with specification
  of a maximum fault time in the Short-circuit mode.

- Automated check for thermal destruction for all lines, transformers, busbars and breakers in the network, taking into account the tripping behavior of the network protection in the Protection mode
- Destroyed network elements are determined and displayed in the result view and in the network graphic
- Detailed view for each network element with listing of all fault locations where a fault leads to the destruction of the element

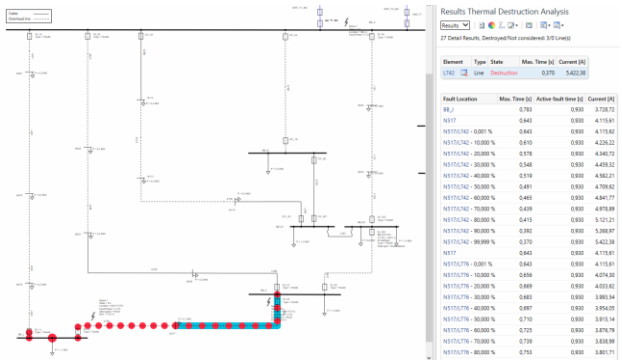


Figure 39: Fault locations (red) in the network graphic and the result view where the selected element (blue) gets destroyed

- Recalculation of faults from the detailed view to analyze a fault case in detail in the network graphic, e.g. the occurring short-circuit currents and the fault clearing time

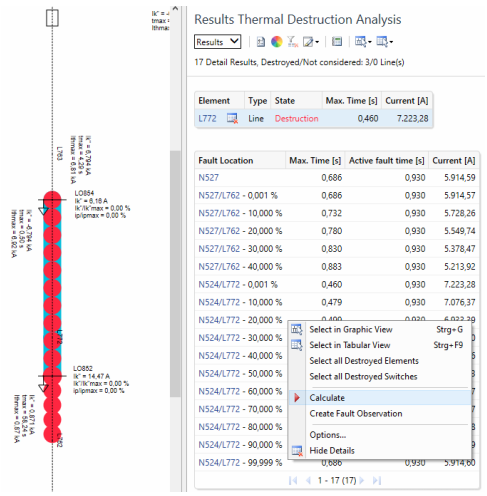


Figure 40: By a right-click on a fault location in the result view, any fault can be recalculated in the network graphic

- Determination of measures regarding network protection, e.g. the adjustment of protection settings or protection concepts, and validation of these with the thermal destruction analysis
- Determination of measures regarding network expansion, e.g. network reinforcements within the scope of target grid planning, and validation of these with thermal destruction analysis
- Thermal destruction analysis with very little time effort due to automated check for thermal destruction of equipment for fault events throughout the network

Modelling

For the check for thermal destruction in the short-circuit mode, the network must be modeled with its primary equipment. This includes the short-circuit current capability of the equipment. In the case of lines, this is specified via the permissible short-circuit current (1s). In the case of transformers, the short-circuit withstand capability is determined based on the rated data according to IEEE C57.109.

For the thermal destruction analysis in the protection mode, the protection devices must be modeled in the network. All protection device types available in PSS®SINCAL are supported. For differential protection, you can set whether it should be considered in the thermal destruction analysis or not.

- Optional limitation of the calculation area, in which fault events are calculated, to network level, network area or network element group.
- Optional limitation of the analysis area, in which it is checked whether fault events in the calculation area lead to a destruction of equipment, to network level, network area or network element group.

Calculation

The thermal destruction analysis is based on the short circuit calculation in the short circuit mode and on the protection simulation in the protection mode. In both modes, fault simulations are performed automatically in the entire network.

- The number of fault simulations along lines can be set flexibly, calculations are also performed at each node
- Thermal destruction analysis for one fault type or for several fault types in parallel (3-, 2-, 1-phase faults)
- Check for thermal destruction in short circuit mode for defined maximum fault times
- Check for thermal destruction in protection mode based on the protection system tripping times, also taking into account cascaded fault clearings
- Safety factor to consider uncertainties (e.g. inaccurate line data or changing currents during the fault clearing process) and identify equipment that will not be destroyed based on its rated data but will face high thermal stress
- Calculation of maximum fault times for every fault location and short circuit current
- Recalculation of specific fault cases from the results of the thermal destruction analysis
- Specification of fault impedances (arc and earth impedances)

- Specification of the faulted conductors in (a)symmetrical networks
- Check for thermal destruction in the main protection case or in the backup protection case (for protection device or circuit breaker malfunctions)
- Configurable automatic distribution of the simulation into multiple processes (to use multiple cores) for the parallelization of the overall simulation task

Results and evaluation options

The results of the thermal destruction analysis are available in the results view and in the network graphic

Result view

- Result list which contains all checked network elements and highlights destroyed elements in color
- Detailed view for each destroyed network element with the listing of all fault locations where the network element gets destroyed
- Calculation results such as the maximum fault time, the associated short-circuit current and the fault type are displayed for each fault location

Network graphic

- Highlighting of single network elements in the network graphic by selecting a network element in the results list. Results from the result list can thus be quickly assigned to the corresponding network element in the network graphic. Furthermore, all fault locations where the selected network element gets destroyed are highlighted in red in the network graphic
- All checked network elements can be highlighted in the network graphic at once, hereby destroyed network elements are colored red
- Starting the fault calculation from the detail view for specific fault locations. Detailed calculation results are then available in the network graphic, allowing analysis of the fault event for this fault location

Report

- The results of the thermal destruction analysis can be saved in PSS®SINCAL and exported as a report in .pdf format

Operating Point/Time Series Calculation (LP)

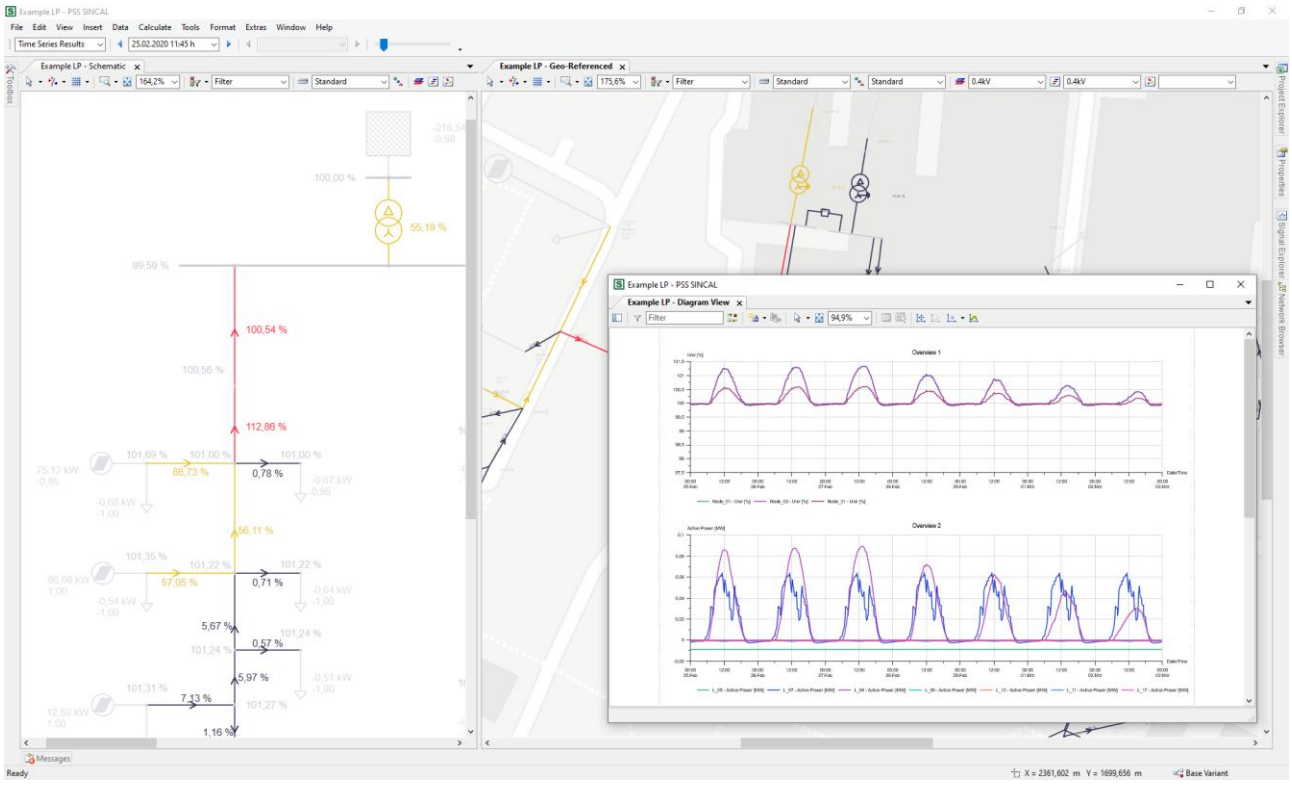


Figure 41: Results of time series power flow calculation in network graphic (schematic and geographic view) and diagrams

Requirements

The quasi-dynamic observation over short and medium-term time periods (from several hours, days to several years) is relevant in addition to the observation of the steady-state behavior of the network at individually selected points in time (operating points). The behavior of the network must be analyzed according to time series in order to not only observe individual predefined operating conditions, but also the behavior of the system over the observed period.

- Power flow calculations considering historical measurement data, forecast data, profiles for generation and consumption (standard load profiles), switching states and the actuating values and effects of various regulating devices
- Quasi-dynamic calculation based on individual power flow calculations
- Analysis of the simultaneity of supply and consumption
- Maximum value determination over the entire time period
- Use of calculation values (in kWh) from customer and calculation data
- Loss analysis over period
- Parameterization and optimization of controllable network elements (e.g. capacitors, reactors, transformers, converters)
- Validated network model based on measurement results
- Determination of generation and consumption costs based on cost profiles

Solution

The module for time series and operating point calculation (LP) in PSS®SINCAL enables the simulation of a network in user-defined time periods and resolutions as well as the calculation of operating points based on the extensive methods for modeling and calculating a power flow.

- Operating point calculation for symmetrical and asymmetrical networks
- Time series calculation for symmetrical and asymmetrical networks
- Full integration of the controlled elements simulated for the power flow and user-defined models in the quasi-dynamic calculation
- Total or user-specified range of results for each network element at each point in time
- Visualization of the equipment utilizations over the entire period

Modeling

For this purpose, the modeling of the network is enhanced by the following options based on the power flow model:

- Operating points for network elements and operating series based on the operating points
- Profiles with variable time step (e.g. 15min) for network elements that model supply or consumption
  - Operating points and series
  - Daily, weekly and annual series
  - Input format of the profiles as common or separate factors or absolute values for active and reactive power
  - Input format of the operating points and profiles as factor or absolute values for active power and node voltage
  - Determination of instantaneous power values based on the entered energy consumption (e.g. meter reading or billing value in kWh) as average value or with parameterizable exponential function
  - Ambient temperature profiles for network areas
- Profiles for controllable elements such as capacitors, reactors, transformers, converters and groups of these elements
- Profiles for the time dependent (dynamic) line/transformer rating to model the temperature dependent change of the rating over time
- Modeling of measured values with profiles for current, active or reactive power
- Overlay of profiles to combine short-, medium- and long-term profiles
  - Multiplicative combination of the profiles
  - Modelling of medium or long-term effects such as seasons, forecasted increase or decrease with long-term profiles
- Integration of user-defined models and controllers (*.xmac) with a time behavior relevant for time series calculation (e.g. battery charge management)
- Simulation of snapshots or whole time series with time series data located in an open and generic external database (e.g. metering or forecasting data) with the time series data interface (module TSDI) without additional transfer of input data

Calculation

The calculation for all operating points or time points in the observation period requires only a single triggering of the calculation.

- Time step for calculations can be selected freely (minutes to days)
- Calculation of the entire simulation period or all operating points
  - Cyclic handling of profiles that are not defined for the entire simulation period
  - Storage of the results for each point in time /operating point
  - Extreme or maximum value determination based on minimum or maximum node voltage or the VPI (violation performance index) of a node and storage of this determined point in time
- Calculation of the cumulative losses and of the duration of consumption and generation
- Options for the usage of the power flow results from the previous time step as iteration start (initialization) for the subsequent steps of the time series calculation
- Complete integration of the load determination (LA module) in the time series calculation to perform scaling or trimming at each point in time

Results and evaluation options

The program provides the following options for evaluating the results.

- Complete results of each individual power flow calculation (for each point in time) for evaluation in graphics, tables and databases (see also LF module) as well as in reports
  - Optional storage of the time series calculation results in an external database to reduce the memory requirement of the network database
- Function for determining maximum, minimum and average values of the entire calculated period or individual time periods in the tabular view
- Diagrams for user-defined presentation of input data and results over user-defined time periods
  - Supply or consumption profiles of the elements (determined from the input data)
  - Voltage and power values of the nodes
  - Utilization of the branches and power flowing over them (lines, transformers, etc.)
  - Power loss and lost energy, costs and duration profile over the period observed for the entire network, the individual network levels and network areas

Network Development

(LD)

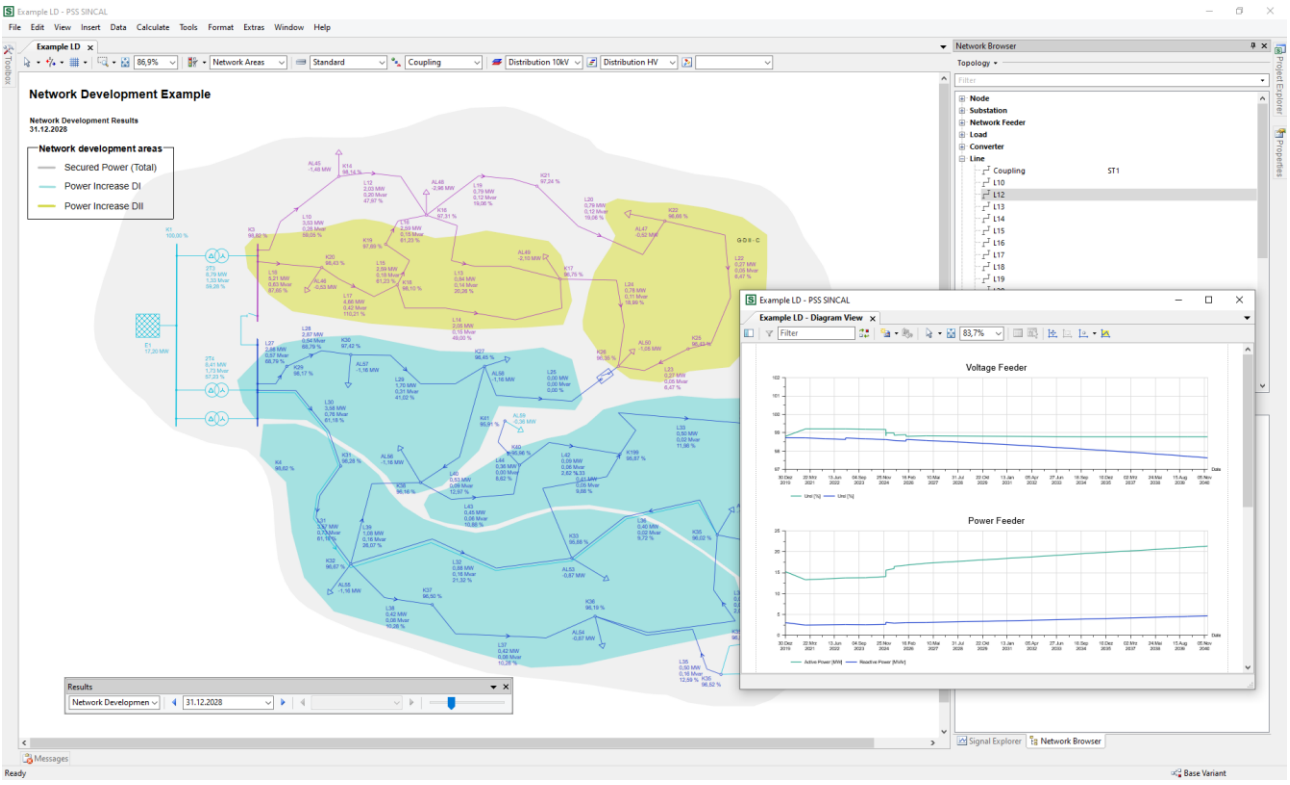


Figure 42: Results of a network development calculation with a 20 year horizon

Requirements

In addition to the observation the network with the loads and generating plants at the actual point in time, it is necessary to observe further points in time in medium and long-term periods (years). For this purpose, the necessary measures for the expansion, restructuring or deconstruction of the network, which result from changes in loads, commissioning and decommissioning or exchange of equipment are to be derived.

- Target network planning for medium to long term periods
- Network calculations considering the predicted growth or decrease rates of loads depending on the network area as well as already known data for the commissioning and decommissioning of equipment
- Power consumption and operating points of power plants or renewable generating plants that change over time (e.g. repowering)
- Evaluation of the guaranteed power capacity for network areas for different scenarios of load increase in the supply areas
- Identification of weak points in the network and prioritization of network expansion and restructuring measures as well as determination of economic savings potential

Solution

The module (LD) in PSS®SINCAL, based on the extensive methods for modeling and calculating power flow, allows the calculation of a network at selected times in the medium- or long-term period which is considered for the target network planning.

- Extensive options for modeling increase, consumption and increments of load power as well as the times for commissioning and decommissioning of network elements
- Calculation of the power flow at all (automatically determined) times in the calculation period at which increase, decrease, commissioning and decommissioning occurs in one single calculation run
- Results at the individual points in time and over the entire time period of the evaluation

Modeling

The modeling of the network is enhanced by the following options based on the power flow model:

- Allocation of increase/consumption rates to loads individually or in groups
  - Continuous consumption or increase rates as a profile with relative factor, relative or absolute power values for loads

    - Increase profiles for the simulation of discrete decrease or increase at individual loads or at network element groups with several loads
    - Increase profiles for the simulation of discrete reductions or increases at network feeders and generators
- Assignment of increase or decrease over user-defined supply areas (polygon areas) in the user interface as graphical element groups
- Issuing of time stamps (date) for the commissioning and shutdown of network elements
- Specification of firm power for the supply of load elements in supply areas for later evaluation
- Integration of user-defined controllers or models (GMB module) with a time behavior (e.g. battery capacity degradation) within a network development calculation

Calculation

The calculation is performed after the start for the entire period in one calculation run.

- Power flow calculation of the network model at all relevant times in one calculation run
    - Standard time step (one year) for the calculations between the start and end date of the observation period
    - Additional calculation at any time (automatically determined) of the modeled characteristic curves for load increase or increase powers
    - Additional calculation at any time of commissioning and shutdown of network elements
- Loss calculation at any calculated point in time
- Optional: Integration of the economic efficiency calculation (CC module) into the calculation for the selected period.

Results and evaluation options

The program provides the following options for evaluating the results.

- Complete results of each individual power flow calculation (for each point in time) for evaluation in graphics, tables and databases (see also LF module) as well as in reports
- Evaluation of the number of violated limit values for voltage at nodes and utilization of network elements
- Visualization of the load density of the supply areas (polygons) in the network graphic at the individual calculation time points
- Diagrams to show the power values, losses, profiles and limit value violations at the individual times during the entire calculation period
    - Individually configurable diagrams of the voltage, power and utilization values at the individual elements
    - Display of the modeled increase or consumption profiles in diagrams
    - Display of the number of violations of the user-defined limit values for node voltages and utilization of lines or transformers
    - Display of the guaranteed power capacity and the consumed power in the polygons for the evaluation of the supply security
    - Power losses at any time and cumulative energy losses

Load Assignment/ Transformer Tap Detection

(LA)

Requirements

To increase the accuracy of the modeling of loads and DERs in the network model, measured values at individual points in time or time periods can be used. By adjusting the modeled values for loads and decentral energy resources (DER) in relation to the measured values, statements about (subordinate) network areas for which no measured values are available should also be made.

- Determination of input data for loads as well as power flow calculations considering measured data or forecast data to refine the modeling of loads and DERs
- Determination of operating points of not measured/forecasted loads or DERs based on selected feeder measurements and metering devices
- Use of maximum or minimum measured values (e.g. from maximum trailing pointer values at the feeder hat) or time series measurements (e.g. feeder measurement with 15 min resolution)
- Optimal utilization of the network capacity based on the measured time series and profiles instead of design for individual operating points
- Validation of load modeling and network model based on measurements

The optimized setting of the position of the regulators of transformers of medium and low voltage substations must be based on measured or calculated values for nodes.

- Determination of optimal tap positions of the transformers to maintain the permissible voltage band in the subordinate network

Solution

The module for load trimming and determination of optimum transformer tap positions (LA) in PSS®SINCAL makes it possible to scale and trim load input data. Trimming can also be used to determine an optimized transformer tap position based on the minimum and maximum voltage values.

- Adaptation of the input data (or factors) of the load elements by scaling or by trimming during the power flow calculation until the minimum or maximum measured values are reached
- Determination of occurred or predicted load or supply states of the network based on measured values
- Separate consideration of loads and decentral energy resources (DER) in the trimming
- Full integration of the functions for calling the scaling or trimming in the time series calculation (LP module)
- Determination of the position of the regulators of transformers to comply with the specified minimum and maximum voltage limit value as well as visualization of the positions in the network graphic

Modeling

The network model for the power flow and time series calculations serves as a basis and includes the modeling of measuring devices and measured values.

The following modeling options are available for scaling and trimming of loads and DERs:

- Modeling of (individual) measuring devices for the integration of measured values or measured value time series (as measured value profiles or time series) on lines or at node elements
  - Input of measured or forecasted values for current and power factor, active and reactive power or apparent power and power factor
  - Assignment of measurement time series as cyclical profiles or operating points with current, active and reactive power or apparent power (LP module)
  - Overlay of profiles to combine short, medium- and long-term profiles (LP module)
- Weighting factor value input for trimming based on basic data at loads, converters, generators and motors (without modeling an additional measuring device)
  - Option to activate participation in trimming for each element or to behave according to the input data
  - Simulation of the relationship of the individual elements to each other using the input data
- Modeling of bidirectional power flow by power consumption as loads and supply from DERs
- Simulation of snapshots or time series with time series data located in an open and generic external database (e.g. metering or forecasting data) with the time series data interface (module TSDI) without additional transfer of input data
  - Linking of measured/forecasted time series for time dependent measurement device input
  - Complementary approach to consider either time dependent power factor from time series or the static modeled power factor of the measurement device

Further input data is available for the function for determining the optimum tap positions of the transformer taps.

- Input of individual limit values for the voltage deviation at the loads
- Specification of profiles for controlled elements (transformers)

Calculation

Various functions (scaling, trimming or determining the position of the regulators) are available for the calculation.

- 'Scale' function for the distribution of the measured values to the individual loads by linear scaling of the input data of the loads
  - Scaling of the loads without consideration of the expected losses (solution not closed)
  - Power flow calculation with scaling results
- 'Trimming' function for the distribution of the power or current values at the measuring devices to the individual loads/DERs by calculating the power flow taking the losses into account
  - Iterative scaling of the load/DER active and reactive power until they match the result of assigned measurement device
  - Full consideration of the losses in the power flow calculation (closed solution)
  - Separate consideration of loads and supply from decentral energy resources (DER)
- Support of the functions for radial as well as meshed networks
- Completely integrated into each power flow based calculation or time series
  - Scaling or trimming for each calculation point in time (module LP)
  - Time dependent weighting of the loads/DERs against each other based on their time dependent profile characteristic (e.g. standard load profile)
  - Stored results for each calculation point in time
- Function for determining the position of the regulators of transformers to maintain the specified minimum and maximum voltage limits

Results and evaluation options

The following possibilities for the result evaluation of the scaling and trimming are provided.

- Results of the load assignment in graphic, table and database as for all power flows or other methods
- Transfer of the results as input values (or factors for the input values) for the loads decentral energy resources (DER)
- Result browser with the start and result values for the elements included in the trimming and the option to take over the data as input data (or factors)

The results of the tap position determination are shown particularly in the network graphic with color-coded visualization.

- Visualization of the determined positions of the regulators in the network graphic with highlighting
- Visualization of the voltage profiles along the feeders and the voltage limits in diagrams

Economic Efficiency Calculation

(CC)

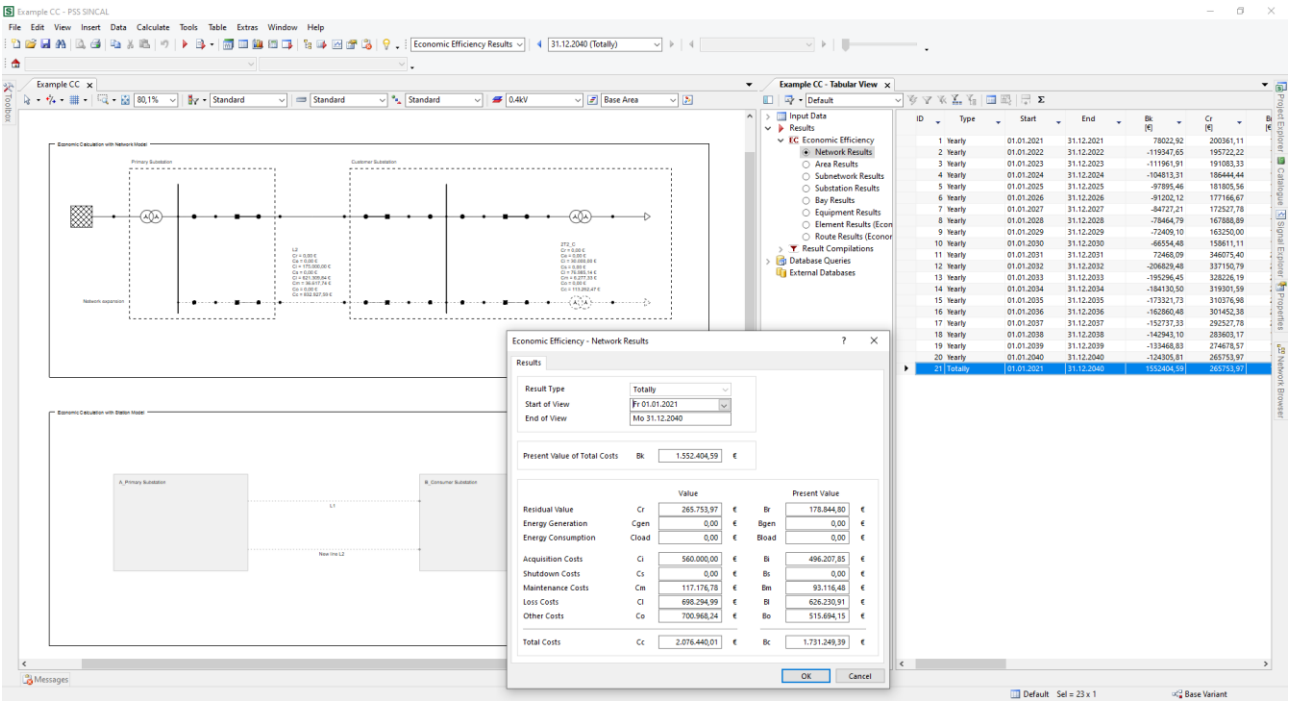


Figure 43: Results of a network economic efficiency calculation with a 20 year horizon

Requirements

Measures based on technical studies and calculations for the expansion, restructuring or deconstruction of the network should also be evaluated from an economic point of view. This observation is carried out in medium and long-term periods (years) within the planning horizon.

- Calculation and comparison of the expenditure and costs of planned variants for the expansion and restructuring of the network
- Assessment of capital expenditures and operating expenditures (CAPEX and OPEX)
- Calculation and assessment of the economic efficiency of a planned measure using the capital value method (also called NPV net present value method calculation)
- Support for investment decisions and the determination of a suitable time (delay or bringing forward of measures)

Solution

The module (CC) in PSS®SINCAL enables an economic efficiency assessment of technical measures and variants for a selected development period of the network and supports the operator in the preparation and selection of measures under economic aspects.

- Additional modeling dimension for one-off expenses for establishment and shutdown and the operating costs of network elements
- Calculation of investment expenditure and costs using the net present value method (with or without discounting) for each year of the period observed and for the whole period
- Optional integration of the economic calculation with loss and generation or consumption costs resulting from power flow calculations

Modeling

The modeling of the network is enhanced by the module with an (optionally entirely separate) model for the representation of costs of the network elements.

- Use of the substation and route model
- Use of the times of commissioning and shutdown of network elements
- Modeling of one-off expenses and operating costs for network elements and their life cycle
  - One-off expenses: Establishment costs, shutdown costs
  - Operating costs: Annual maintenance and servicing costs, annual operating costs
  - Individual life cycle of the network elements
- Parameters for the annual interest rate and inflation
- Factors for modeling the technically unavailable energy
- Economic efficiency calculations (without loss observation) already possible without a complete and electrically correct network model

Calculation

The calculation is performed after the start for the entire period in one calculation run.

- Calculation of a user-defined analysis period of several years between observation date and planning horizon
- Net present value method for determining costs in annual intervals
  - Summation method with cost calculation without discounting at the time of observation
  - Capital value method/net present value method with cost calculation including the discounting of all costs at the time of observation
- Calculation of capital expenditures (CAPEX) and operating expenditures (OPEX)
- Optional: Integration in load development (module LD) for more detailed calculation of losses and cost profiles for generation and consumption in annual intervals

Results and evaluation options

The program provides the following options for evaluating the results.

- Complete results for each year within the observation period in graphics, table and database as well as in reports
  - Annual operating costs
  - Year-specific present value, discounted net present value and residual value
- Results for the individual network elements, the entire network, the individual network areas, substations, bays and routes
- Totals for the entire observation period for costs and present value from the results of the individual years for the evaluation of economic efficiency

Network Stress Test

(NST)

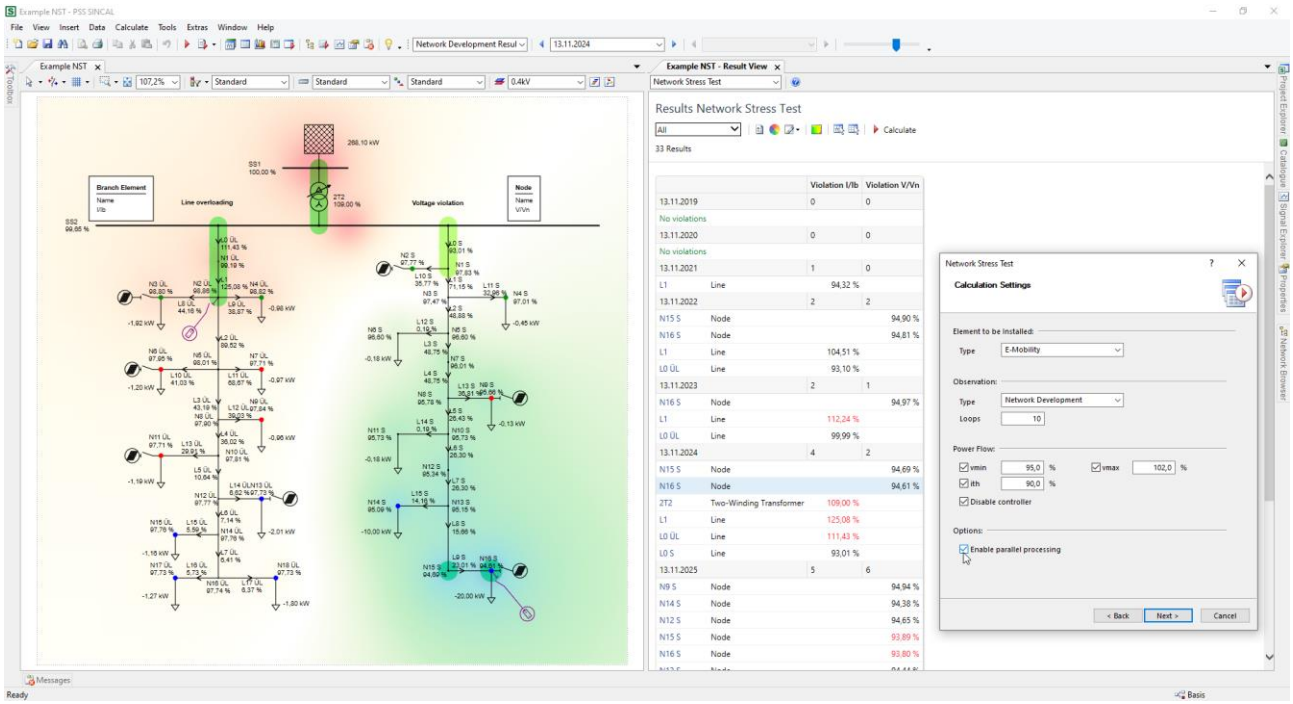


Figure 44: Calculation results from Network Stress Test in network graphic and result view

Requirements

The integration of the charge infrastructure for electro-mobility or decentral energy resources (DER) leads impacts mainly the distribution networks.

Since these loads or feed-ins vary both in terms of location and time, the planning cannot work with predefined locations and times for the expansion of the charging infrastructure (and comparable elements to be modeled, such as heat pumps) or decentral energy resources (DER). A stochastic approach is required for a random distribution of the planned consumers or power generation systems in the supply area and the subsequent calculation and network analysis.

- Checking of the utilization (loading) of equipment due to the additional charging infrastructure/ decentral energy resources (DER)
- Checking of the permissible deviations of the network voltage due to the additional charging infrastructure/ decentral energy resources (DER)
- Provision or inclusion of the required power by the local substation
- Determination of the critical penetration of the supply area in a medium to long-term planning period
- Identification of weak points in the network for planning the network expansion or reinforcement

Solution

The module for performing a network stress test (NST) in PSS®SINCAL allows you to analyze the effects of increasing integration of loads decentral energy resources (DER) in the supply area.

- Analysis of the absorption capacity of supply areas for load elements/ decentral energy resources in a probabilistic bottom-up approach by random distribution of the elements
- Classification of possible connection points and the loads/converters to be connected by means of types
- Calculation of a user-defined number of loops and thus a random configuration in each loop
- Variation (increase) in network penetration over the analyzed period
- Interactive evaluation and documentation of critical configurations in relation to limit values for voltage and utilization (loading)

Modeling

The modeling is based on a network model for steady-state power flow calculations.

- User-defined selection of the network area to be analyzed
- Specification of the number of mobile consumers (loads) to be placed and their charging capacities
  - Additions at user-defined points in time to define the increase in mobile consumers over years
  - Types of consumers
  - Number of consumers
  - Specification of charging options (connection to various charging infrastructures) or producers
  - Connection type (3- or 1-phase)
- Definition of possible connection points as candidates for the connection of charging infrastructure
  - User-defined types through network element groups with network nodes to be observed
  - Specification of the maximum connected load for the nodes of a type
  - Specification of the maximum permissible number of charging infrastructure to be connected (e.g. maximum 2 for all nodes of the type "single-family house")
- Optional: Integration of future network changes (modeling) for calculations with the LD module, e.g. for the development of load values and the establishment and decommissioning or shutdown of elements

Calculation

All individual runs at all selected time points are calculated in one calculation run.

- Calculation at all selected points in time or at the current network status
- Calculation of all loops with a relevant generated random combination of connected loads/decentral energy resources
  - Random distribution of the consumers at the predefined possible connection points at the beginning of each cycle for stochastic distribution of the loads as a simulation of the charging infrastructure
  - Random distribution of the decentral energy resources (DER) at the predefined possible connection points at the beginning of each loop for stochastic distribution of the supply
  - Power flow calculation for generated load situation
- Analysis of the results regarding limit violations in the analyzed network area
  - Logging of thermal overloads and voltage range violations

Results and evaluation options

The program provides the following options for evaluating the results.

- Result view with the tabular representation of the results for each analyzed point in time and the respective maximum values for utilization (loading) and voltage deviation
  - Display of the elements with limit violations for the calculated points in time
  - Detailed view of the distribution variants (specific positioning of the loads/converters) for the determined limit value violations as well as the calculated values
  - User-defined filter options to reduce the amount of listed results (all, only limit violations, only worst case)
- Interactive evaluation from the results view in the network graphic
  - Graphical identification of elements with at least one violation (only the selected element, "all", by date)
  - Updated heat map for each time step
- The results of the extensive calculations are stored in an external SQLite database

Maximum Hosting Capacity
(ICA)

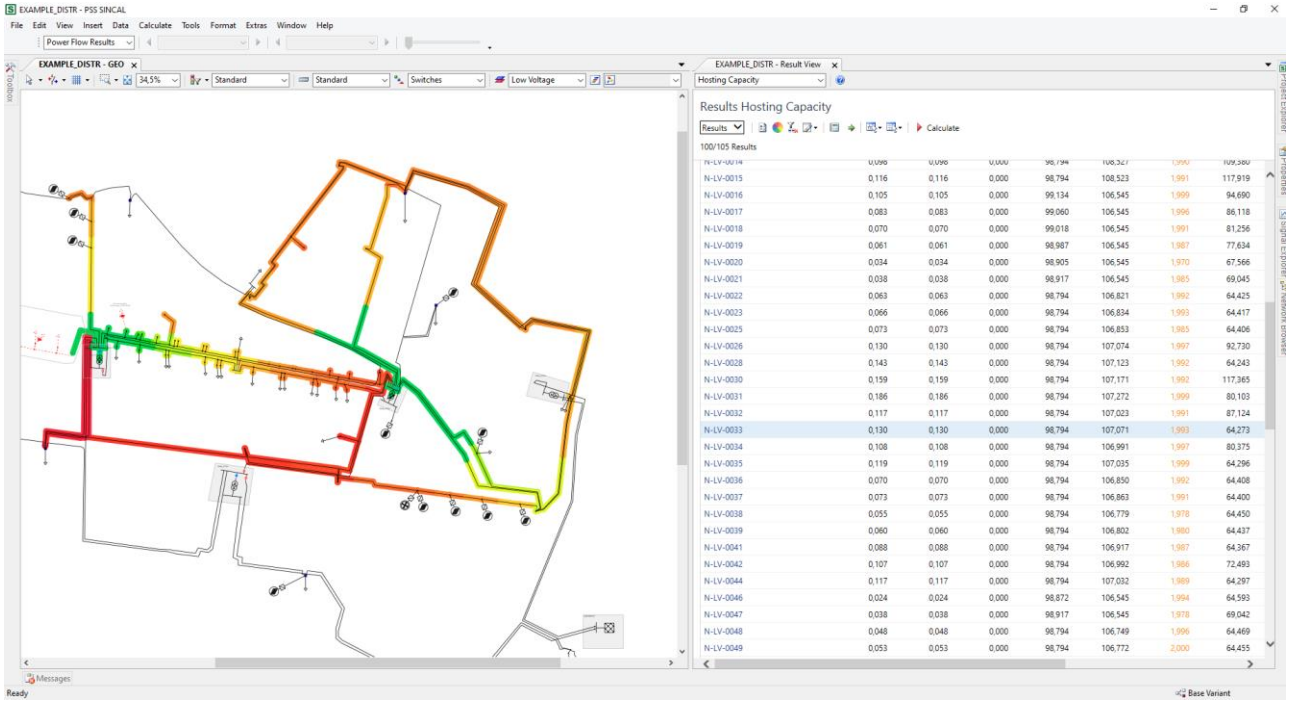


Figure 45: Hosting capacity visualization for DER in network graphic of a medium voltage distribution grid feeder

Requirements

In order to analyze the integration of decentral energy resources (e.g. photovoltaic, wind power plant, combined heat and power plant), as well as different load types (e.g. charging infrastructure for electromobility, heat pumps, Power2Heat, Power2Gas) into distribution networks, an approach is required to determine the connection capacity at the networks connection points. The analysis should not only include the power flow-based state evaluation, but also short circuit analyses. Based on these analyses, it is possible for the network operator to proactively steer the integration of loads and generation systems by regularly publishing the results.

- Quantitative analysis of selected connection points in network areas regarding their maximum capacity of additional connected active power of decentral energy resources (DER) or loads
- Performant and automated procedure that can be used for re-analysis after any change in network state or topology
- Determination of the hosting capacity with respect to different operating points or on historical or forecast time series (profiles) up to several years
- Prevention or postponement of network expansion and reinforcement measures through optimal use of existing capacity
- Publishing regional connection capacities as steering instrument for expected connection requests

Solution

The module for determining the maximum hosting capacity (ICA) in PSS®SINCAL automatically determines the largest power value of a decentral energy resources (DER) or load that can be connected to any node of a network area to be analyzed without violating technical limitations. The user is guided step by step through the setting and execution of the calculation.

- Determine the maximum connectable power at the nodes for which the user-defined criteria are met
- Integration of the individual work steps in an efficient, specified workflow with a separate screen form without additional modeling effort in the network model
- Automatic, combined calculation of a large number of power flow and short circuit calculations during the analysis workflow

Modeling

The necessary steps before the calculation
do not require the user to adapt the network model for the large number of calculations but can be done directly in the screen form.

- User-defined selection of the nodes of the network areas, levels and groups to be analyzed
  - Selection of nodes according to already defined network areas, levels and groups or individual analysis of single nodes
  - Exclusion of nodes and elements from the analysis

    - Formation of clusters according to criteria of voltage deviation or distance of neighbor nodes
- User-defined definition of the observation period for the analysis
- Definition of the element to be connected as converter for the simulation of generating plants with converter
    - Terminal power as active power between a minimum and maximum value with constant power factor
    - Simulation of the converter's short-circuit current with factor and angle
    - Simulation of the permissible operating range of the respective system in its user-defined voltage band
- Definition of the element to be connected as a load to simulate loads or converters take power from the network
    - Terminal power as active power between a minimum and maximum value with constant power factor
- Simultaneous or separate connection of elements to the selected nodes
- User-defined value ranges as criteria for power flow calculation for voltage and thermal load, which must not be violated by connecting the element to the node, as well as options for handling transformers
    - Voltage band violation
    - Voltage deviations (voltage drop)
    - Voltage deviations (voltage rise by DERs, acc. method of guideline VDE-AR)
    - Thermal utilization (loading) of lines and transformers in the power flow
    - Allow return feeding via transformers
    - Activated or deactivated controllers (e.g. tap position control)
- User-defined maximum values as criteria for short-circuit currents that must not be violated by the additional contribution of the new the element

Calculation

The calculation is performed considering the selected methods and limits and is started in a separate dialog box. During the calculation the loads or feed elements are then temporarily added to the network model. Thus, the network model is unchanged after the calculation.

- Automatic execution of all necessary individual calculations
    - Execution at all nodes / busbars
    - Clustering by user-defined grouping of geographically close nodes (distance in meters or kilometers) to increase the calculation performance
- Determination of the maximum possible terminal power at each of the selected connection nodes with respect to all the network state in all operating points / points in time
    - Calculation based on the current state of the network
    - Calculation of a valid maximum value with respect to all defined and active operating points of the network
    - Calculation of a valid maximum value with respect to all points in time resulting from the modelled time series (load and supply profiles) and linked time series data (module TSDI)
    - Calculation based on automatically generated operating points through an internal analysis of the time series before the calculation
- Storage of critical values (worst case) for evaluation to reduce the volume of the result data
- Storage of the network elements that limit the connection power at the node and the criterion (violation of the specified value range)
- Configurable automatic distribution of the simulation into multiple processes (to use multiple cores) for the parallelization of the overall simulation task

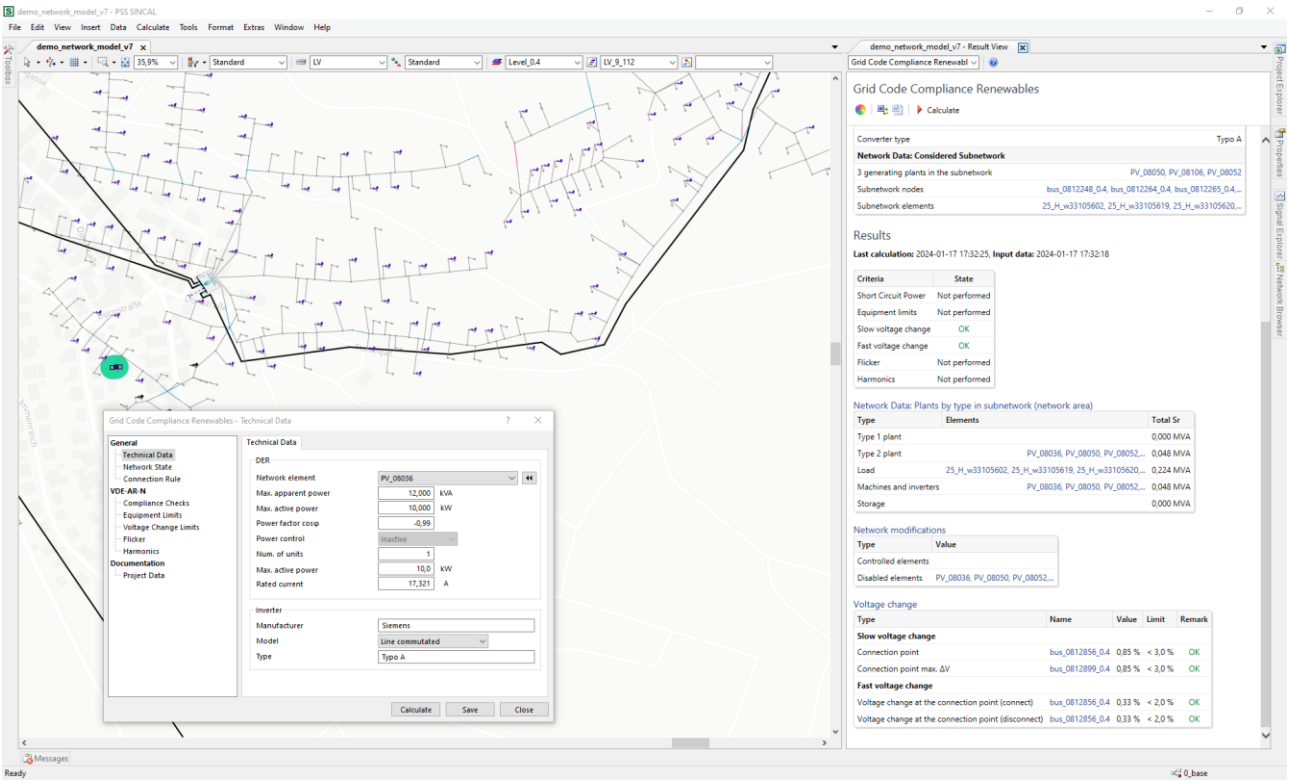
Results and evaluation options

The following options for evaluating the results are provided.

- Display of the results as a user-definable, highlighting of elements in the network graphic for quick visual assessment of the hosting capacity by means of the highlight color
- Display of the results for the maximum connectable power at the nodes as an interactive table in the result view
    - (Consolidated) documentation of the calculation results
    - Evaluation for each node at which the calculation was performed in a separate table row
    - Result for the maximum connectable power at each node
    - Display of all criteria, the limiting criterion (with link to the element(s) where the limit is reached), the time stamp or operating point and a status
    - Export of the results as *.csv file
- Storage of the results in an open result database for further analysis

Grid Code Compliance Renewables

(EEG)



Requirements

The integration of decentral energy resources (DER) (e.g. photovoltaic systems, wind turbines, combined heat and power plants) into distribution networks is particularly occurring on medium and low voltage network levels. In the planning phase, many countries require that the connection conditions of these systems must be verified during the design phase based on procedures and criteria defined in national standards and guidelines. The large number of (often parallel) requests to a network operator requires their careful but rapid processing and documentation.

- Implementation of a standardized procedure for checking specified limit values for the deviations of voltage, short-circuit behavior and the emission of harmonic voltages (connection assessment)
- Automatic processing of the assessment in order to process a large number of requests in a short time
- Documentation and securing of the results of the connection check for technical and legal discussions

Solution

The verifying of the connection conditions as a module (EEG) in PSS®SINCAL offers a separate screen form for the individual steps of a connection check by the network operator. The user is guided step-by-step through the data input of the DER system, the selection of the process and analysis area and the definition of the respective limit values as well as the execution of the calculation and evaluation of the results.

- Integration of the individual work steps in an efficient, specified workflow with its own screen form without additional modeling effort in the network model
- Summary of the calculations required for the check (power flow, short circuit and optional harmonics)
- Default values according to the limit values of the standards and guidelines as well as option for adjustment of the values by the user
- Automatic evaluation of the calculation results against the limit values and documentation

Modeling

The necessary steps before the calculation do not require the user to adapt the network model in addition to the modelling of the DER to be assessed for a single calculation but can be done directly in the screen form.

- Use of detailed technical parameters of the generation system to be connected
  - Rated values for power, power factor and current of the DER
  - Properties of the converter for correct handling of harmonic currents for systems with multiple inverters
- Consideration of DERs/generation systems with a separate modelled transformer as well as systems composed of several network elements (transformer, cables, etc.)
- Calculation and evaluation methods (generic mode)
  - Consideration of the network level (low or medium voltage)
  - Flexible consideration of modeled operating points in the network model (Module LP)
  - Consideration of user-defined control system for active/reactive power of the element
  - Utilization of equipment (power flow and short circuit)
  - Slow voltage change (acc. VDE AR methodology)
  - Optional P/Pmax and power factor variation to support planning and sizing process
- Calculation and evaluation methods according to VDE-AR-N 4105 and 4110 (2018, Germany)
  - Observation of the network level (low or medium voltage)
  - Consideration of user-defined control system for active/reactive power of the element
  - Consideration of modeled operating points in the network model (Module LP)
  - Short circuit power at the connection point and the (sub-)station busbars for stability assessment
  - Utilization of equipment (power flow and short circuit)
  - Fast and slow voltage change, flicker and harmonics
  - Optional P/Pmax and power factor variation to support planning and sizing process
- Calculation and evaluation methods according to NER (Australia) based on IED 61000-3-6/-7
  - Observation of the network level (high, medium or low voltage)
  - User-definable power factor to determine the voltage change
- Calculation and evaluation methods according to IEEE 1547-2018 (USA)
  - User-definable adjustment of the factor for the loads to simulate the minimum load situation
  - Observation of the PCC, POC or a user-defined node as RPA
- User-definable adjustment of limit values for permissible voltage deviations, element utilization, flicker and harmonic current

Calculation

The calculation to verify the connection conditions is performed directly at the element to be connected. The network model is unchanged after the calculation and the changes in the network model required during the calculation (e.g. separation from other plants for individual calculation steps) are documented for the user.

- Calculation of all individual calculation steps (load flow, short circuit, harmonics) of the selected calculation and evaluation method in one calculation run
- Automatic activation and deactivation of elements (e.g. already existing generation systems) as well as their regulating devices (e.g. tap setting of the transformers) temporarily in the individual steps of the calculation without lasting change of the network model
- Integrated evaluation of the calculation results for the network or the individual network elements compared to the specified limit values or reference values
  - Slow and fast voltage change (voltage drop)
  - VDE-AR-N: Calculation of allowed flicker and harmonic levels and evaluation against entered values based on the simplified approaches of the guideline without frequency-dependent network model (module OB not required)
  - Generic / VDE-AR-N: List of supply transformers and their impedance
- Integrated evaluation of the utilization of lines and cables, as wells as transformers compared to the user-defined limit values
  - Evaluation of the equipment utilization in the load flow (thermal) and short circuit (maximal initial short circuit currents)
  - Evaluation of the maximum short-circuit currents at nodes / busbars
  - Generic / VDE-AR-N: Evaluation of the tripping time for lines and cables

Results and evaluation options

The program provides the following options for evaluating the results.

- Integrated evaluation of the calculation results for the network or the individual network elements compared to the specified limit values or reference Presentation of the results in the result view with a summary of the calculations carried out and detailed results of the individual criteria checked
    - Status of the analysis criteria (OK, not passed, not performed)
    - Interactive link to the observed elements in the area of observation as well as the activated and deactivated elements in individual calculation steps
    - Maximum values of the calculation results used for the evaluation against the limit values and link to the network element where the value occurred
    - Diagrams for the P/Pmax and power factor parameter variation calculations
    - Optimized connection power avoiding voltage limit violation
- VDE-AR-N: Export the results to a (user-definable) report (*.docx) in Microsoft Word for documentation and further processing

Contingency Analysis and Resupply

(CA)

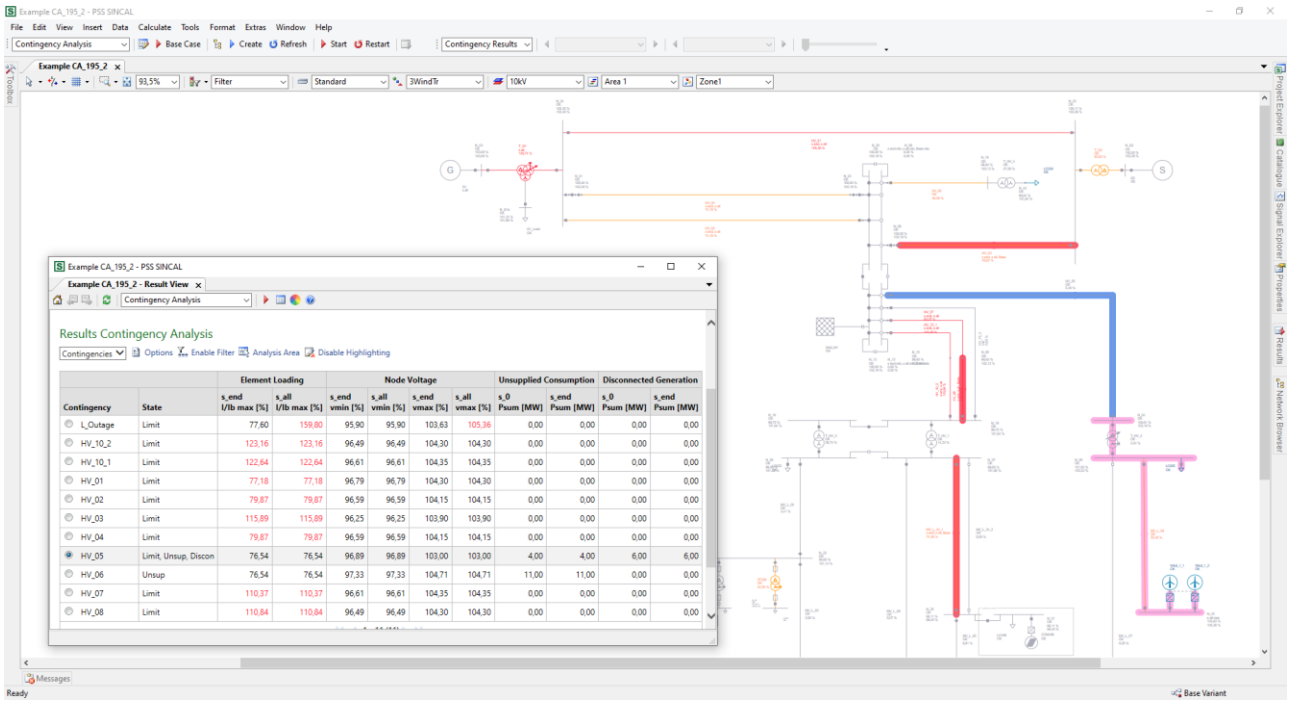


Figure 46: Analyzing Operational Security by Contingency Analysis

Requirements

The aim of the contingency analysis is to evaluate the operational security after outage occurrences of equipment and network feeders. The contingency analysis provides the network operator information about the operational security and reliability of the network. The aim is not only to evaluate the network state after the outage itself, but also intermediate stationary states during switching sequences taken to resupply consumers and reconnect generation after the outage step by step.

The network operator needs information regarding:

- Supply interruptions and validation of the (remedial) actions to ensure a compliant operation with respect to operational and regulatory limits
- Detection of impermissible and critical network states (voltage deviations, overloads) in the event of equipment malfunction
- Validation of the (n-1), (n-x) or (n-1-1), (n-x-y) criteria in the network
- Validation of the prepared / implemented (remedial) actions in outage scenarios
- Validation of the network state before unplanned maintenance work or switching of individual or multiple equipment before performing the actions
- Evaluation of the priority of network extension and development measures regarding the (n-1) security and the resupply options within the network
- Evaluation of grid connection requests (both for load and generation) regarding the (n-1) security and the resupply options within the network

Solution

The contingency analysis and resupply (CA) module in PSS®SINCAL automatically simulates the stationary state after an outage occurrence (contingency) of equipment and potential action schemes and evaluates the network state after (and during) the steps of the outage (and potential sequence).

- Automatic generation of (n-1) outage combinations of lines, transformers, generating plants, busbars and user-defined configuration of multiple outages
- Automatic generation of outages depending on predefined utilization limits of equipment with respect to the results of the base case
- Individual configuration of sequences comprising optionally several (time referenced) steps with occurring outages or taken actions as switching and set point adaption
- Simulation of all automatically and manually configured contingencies within the contingency list, post-processing and evaluation of results
- Visualization of outages, not supplied load, not connected generation, limit violations and maximum / minimum results in the network graphic
- Presentation of all calculated contingencies as well as summary for all elements / nodes in interactive result

views for the comprehensive analysis and to full extend in the tabular view

Remedial and resupply actions can also be analyzed if required. The offered strategies determine the possible switching actions to ensure both resupply of loads after an outage and keeping the network state within configured limits.

- Resupply by switching actions, load shedding and load reduction
- Support of topological and feeder-based resupply strategies

Modeling

The modelling of the network is not requiring additional parameters in extension to the requirements for a power flow compliant model.

- Required are the thermal loading limits for overhead lines, cables and switches and the voltage limits for network levels or nodes and busbars
- Explicitly modelled switches offer significant additional value as more elaborated strategies for realistic outage creation and resupply actions can be applied

Outage and outage sequence

- The automatic creation of the contingencies for the contingency list is supported by a workflow with the configuration of the contingency area and the selection of considered element types.
  - Optional consideration of the base case result during contingency creation
  - Optional evaluation and consideration of the switchable area (section) during creation of contingencies based on a topology evaluation
  - Refresh routine for the contingency list after updates / extensions of the network model
- Configuration of user defined (“manual”) contingencies and contingency sequences containing besides outage affected equipment as well switching actions and parameter adaptions in each step of a sequence
  - Network element outages (single or common)
  - Switching actions (open / close)
  - Setting of parameters (e.g. set point adaption, tap position, ...)
  - Configuration of sequences with several steps and time reference
  - Interaction with network graphic for easy configuration and creation
- Direct calculation of single contingencies (or sequences) out of the list

Outage and outage sequence

- Determination of potential resupply actions based on the element-based resupply functionality
  - Start via selection in network graphic or API function
  - Own parameter set to choose strategy and limits to be considered
  - Own result evaluation in the result browser
  - Creation of contingencies for the contingency list based on the element-based result

Calculation

The contingency analysis is based on power flow calculations. In each individual power flow calculation, one or more elements – due to the outage – are not considered.

- Preparation of the simulation of all contingencies and its execution based supported by a workflow
  - Configuration of an analysis area for the systematic selection of the network elements to be protocolled and the reduction of results
  - Configuration of limits for loading (utilization) and voltages for the automatic pre-processing and evaluation of results
  - Function for quick restart (without workflow wizard)
- Re-calculation of selected contingencies (and sequences) based on power flow calculations and full result sets for every step
- Configurable automatic distribution of the simulation into multiple processes (to use multiple cores) for the parallelization of the overall simulation task

Results and evaluation options

The results of the contingency analysis are shown in the result view, the network graphic and the tabular view.

Result View

- Result view with two modes of presentation for the evaluation with respect to the contingency list or with respect to the maximum / minimum element and node results over all calculated contingencies
- Tabular presentation selected limits (loading, voltage) and indicators (un-supplied load, disconnected generation) with the option for a detailed analysis of the outages and affected elements causing the protocolled limit violations
- Result View synchronized with the colored highlighting in the network graphic
- Direct re-calculation of selected contingency

Tabular view

- Tabular presentation of alle results of a contingency maximum, minimum, status, counter, violation performance indices (VPI), un-supplied load, disconnected generation, ...)
- Selection of affected network elements in network graphic

Network graphic

- Visualization of Results for the elements / nodes mode as annotations in the network graphic to support localization and colorization of graphic elements depending on the result values (e.g. summed up number of limit violations occurred at an element over all performed contingency calculations)
- Colorized highlighting of the elements (per step of a sequence) with violated limits, the unsupplied elements and the elements affected by switching actions or parameter adaptions

Probabilistic Reliability Analysis
(ZU)

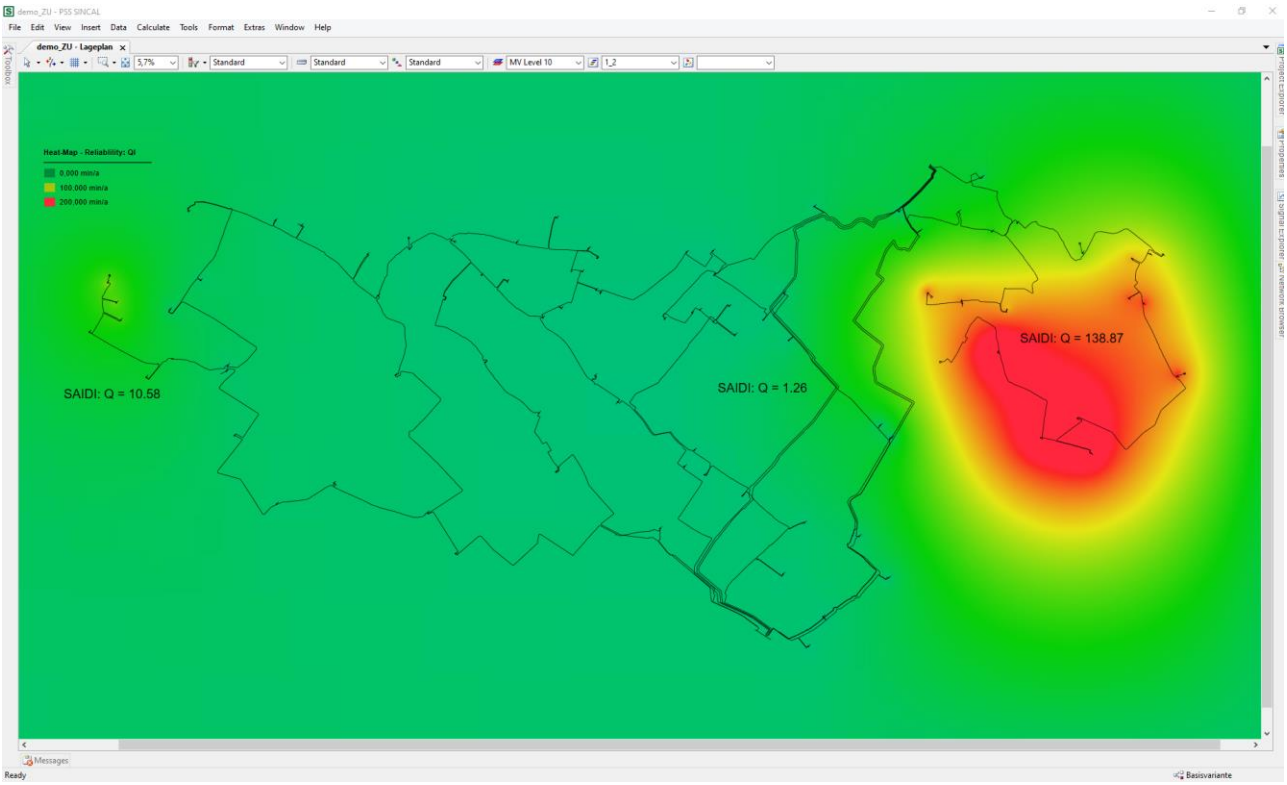


Figure 47: Analyzing Grid Operation Security by Probabilistic Reliability Analysis

Requirements

The aim of the probabilistic reliability analysis is to draw conclusions about the future occurrence of supply interruptions based on failures observed in network operation in the past. For this purpose, the indices of supply reliability of the entire network under observation or of individual customers are calculated from the operating behavior of the components and their interaction in the network based on failure models.

- Determination of the supply reliability considering the statistical relevance of equipment failures in contrast to the classical application of the deterministic (n-1) criterion
- Quantitative comparison of system or network concepts that do not differ according to the (n-1) criterion
- Determination of reliability indices for load nodes, network areas or the entire network as well as contributions from equipment
- Analysis and derivation of measures to increase the reliability of supply

Solution

The probabilistic reliability analysis (ZU) in PSS®SINCAL is a significant extension of the contingency analysis and resupply (CA) module and enables the calculation of reliability indicators based on the topological and electrical network model, probabilistic failure models and operating behavior of components as well as restoration of supply measures in case of supply interruptions

- Detailed and quantitative description of supply reliability in the observed network area
- Identification of the contributions of individual components to the reliability level and analysis of weak points in the network
- Calculation of reliability indices per network node to which load elements are connected (“consumer indices”), as well as reliability indices for the entire network (“network indices”) such as the interruption frequency, average interruption duration and the product of both indices, unavailability of supply per network customer and year

Modeling

Probabilistic reliability calculations require system modeling with the following aspects:

Topological and electrical network model

The basis for the calculations is a network model for power flow and short circuit calculations. Other modeling steps are also carried out:

- Time curve of the consumer loads to be supplied (annual load duration curves)
- Basic modeling of the protection concept (type, direction of action and installation location of the protection device) to define the tripping areas

Probabilistic fault models for components

Different fault models from failure statistics and their overlapping can be considered:

- Stochastically independent single failure of an electrical equipment (short/long)
- Common mode failure (one event leads to simultaneous failure of several components)
- Multiple ground fault with multiple failure (network with isolated neutral or ground fault compensation)
- Failure during deterministic disconnection of components (short/long, e.g. maintenance)
- Spontaneous unnecessary protection operation
- Unnecessary protection operation (consequential fault)
- Protection device malfunction (consequential fault)
- Circuit breaker malfunction (consequential fault)

Models for the remedial measures

In probabilistic reliability calculations, the following are some of the remedial measures modelled:

- Isolation of the fault-affected component/equipment
- Any reclosing of non-fault affected equipment in a tripping area
- Busbar transfer in stations with multiple busbar
- Switching on of elements that are switched off during normal operation

The **operating behavior of the components** is described via so-called reliability data:

- Failure rate **H**
- Down time **T**
- Conditional probabilities **p** (in case of subsequent failures)

These can be taken from individual failure statistics or from technical literature. The module (ZU) provides reliability data from various sources in PSS®SINCAL, which can be imported into the respective network model and assigned to the components if required:

- FNN failure and availability statistics
- IEEE 493 (Gold Book)
- CIGRE working group publications

Calculation and results

The calculations are performed according to the homogeneous Markov method. This method models the failure of the network components, analyses the influence of these failures on the supply situation of the customers and simulates the resupply process in case of supply interruptions.

The following so-called reliability indices can be calculated:

- Frequency of supply interruptions $\mathbf{F}_i$ (1/a)
- Average duration of supply interruptions $\mathbf{T}_i$ (h)
- Probability of supply interruptions/unavailability $\mathbf{Q}_i$ (min/a)
- (Cumulated) interrupted power $\mathbf{P}_i$ (MVA/a)
- (Cumulated) energy not supplied $\mathbf{E}_i$ (MVAh/a)
- Interruption costs $\mathbf{C}_i$ (EUR/a).
- Momentary average interruption frequency index **MAIFI** (1/a)
- System average interruption frequency index **SAIFI**/Average system interruption frequency index **ASIFI** (1/a)
- System average interruption duration index **SAIDI**/Average system interruption duration index **ASIDI** (min/a)
- Customer average interruption duration index **CAIDI** (h)

It should be noted that the calculated reliability indices represent expected values, so that deviations between calculation results and actual reliability behavior can occur in the observation period. This so-called prognosis uncertainty is a characteristic property of systems that are affected by very rare events, such as failures in electrical networks, and is not a consequence of approximations or errors in the calculation or in the input data.

Evaluation options

The following evaluation options are available after the calculation.

- Logged sequence of reliability calculation and evaluation
  - Storage in *.log files
  - Analysis of the effects of switching measures for resupply in detail for each individual failure state
- Display of the indices at the respective load nodes in the network graphic, in result screen forms and in the tabular view

- Display of reliability results for individual network areas and for the entire network in result screen forms and in the tabular view
- Evaluation of the contributions of the individual equipment to the reliability indices of the individual consumers and the entire network
- Color display of consumer indices and the component contributions to these indices using the heat map function in the network graphic for evaluation

Optimal Network Structures
(ON)

The purpose of this optimization in the module Optimal Network Structures (ON) in PSS®SINCAL is the determination of the best possible structure for medium-voltage networks. The optimization is based on a station-and-route model defining possible connections between infeed and loads. The conventional operating forms of loops and feeders serve as the basis for structure optimization.

The optimization of Greenfield developments or existing networks can be carried out. The optimization has the objective to minimize losses while complying with technical limits (max. feeder load, max. voltage drop, etc.). The costs of transforming the network into the proposed structure are determined.

- Three optimization methods
  - Rotating radial feeder
  - Best savings
  - Best neighbor
- The first static optimization loop determines the target network solution.
- In a second loop, the dynamic optimization calculates the optimal network development sequence for the transformation from the initial into the target network at minimum cost.

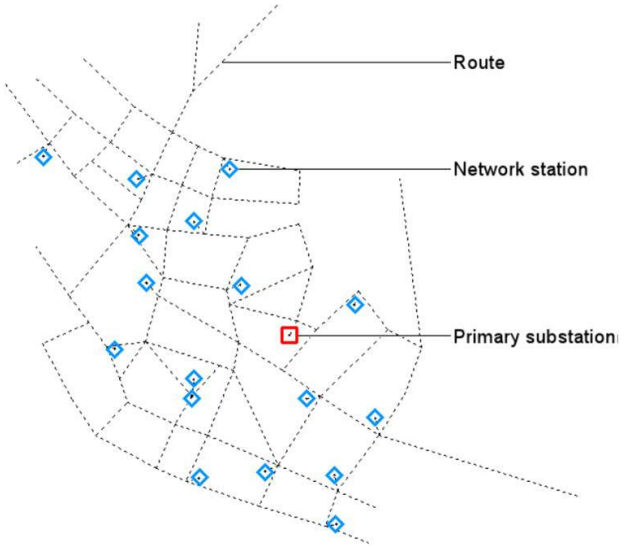


Figure 48: Routes and stations before the simulation

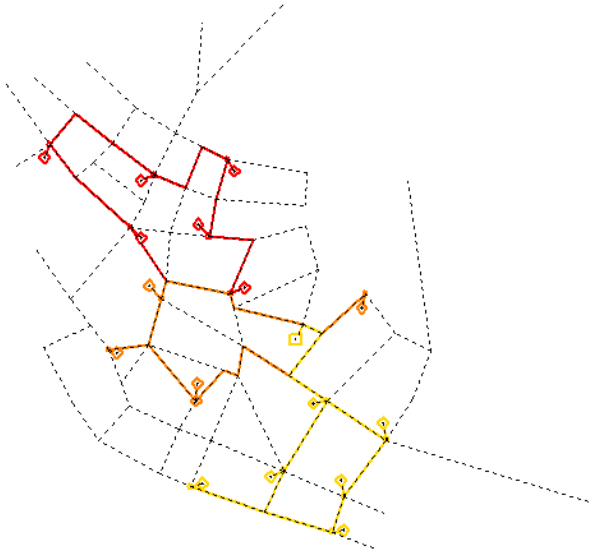


Figure 49: Determined lines and cables along the routes

Load balancing
(LB)

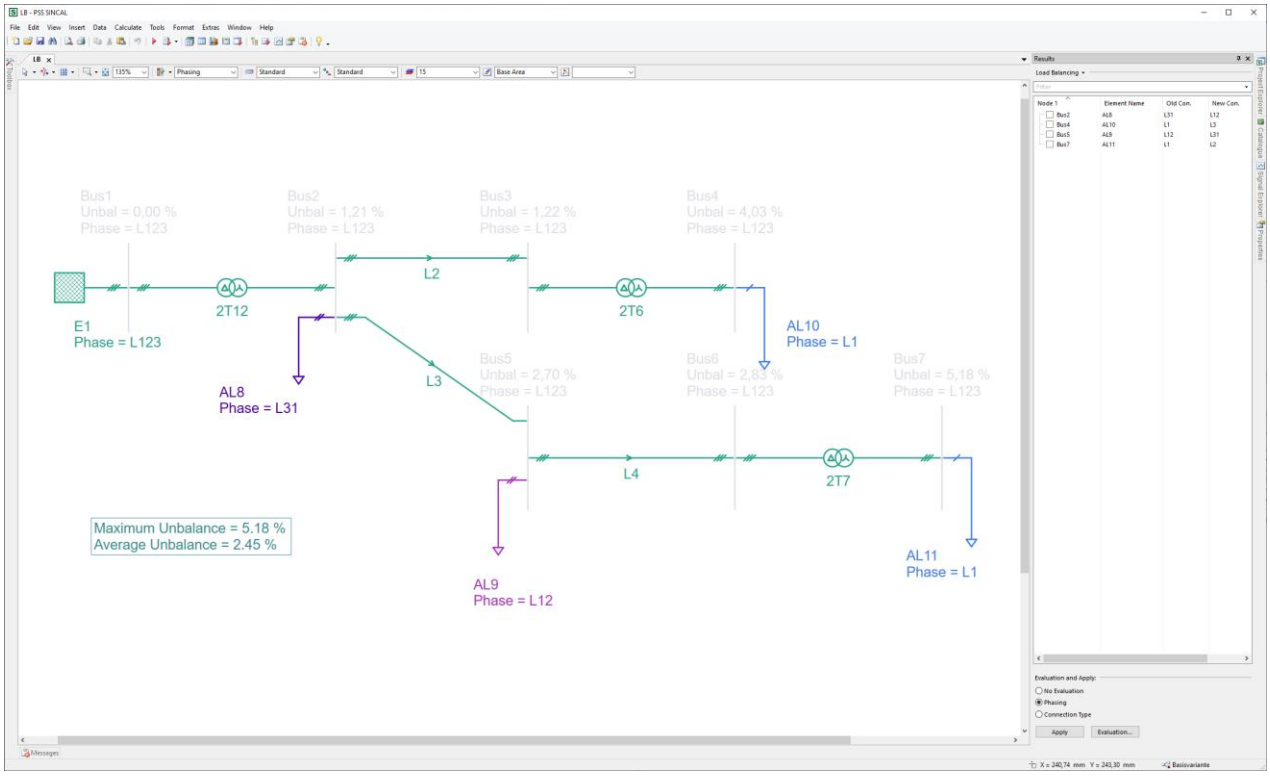


Figure 50: Load balancing performed in an asymmetrical loaded network

The module Load Balancing (LB) in PSS®SINCAL can be used in asymmetrical networks to optimize the connection of single- and two-phase connected loads with the objective to achieve a balanced system state. Complete feeders can be re-linked as a whole.

Load balancing is a combinatorial problem which is solved by using a genetic optimization algorithm that varies the combinations of the connected phases of single phase (L1-G, L2-G, L3-G) and two-phase (L1-L2, L2-L3, L3-L1) connected loads.

The result of the optimization is the system configuration that results in the lowest system unbalance factor of all analyzed combinations.

The result dialog lists the existing and newly proposed phase connections for loads where changes in phase connection would achieve a more balanced power flow in the network. The result can be reviewed in the result dialog window where changes of the connected phases can be applied to the network for selected loads.

Optimal Branching
(OT)

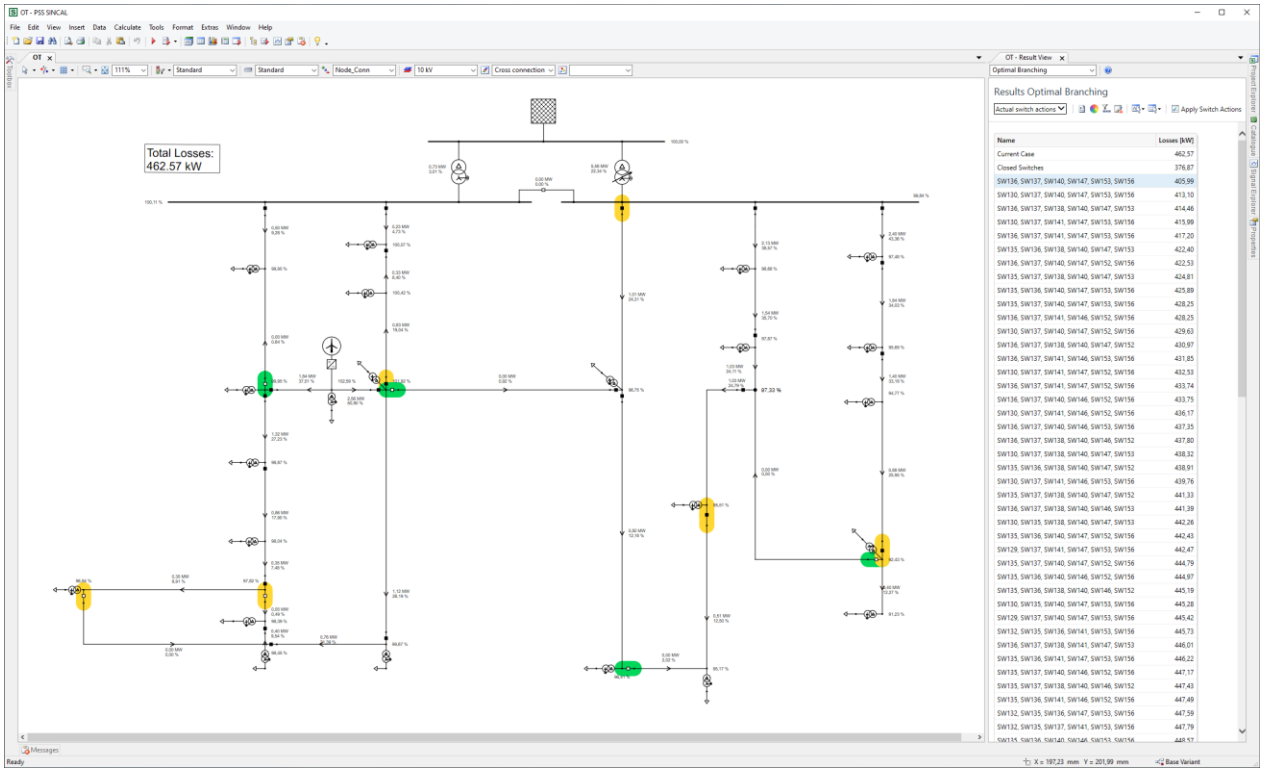


Figure 51: Determined separation point combinations and representation of the separation points in the network graphic

Requirements

Distribution networks are usually operated radial, even if they have a meshed topology. The reason for this is that radial networks are simple to operate, e.g., from the perspective of network protection.

The existing meshed network structures must be separated for this purpose. When searching for the optimum separation points, losses should remain as low as possible on the one hand, and on the other hand, limits for the equipment loading and the voltage band must not be violated.

Solution

The Optimal Branching module in PSS®SINCAL enables an automated separation point search for separating meshed network structures into radial networks.

The modelling of the possible switching locations is necessary here.

The network area in which the network is to be unmeshed, as well as the network area to be considered for the check of the limits and the consideration of the losses can be freely selected.

With the separation point optimization, all possible separation point combinations are determined and evaluated taking into account specified limit values and occurring losses.

The valid separation point combinations are then output, starting with the lowest losses. When one of these separation points combination is selected, the separation points to be opened are highlighted in the network graphic.

The takeover of a separation points combination is done directly from the results.

Modelling

To perform the optimum separation points search, the network must be modelled with its primary operating equipment for the power flow calculation. In addition, the separation points must be defined. This is done either by modelling switches or by defining terminals as potential separation points.

- Free definition of the switching area in which modelled separation points may be switched via selection, network level, network area or network element group.
- Free definition of the analysis area in which limits are checked and losses are considered via selection, network level, network area or network element group.

Calculation

Based on the network structure, all meshes to be unmeshed in the network are identified in a first step. Then, based on the meshes, the possible separation points and the defined switching area, all valid separation points combinations are determined. Load flow calculations are

performed for these and the results are evaluated with the specified limit values and the losses that occur. Only separation points combinations without limit value violations are output as results.

- Limit value check for loading, voltage band and voltage change
- Ignoring existing switching states at the separation point optimization
- Definition of terminals in the switching area as potential separation points
- Configurable automatic distribution of the simulation into multiple processes (to use multiple cores) for the parallelization of the overall simulation task

Results and evaluation options

The results of the separation point optimization are available in the result view and in the network graphic.

Result View

- List of results showing the best separation point combinations with the lowest losses and no limit violations
- Apply selected separation points combinations directly from the result view
- Listing of the determined meshes
- Detailed view for each separation points combination with a list of separation points and information on which separation points must be opened and closed

Network graphic

- Highlighting of the determined separation points combinations in the network graphic by selecting them in the result list.
- Visualization of the determined meshes in the network graphic

Compensation Optimization
(CO)

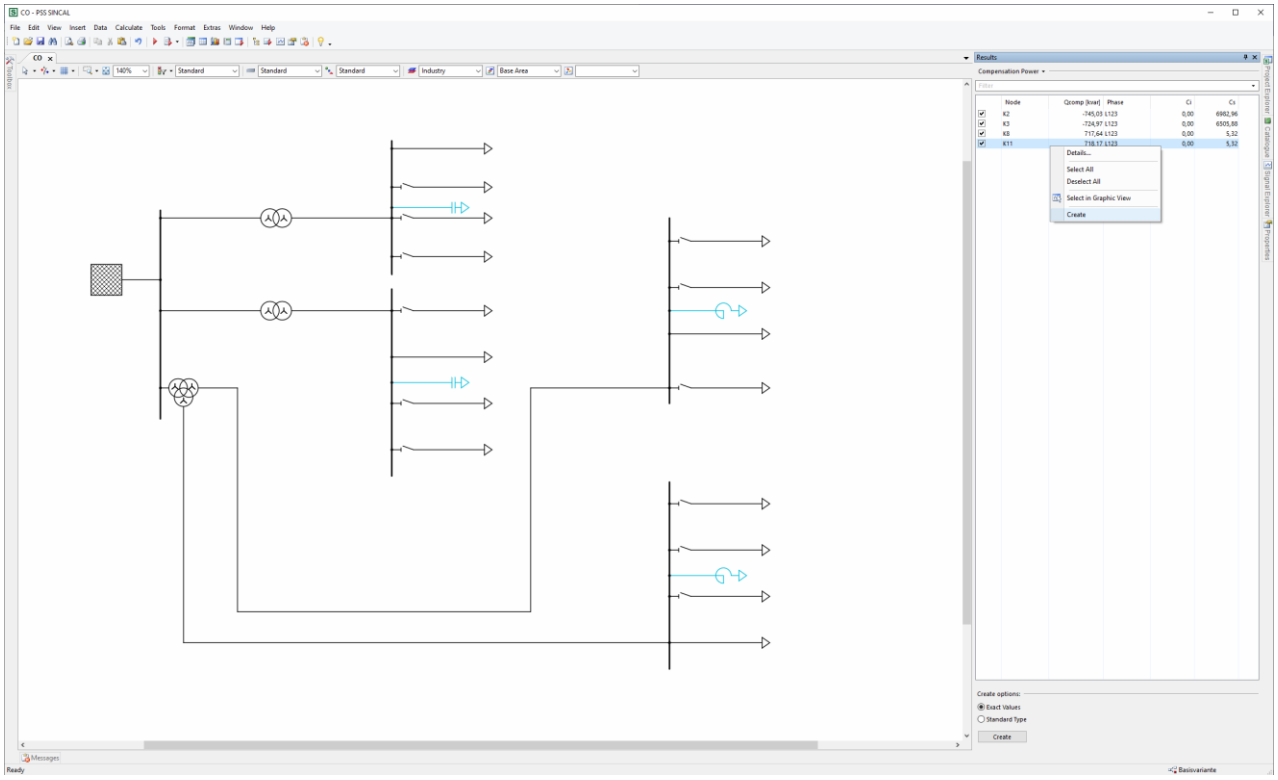


Figure 52: Determination of compensation elements with Volt/Var Optimization to improve the voltage curve

The optimized utilization of reactive power compensation has a positive effect on network operation.
Typical advantages are:

- Reduction in transported apparent power and loading of network components
- Reduction in system losses
- Improved voltage profile and mitigation of voltage limit violations
- Postponement of otherwise required network reinforcements
- Reduction of costs of reactive power consumption

The module compensation optimization (CO) in PSS®SINCAL offers methods for the optimized usage and placement of reactive power compensation equipment.

Reactive power optimization

A series of load-flow calculations for the entire network determines the required reactive power. In each individual load-flow calculation, a fraction of the reactive power requirement at the transformers is compensated. The reactive power requirement can be inductive or capacitive. The calculation of the reactive power requirement is carried out for selected voltage levels. In the graphical network diagram, shunt reactor or capacitor symbols are depicted at the lower voltage side terminals of transformers for network areas where reactive power is needed to achieve a specified power factor. PSS®SINCAL can also propose standard ratings based on types specified in the equipment data base.

All relevant power flow results (such as the required reactive power, reduction in losses, etc.) can be displayed.

Automatic capacitor placement

This optimization method has the objective to reduce network losses by placing capacitors in the network. PSS®SINCAL can identify optimum locations for capacitor installation offsetting the costs for capacitors and expected savings from reduced losses. Based on costs and savings the return on investment is calculated.

Volt/Var Optimization
(VVO)

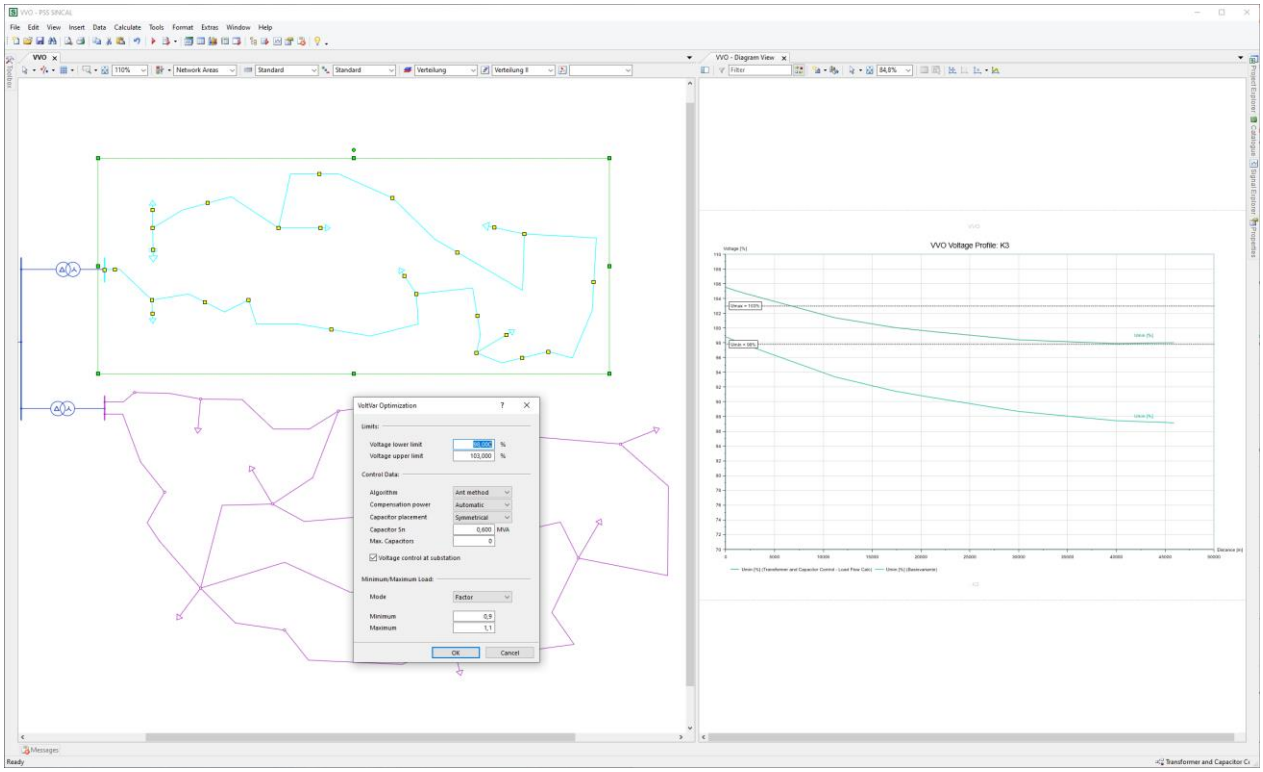


Figure 53: Determination of compensation elements with Volt/Var Optimization to improve the voltage curve

With the module Volt/Var Optimization (VVO)of PSS®SINCAL the voltage and the power factor can be controlled in radial medium- and low-voltage feeders, which can be symmetrical or asymmetrical, with the result that all consumer nodes are located in the defined voltage range and that the transferred reactive power is as low as possible.

The optimization of the voltage is required to ensure acceptable network operation on the basis of the prescribed limits for all consumers at the feeder.

The optimization of the power factor reduces the transfer of reactive power (and hence the losses) at the feeder. The power factor decreases with the number of inductive consumers (the cable capacities reduce this effect slightly).

The aim of Volt/Var optimization is to determine at which point of the feeder capacitors should be installed and how the transformer must be set at the beginning of the feeder. The number and the size of these capacitors are automatically determined by the software. This will ensure that the consumer nodes of the feeder are within the permissible range under high load and under low load.

Load flow optimization
(OL)

PSS®SINCAL Load Flow Optimization (OL) is a module for evaluating and enhancing network structures and loads. It is used for network operating maintenance and in network planning. The method alters network variables within a defined control range to minimize active power losses. This lets the user evaluate the networks and work out network variations to ensure cost-effective network planning.

The module determines network conditions with the fewest possible transmission losses and the smallest number of violated technical limits. This reduces the voltage variance at the network nodes.

The system variables in this case are generator voltages, generator reactive powers and the transformation ratios of the transformers. Observed limits are the loading of plant and equipment, the voltage range and the P/Q diagram allowed for the generators.

Two different algorithms are offered to solve the problem:

- Indirect gradient method
  - Optimization with an indirect gradient method with an external penalty function
  - Determination of a set of permissible solutions and then selection of the optimum
  - Problem classification after network model creation as problem to minimize a specific non-linear function (objective function or cost function)
  - Recovery of predefined technical limits for network elements as non-linear secondary conditions either as an equation or an inequation
- Generic method
  - Based on the „Ant“-Algorithm as kind of swarm intelligence with meta-heuristic optimization
  - Accuracy control by defining the number/level of generations
  - Result independent from the starting condition

Network Planning Tools (Electrical Networks)

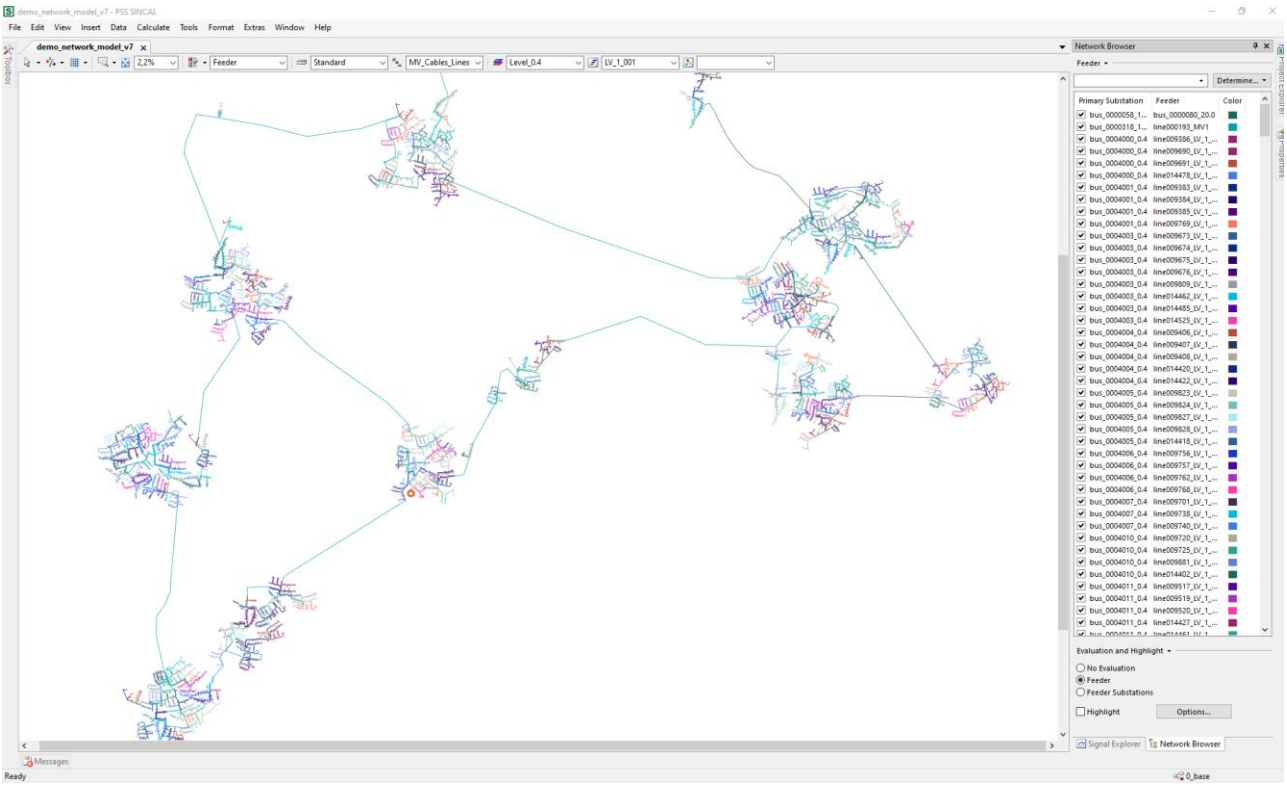


Figure 54: Utilizing Network Planning Tools in PSS®SINCAL (shown here: feeder determination)

Overview

The network planning tools of PSS®SINCAL provide extended functions for electrical networks to optimally support various planning and evaluation tasks.

- Modeling tools for fast and systematic manual modeling in the network graphic
- Feeder determination, evaluation and documentation for the supply areas of the substations depending on the switching state of the network
- Line and route calculations to determine short or optimized routes in the network and with respect to new or adapted routes
- Functions for determining the line or route data (e.g. charging current, impedance) of the selected network elements
- Function to determine the cumulated power and load density (e.g. MW/km2) based on polygons in geographically oriented network models

Modeling tools in the network graphic

- Functions for automatic splitting or coupling of busbars
- Function for automatic creation of feeder panels (bays) at busbars for all supported modelling paradigms: bus-branch (using impedance less connectors) / bus-branch-breaker / node-breaker to support efficient (sub-)station modeling
- Inserting of new switches (with automatic re-connection of the branch elements and the connected busbars / nodes)
- Functions for joining several line and cables to segmented lines (with individual segments) and to reconstitute lines and cables from a segmented line
- Insertion of new connection nodes along line or cable routes
- Complete tracing and evaluation based on network area, levels and structures (e.g. search feeding element)
- Global switching between modeling of load elements as simplified loads or as loads with several customer loads and their billing values

Feeder determination

For the analysis of the structure of an electrical network by automatically determining the feeders as supply areas outgoing from the substations.

- Feeder determination based on structure descriptions using the marking of nodes or based on the substation model
  - Simple feeder determination of nodes marked as primary substations
  - Advanced determination of feeders with substations and main busbars
- Display of the determined feeders in the network browser and the network graphic
  - List of all feeders and their names in the network browser
  - Optional storage of the feeders in the database
  - User-defined colored display and highlighting of the feeders in the network graphic
- Synchronization with the current switching state of the network model
- Feeder documentation via export to Excel for the documentation of planning data
  - Feeder overview with topological information, including the minimum and maximum values of line cross sections, utilization (based on results of the power flow calculation), node voltages along the feeder
  - Overview of lines, transformers and switches in the feeder with topological information and including line types, line lengths, full-load power
  - Overview of the feeders that can be connected to the respective feeder by switching operations
  - Overview of the unsupplied elements in the network

Equipment sizing

The equipment sizing function is available to assist in the selection of suitable lines or a suitable transformer type.

- Line sizing based on (user-definable) standard types, considering technical specifications (e.g. voltage drop, thermal limit current and short-circuit current)
  - User-defined limit values for voltage and current values
  - Optional consideration of entered installation costs
  - Prioritized result list of the selected standard types for selecting and creation of the selected line type in the network model
- Transformer sizing based on (user-definable) standard types, considering maximum power and short-circuit current
  - User-defined limit values for the maximum and minimum short-circuit current
  - Optional consideration of entered costs for the installation
  - Prioritized result list of the selected standard types for selecting and creation of the selected transformer in the network model

Line and route calculation

The following two functions are provided for calculating the shortest routes in the network or routes optimized according to different parameters.

- Simple line calculation to determine the shortest route between connected start and end nodes
- Extended route calculation for determining a route, considering parameters such as installation costs (per length), maximum distances, route types based on a geographical route model

Determination of line and route data

This function enables the data of selected routes (consisting of many lines) to be evaluated.

- Determination of the length, charging power and charging current
- Determination of the positive and zero-system data of reactance, impedance and capacitance

Determination of power and polygon data

This function enables the power data of selected node elements to be evaluated.

- Determination of the summated power values of the generation elements and loads connected to the selected nodes
- Determination of the number of loads, nodes and lines in the area of graphically created polygons in geographical network graphics as well as calculation of the polygon area and resulting load density

Determination of the compensation impedance

This function enables the impedances between a node and a two-winding transformer to be determined automatically.

Determination of earth fault compensation data

This function enables to determine the compensation impedances of arc-suppression coils and resistors as a function of a specified detuning and attenuation based on a single-line to earth-fault short circuit calculation in networks with isolated neutral or earth fault compensation. Furthermore, an almost complete compensation of the earth fault current is possible by means of a negative resistance (corresponds to residual ohmic current compensation) as a parallel connection to the neutral point. The determined values can be automatically transferred to the neutral point.

Evaluation functions

Other functions are provided for the evaluation in addition to the possibilities for graphical evaluation of the input data and results of the network model in the network graphic.

Multiple Faults

(MF)

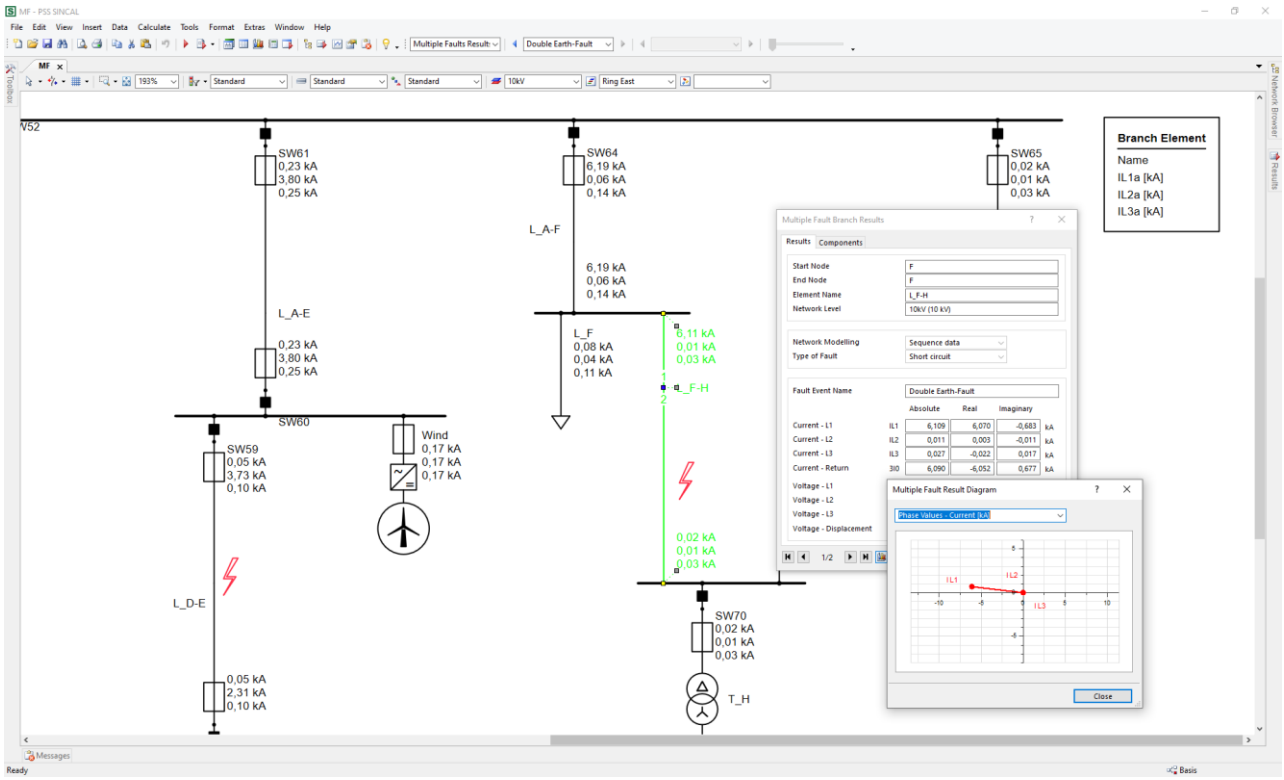


Figure 55: Simulation of fault events with multiple fault locations / fault observations

Requirements

The individual placement of faults is required for simultaneous fault observations at several points in the network (e.g. to analyze the voltage rise in the event of two separate simultaneous line-to-earth short circuits) as well as faults or interruptions along lines.

- Calculation of faults and line interruptions occurring simultaneously or in short succession at several locations
- Placement of fault observations at nodes or at different positions (fault locations) along a line
- Individual simulation of occurring faults (e.g. two separate simultaneous line-to-earth short circuits as well as 3- and 1-phase auto-reclosure)
- Repeated calculation of identical fault configurations
- Using the results as a basis for setting protection

Solution

The multiple fault calculation (MF) module in PSS®SINCAL allows you to combine individually defined fault observations into multiple faults, calculate them simultaneously and observe their effects.

- Any user-definable fault locations on busbars and lines for short circuit with or without line-to-earth connection and line interruptions
- Any combination of the individual fault observations (and fault types) as fault packages and simultaneous calculation of the occurring fault events
- Switch between the results of the calculation of different fault combinations (fault events)

Modeling

Individual user-defined fault observations at different locations in the network can be combined as fault events.

- Modeling of faults on busbars as fault observations
  - 3-, 2- and 1-phase short circuit
  - Support of all possible combinations of the conductors involved in a fault
  - Optional simulation of the return conductor or earth connection for the different types of faults and assignment of additional data for arc and earth fault impedance
- Modeling of faults on lines and line interruptions as fault observations at any position along the line
  - 3-, 2- and 1-phase short circuit of all possible combinations of the L1, L2, L3 conductors involved
  - Optional simulation of the return conductor or earth connection for the different types of faults and assignment of additional data for arc and earth fault impedance

    - 3-, 2- and 1-phase interruption of the conductors before fault observation can be modeled for the L1, L2, L3, N conductors involved
- Combination of any number of defined fault observations into fault events

Calculation

All defined fault events in a network are calculated in one calculation run and the results of the fault events are made available.

- Calculation based on all methods available for short circuit calculation (see SC module)
    - Determination of the initial load considering the current operating state (power flow solution) of the network
    - Simulation of the network elements in symmetrical components
- Automated calculation of all modeled faults in the fault events
- Automatic calculation of all fault events in one calculation run

Results and evaluation options

The program provides the following options for evaluating the results.

- Detailed numerical calculation results and graphical representation in vector diagrams (L1, L2, L3 conductors as well as symmetrical components)
- Switch in the user interface between the results of the calculation of multiple fault events

Motor Start-Up
(MA)

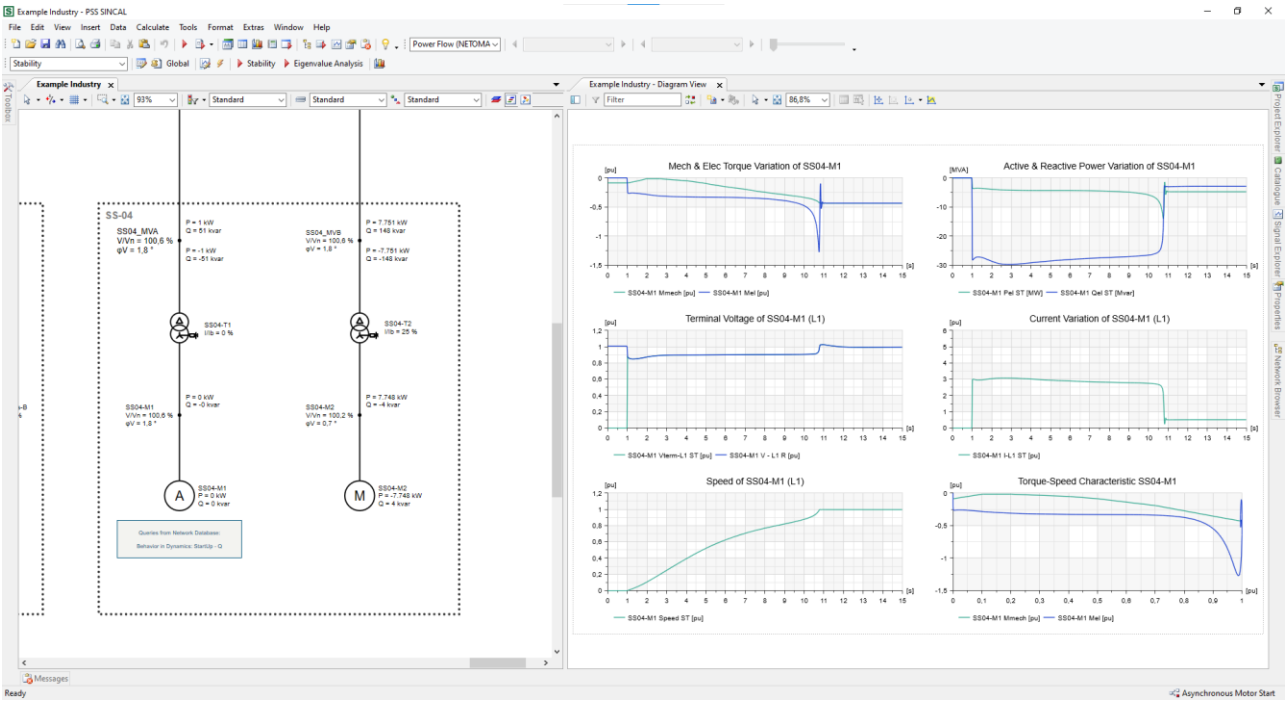


Figure 56: Analyzing Motor Start-Up by Steady-State Methods

Requirements

The operation of asynchronous machines in industrial, power plant or distribution networks requires their design for parallel and sequential starting. The sizing must be carried out with regard to the network load, the motors themselves and the protection behavior. Among other things, the following must be analyzed:

- Assessment of the ability of one or more motors to start up against given load torque characteristics and determination of start-up times
- Calculation of the voltage drop and the network load for single and parallel motor start-ups
- Determination of sequential start-up times of several asynchronous machines
- Determination of the steady-state operating points

Solution

Based on the quasi-dynamic power flow calculation, PSS®SINCAL offers with the motor start-up module (MA) an effective tool for the evaluation of simultaneous or any sequential motor start-ups and the associated network loads. The motor characteristics are basically compared with the load characteristics, considering the electrical properties.

- Simultaneous or successive sequences of start-ups of any number of asynchronous machines
- Use of customizable characteristic curves for torque and start-up current
- Use of standard characteristics according to NEMA
- Constant and switchable star/delta connection of the stator windings for motor start-up
- Consideration of devices for the soft start (soft starter) of asynchronous machines
- Display of results for voltages and currents as well as the determined characteristic curves for each calculated point in time in diagrams and network graphic

Modeling

The calculation of the motor start-up for the model is based on the topological definition of the electrical network (PF module) and on the entered or provided characteristic curves for 3-phase asynchronous machines.

- Possibility to enter basic data according to manufacturer's specifications (nameplate) or according to NEMA
  - Number of pole pairs, efficiency, starting current ratio, rated power, rated current, rated voltage, rated speed and other characteristic values
  - Provision of the 5 standardized types (A to E) according to NEMA, which are characterized by a minimum amount of basic data
  - Ability to enter equivalent circuit diagram sizes for use as a NEMA type
- Definition of motor characteristics for consideration in the calculation

    - Definition of load torque characteristics based on the given or freely chosen ratings
    - Definition of motor torque characteristics based on the given or freely chosen ratings
    - Definition of start-up characteristics for star or delta circuit based on the specified or freely chosen ratings
    - Consideration of pre-defined characteristic curves (torque/speed characteristics) when using the NEMA standard types
    - Provision of standard characteristic curves in the absence of individual characteristics
- Modeling of the soft starters and the winding circuit to represent the limiting elements of the motor start-up
    - Simplified current limitation by specifying maximum values
    - Use of an autotransformer/starting transformer with several switching steps and freely definable short-circuit voltages in the steps
    - Switchable capacitor unit with direct input of reconnect time and compensation power
    - Combinations of the switchable options with the simplified current limitation
    - Constant and switchable star/delta connection of the stator windings taking into consideration a current switch value
- Integrated tool for deriving park equivalent circuit diagram data from NEMA input data for time domain simulation (ST, EMT modules)

Calculation

The quasi-dynamic calculation of the motor start-up is based on a sequential power flow calculation (PF module), in which individual steady-state calculations are carried out at a definable uniform distance. Based on the modeling principle described above, the state variables of the motors to be started are calculated quasi-dynamically from the characteristic curves at the defined starting time, so that in addition to the influence on the network, the processes in the motors can also be evaluated.

- Effective calculation of each individual point in time based on the steady-state power flow calculation
- Calculation of the effect of a motor start-up on the network and the feedback to the motor
    - Voltage drops, increased current and power consumption
    - Mutual influence of several motor start-ups
    - Start-up times depending on network behavior
- Calculation of the effect of devices for the soft start (soft starter)

Results and evaluation options

The program provides the following options for evaluating the results.

- All variables determined in the power flow calculation, such as voltages, currents and power, can be displayed directly in the network graphic for each point in time
- User-defined result diagrams of motors and network elements (e.g. voltages, currents, start-up current, slip etc.)
- Diagrams of the input data for start-up current over speed as well as for the motor and load torque characteristics
- Determination and display of actual motor characteristics depending on the network behavior and the behavior of the equipment for the start-up:
    - Load and motor torque
    - Display of the complex start-up current in the Heyland circle

Electrical Networks – Protection Modules

Overcurrent Time Protection Simulation
(OC)

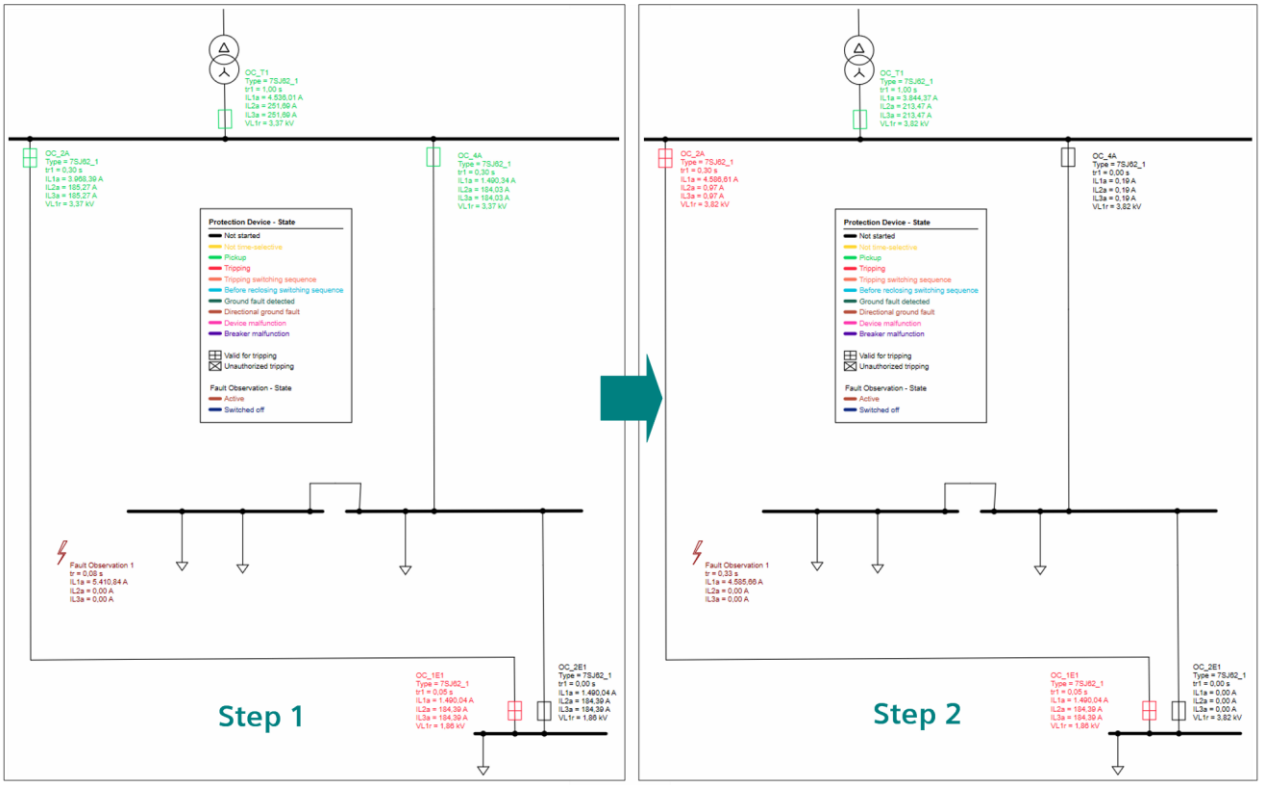


Figure 57: Protection simulation with stepwise fault clearing

Requirements

The task of network protection is to clear faults occurring in the network quickly, reliably and selectively, in order to protect plant and personnel and to ensure the continued operation of undisturbed network areas. A simulative validation of the setting values is necessary in order to verify these requirements. The following questions must be clarified here:

- Are faults being cleared selectively?
- How long does the network protection need to clear faults?
- Have the protection device parameters been set correctly regarding any load and short circuit currents?

The following is also required:

- Analysis of the fault clearing process
- Analysis of the influence of decentralized generation on network protection
- Creation of grading diagrams based on the setting values
- Documentation of the protection setting values
- Analysis of faults that have occurred
- Reliable detection of earth faults in compensated and isolated networks

Solution

The overcurrent time protection simulation (OC) module in PSS®SINCAL enables to simulate the behavior of protection during fault events in the network. Based on the results, the protection behavior can be analyzed and the protection setting values can be checked. Overcurrent time protection devices, fuses, low-voltage circuit breakers, reclosers, bimetals and miniature circuit breakers as well as devices for the earth fault detection are supported.

- Stepwise fault simulation including the calculation of fault clearing times
- Interactive analysis of the fault clearing process in the network graphic with relevant information on current, time and color coding of the protection devices
- Verification of the setting values and checking for selective fault clearing
- Automated creation of diagrams showing the tripping behavior and creation of grading diagrams based on the setting parameters
- Protection documentation for protection paths containing the path in the network topology and the corresponding grading diagram

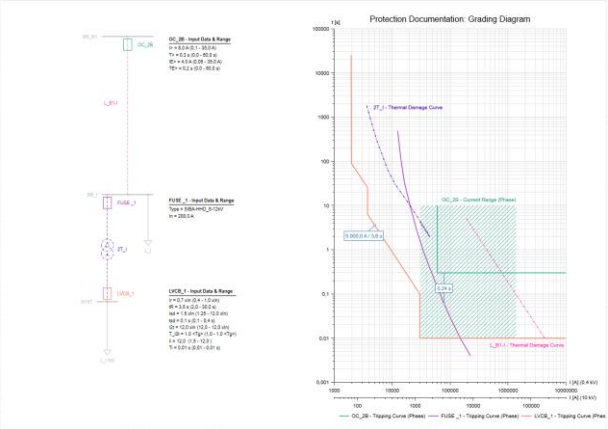


Figure 58: Protection documentation for one protection path

- Reports with protection device setting values

Modeling

Manufacturer-specific protection devices can be selected for modeling from the protection device library supplied. It is also possible to create user-defined protection devices.

- Protection device library with several thousand protection devices, which contains the protection device types overcurrent time protection, fuses, low voltage circuit breakers, reclosers, bimetals and miniature circuit breakers
- Earth fault detection for compensated (resonant earthed) and isolated (unearthed) systems based on the wattmetric method and the admittance method

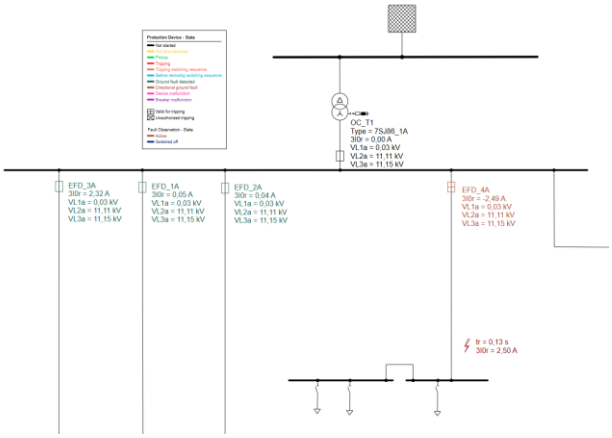


Figure 59: Earth fault detection in a compensated system

- Ability to create user-defined protection devices based on predefined device models, using predefined IEC and ANSI characteristics or custom tripping characteristics (via data points or formulas)
- Teleprotection between protection devices for the simulation of signal comparison, transfer trip or interlock
- Manual or automatic modeling of the short-circuit behavior of primary equipment such as cables, busbars, transformers, motors and synchronous machines with regard to starting currents, decay currents, inrush currents and short-circuit current capabilities
- Specification and consideration of arc and ground impedances
- Global or individual local setting of circuit breaker opening time as well as protection idle and release time
- Common or individual tripping time behavior of steps
- Management of protection device parameter sets in network status files via export and import function

Calculation

The protection simulation is carried out in steps. One step is generated for each protection trip. Steps are calculated until the fault is cleared or no further protection device can pick up. Results are provided for each calculation step. The simulation can be based both on the short circuit calculation as well as on the dynamic calculation (RMS).

- 3-, 2- and 1-phase faults with and without earth connection can be calculated
- Simulation in radial networks and meshed networks
- Protection simulation across different voltage levels
- Fault simulation at nodes and branch elements
- Simulation of primary and backup protection
- Specification and consideration of a factor for checking pickup reliability
- Simulation of simultaneous occurring faults (e.g. double earth-faults)
- Check for overload tripping

Results and evaluation options

The results of the overcurrent time protection simulation are provided in the network graphic, the diagram view, the result view and in the tabular view. The protection device settings can also be exported as a report.

Network graphic

- Interactive stepwise analysis of the fault clearing process in the network graphic, including the graphical display of picked-up and tripped protection devices and switched off network areas in the network graphic
- Checking the time selectivity in the network graphic by coloring or forced tripping if a specified selectivity distance is not adhered
- Checking the pickup reliability regarding the minimum short-circuit current
- Detailed results in each protection device (short-circuit current, fault distance, status ...) for analysis of the protection behavior and quick comparison with the set pickup and zone settings

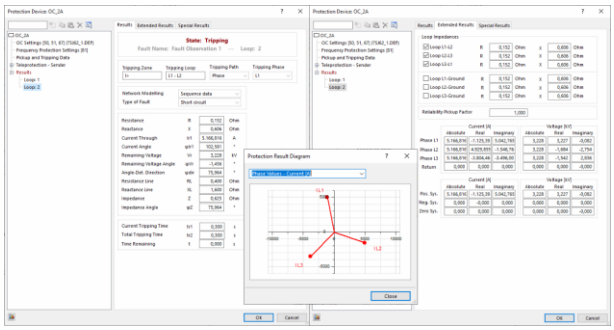


Figure 60: Detailed results of the protection simulation allow an in-depth analysis of the fault clearing process

- Result diagram for earth fault detection incl. display of the set current threshold value

Diagram view

- Documentation of protection paths in the network graphic including the display of the protection device characteristics and primary equipment characteristics in a grading diagram
- Automatically generated I/t-diagrams based on the setting values for overcurrent protection devices
- Creation of user-defined grading diagrams
- Protection device settings can be changed directly in the diagram view, the diagrams can be updated automatically
- The displayed damage characteristic curves for lines, generators, motors (stators and rotors) and transformers can be used to check whether destruction of equipment occurs in relation to the switch-off times of the network protection
- Check of the selectivity in the diagram by displaying the time difference between curves
- Show/hide or highlight single characteristics

Result view

- Display of picked-up and tripped protection devices with the information if they are allowed to trip, regarding the selectivity
- A switch of the fault clearing steps update the results in the result view and allows to interactively track the fault clearing process between the network graphic and the result view
- Especially in large geographic networks the result view supports to keep the overview, with a click on a protection device it is marked in the network graphic

Tabular view

- The protection device setting values and the simulation results are available in tabular view and can be evaluated directly here

Report

- The protection device setting values can be exported as a predefined or user-defined report for further use (e.g. for protection device parameterization)

Extended Protection Simulation
(SZ)

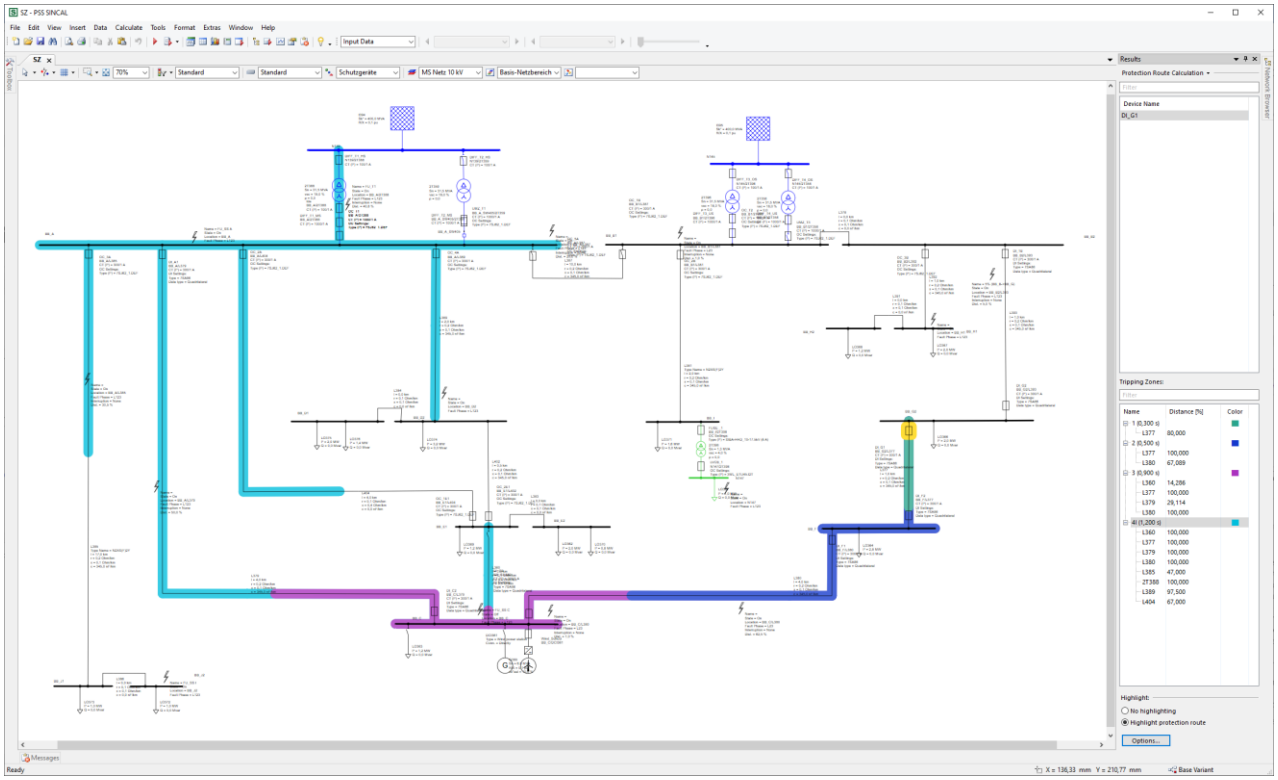


Figure 61: Protection route calculation shows the actual reach of protection devices considering effects which increase/decrease the reach

Requirements

Distance protection and differential protection devices are primarily used in meshed distribution networks and in transmission networks. Especially in meshed networks and networks with decentralized generation, effects occur, which change the reach of the protection devices.
A simulative validation of the setting values is necessary in order to verify the setting of these protection devices. Primarily the following questions must be clarified here:

- Are faults being cleared selectively?
- How long does the network protection need to clear faults?
- Have the protection device parameters been set correctly regarding any load and short circuit currents?

The following is also required:

- Analysis of the changed reach of protection devices due to effects such as intermediate infeed or parallel follow-up lines (underreach/overreach)
- Post-mortem analysis of faults occurred in the network
- Analysis of the fault clearing process
- Creation of grading diagrams based on the setting values
- Documentation of the protection setting values
- Simulation of voltage and frequency protection, e.g. of decentral energy resources (DER)

Solution

The extended protection simulation (SZ) module in PSS®SINCAL extends the functionality of the overcurrent time protection simulation (OC) module. Here distance protection, differential protection, voltage protection and frequency protection device types are additionally supported. Beside the simulation of the behavior of the protection devices and the check of the protection setting values, additional analysis options are available, such as the calculation and display of the actual reach of protection devices.

- Extension of the protection simulation with distance and differential protection devices, voltage and frequency protection
- Stepwise event-oriented fault simulation including the calculation of fault clearing times
- Interactive analysis of the fault clearing process in the network graphic
- Verification of the setting values and checking for selective fault clearing
- Calculation and display of the reach of protection devices in the protection route calculation. Cascaded fault clearings, parallel line effects and intermediate

infeeds (e.g. by decentral energy resources) are considered

- Diagrams showing the actual zone reaches of the protection devices for evaluating the tripping behavior (based on fault simulations)
- Post-mortem analysis, fault locater to analyze/locate faults that have occurred in the network
- Reports with protection device setting values

Modeling

Manufacturer-specific distance protection devices can be selected for modeling from the supplied protection device library. A generic model is available for differential protection, voltage protection and frequency protection.

- Extension of the protection simulation function to include distance and differential protection devices, voltage and frequency protection
- Teleprotection between protection devices for the simulation of signal comparison, transfer trip or interlocking

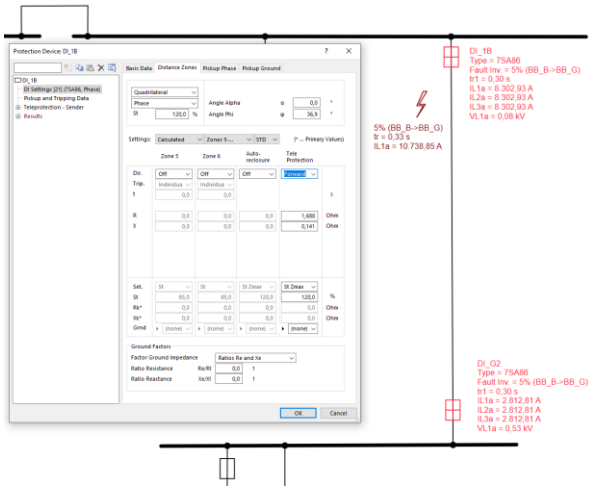


Figure 62: Teleprotection with two protection devices to get a fast fault clearing at 100% of the line

- Support of all common pickup types like current pickup, U/I pickup, U/I/φ pickup and impedance pickup
- Specification and consideration of arc and ground impedances
- Global or individual local setting of circuit breaker opening time as well as protection idle and release time
- Management of protection device parameter sets in network status files via export and import function
- Creation of measuring points with measured values, which for example were recorded during fault events in the network, for post-mortem analysis
- Direction determination based on different methods and on the basis of short circuit or pre-fault voltage
- Earth fault detection with U, I, I or U, I and U
- Optional limitation of the area to be checked of the protection route calculation by a defined network area or existing protection areas limited by protection devices

Calculation

The protection simulation is carried out in steps. One step is generated for each protection trip. Steps are calculated until the fault is cleared. Results are provided for each calculation step. The simulation can be based both on the short circuit calculation as well as on the dynamic calculation (RMS).

- 3-, 2- and 1-phase faults with and without earth connection can be calculated
- Specification and consideration of arc flash and ground impedances
- Simulation in radial networks and meshed networks
- Protection simulation across different voltage levels
- Fault simulation at nodes and branch elements
- Simulation of primary and backup protection
- Specification and consideration of a factor for checking pickup reliability
- Check for overload tripping

The protection route calculation is based on an automated fault simulation along protection areas as well as on the evaluation of the tripping zones/steps in the device.

- Calculation of the actual reach of protection devices using automated fault simulation along protected areas
- User-defined specification of the accuracy of the calculation

With the function fault locater, the system calculates back to the fault location based on specified measured values.

- Calculation of all possible fault locations in meshed networks, which allows the determination of the actual fault location if several measuring points are specified (post-mortem analysis)

Results and evaluation options

The results of the extended protection simulation are provided in the network graphic, the diagram view, the result view and in the tabular view. Furthermore, the protection device settings can be exported as a report. The results of the protection route calculation are shown in the network graphic and in the diagram view. The results of the fault locater are provided in the network graphic.

Network graphic

- Interactive stepwise analysis of the fault clearing process in the network graphic, including the graphical display of picked-up and tripped protection devices in the network graphic

- Checking the time selectivity in the network graphic by coloring or forced tripping if a specified selectivity distance is not adhered
- Checking the pickup reliability regarding the minimum short-circuit current
- Detailed results in each protection device (short-circuit current, fault distance, status ...) for analysis of the protection behavior in the network graphic and quick comparison with the set values
- The reach of protection devices can be displayed in color in the network graphic for each zone/step. Further, results for the reaches in % are provided
- Setting diagrams for differential protection and U/I pickup
- Visualization of possible fault locations in the network graphic and result table with determined fault location (post-mortem analysis)

Diagram view

- Automatically generated R-X diagrams based on the setting values for distance protection devices
- R-X diagrams including the display of the calculated fault impedance can be generated manually

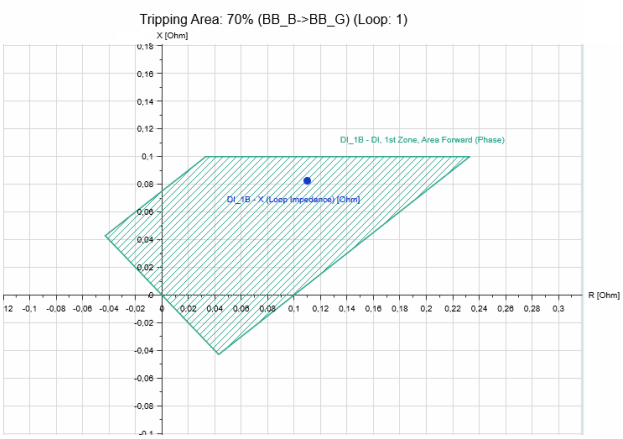


Figure 63: Calculated fault impedance displayed in the impedance diagram (X-R) shows which zone trips

- Result diagrams of the protection route calculation in R-X, X-t, Z-t, Zmeasured-Zpath and Xmeasured-Xpath, which show the actual reach of the protection devices considering intermediate infeed and parallel follow-up lines

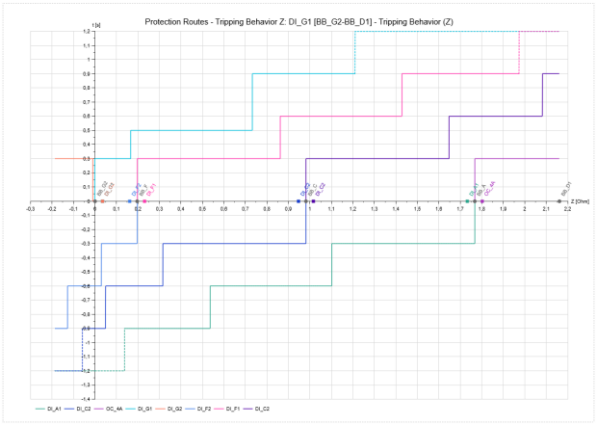


Figure 64: Grading diagram (X-t) shows the actual reach of distance protection devices considering effects which increase/decrease the reach

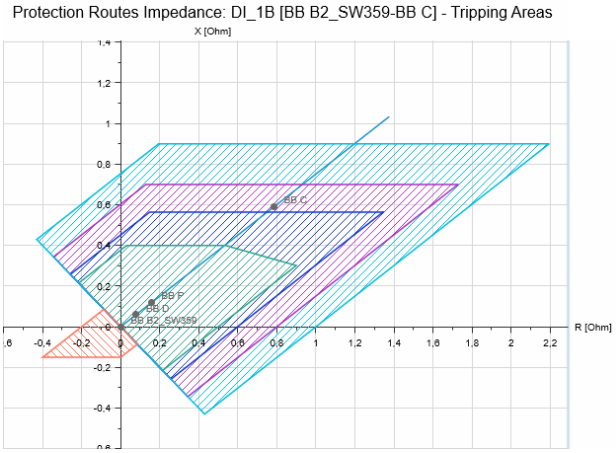


Figure 65: Impedance Diagram (X-R) shows the zone settings and the line impedances

- Creation of user-defined grading diagrams
- Protection device settings can be changed directly in the diagram view, the diagrams can be updated automatically
- Show/hide or highlight single characteristics or areas

Result view

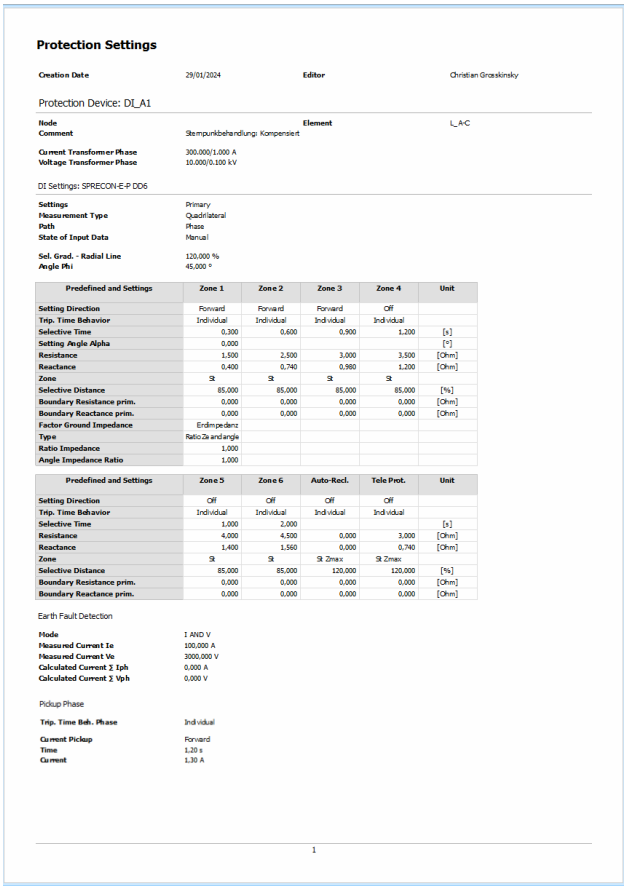
- Display of picked-up and tripped protection devices with the information if they are allowed to trip, regarding the selectivity
- A switch of the fault clearing steps update the results in the result view and allows to interactively track the fault clearing process between the network graphic and the result view
- Especially in large geographic networks the result view supports to keep the overview, with a click on a protection device it is marked in the network graphic

Tabular view

- The protection device setting values and the simulation results are available in the tabular view and can be evaluated directly here

Report

- The protection device setting values can be exported as a predefined or user-defined report for further use (e.g. for protection device parameterization)



Protection Settings

Creation Date 29/01/2024 **Editor** Christian Grasskinsky

Protection Device: DI_A1

Node **Element** L_A-C
Comment Sternpunktbehandlung: Kompensiert

Current Transformer Phase 300.000/1.000 A
Voltage Transformer Phase 10.000/0.100 kV

DI Settings: SPRECON-E-P DD6

Settings Primary
Measurement Type Quadrilateral
Path Phase
State of Input Data Manual

Sel. Grad. - Radial Line 120.000 %
Angle Phi 45.000 °

Predefined and Settings	Zone 1	Zone 2	Zone 3	Zone 4	Unit
Setting Direction	Forward	Forward	Forward	Off	
Trip. Time Behavior	Individual	Individual	Individual	Individual	
Selective Time	0,300	0,600	0,900	1,200	[s]
Setting Angle Alpha	0,000				[°]
Resistance	1,500	2,500	3,000	3,500	[Ohm]
Reactance	0,400	0,740	0,980	1,200	[Ohm]
Zone	St	St	St	St	
Selective Distance	85,000	85,000	85,000	85,000	[%]
Boundary Resistance prim.	0,000	0,000	0,000	0,000	[Ohm]
Boundary Reactance prim.	0,000	0,000	0,000	0,000	[Ohm]
Factor Ground Impedance	Erdimpedenz				
Type	Ratio Za and angle				
Ratio Impedance	1,000				
Angle Impedance Ratio	1,000				

Predefined and Settings	Zone 5	Zone 6	Auto-Recl.	Tele Prot.	Unit
Setting Direction	Off	Off	Off	Off	
Trip. Time Behavior	Individual	Individual	Individual	Individual	
Selective Time	1,000	2,000			[s]
Resistance	4,000	4,500	0,000	3,000	[Ohm]
Reactance	1,400	1,560	0,000	0,740	[Ohm]
Zone	St	St	St Zmax	St Zmax	
Selective Distance	85,000	85,000	120,000	120,000	[%]
Boundary Resistance prim.	0,000	0,000	0,000	0,000	[Ohm]
Boundary Reactance prim.	0,000	0,000	0,000	0,000	[Ohm]

Earth Fault Detection

Mode I AND V
Measured Current Ie 100,000 A
Measured Current Ve 3000,000 V
Calculated Current Σ Iph 0,000 A
Calculated Current Σ Vph 0,000 V

Pickup Phase

Trip. Time Beh. Phase Individual

Current Pickup Forward
Time 1.20 s
Current 1.30 A

1

Figure 66: Report with the protection setting values can for instance be used for the device parametrization

Distance Protection Setting Calculation
(DI)

Requirements

Selectivity in distance protection is achieved by a combination of time and distance graduation. The distance graduation primarily requires the calculation of the zone settings in X and R. Hereby, uncertainties (e.g. due to deviating line data) have to be considered when selecting the graduation factor. Additionally, in meshed networks effects occur that change the reach of the protection devices, this is particularly relevant for backup protection.

- Automatic calculation of protection setting parameters for distance protection devices
- Automatic parameterization/setting of protection devices

Solution

The distance protection setting calculation (DI) module in PSS®SINCAL enables automated calculation of zone settings for distance protection devices. Depending on the selected setting strategy, intermediate infeed and parallel follow-up lines, that change the reach of the protection devices, are considered.

- Automatic calculation of distance protection device specific zone settings

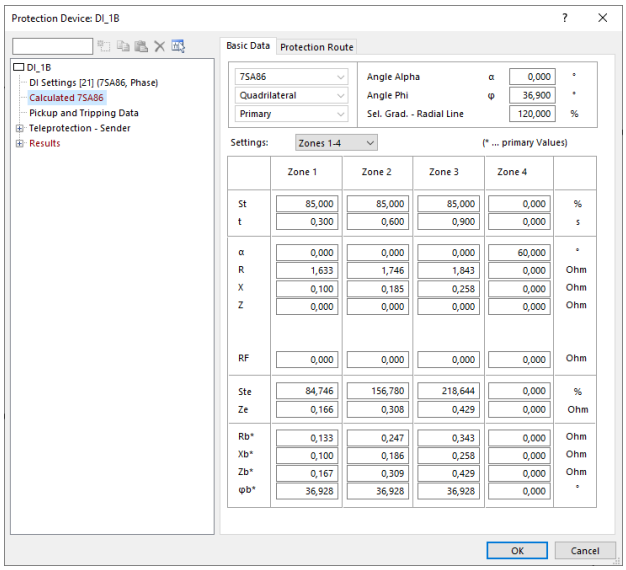


Figure 67: Zone settings as a result of the distance protection setting calculation

- Support of different setting strategies (DISTAL, line impedance, line impedance connected, medium voltage networks)
- Generation of graduation plans based on the calculated setting values of the distance protection devices

Modeling

The basis for the calculation of the setting values are the distance protection devices present in the network and the network topology. The calculation in radial and meshed networks is supported.

Calculation

The calculation of the setting values depends on the selected setting strategy and the specified grading factors.

- Support of the setting strategies DISTAL (always selective), line impedance (based on the line impedances), line impedance connected (based on the line impedances, all switches connected) and medium voltage networks (based on the fault loops)
- Automatic calculation of the zone settings of the distance protection for up to 6 zones plus automatic reclosing and signal comparison
- Calculation of the primary or secondary setting values
- Automatic determination and use of the shortest follow-up line
- No limitation in relation to the network size

Results and evaluation options

The results of the distance protection setting calculation are shown in the network graphic, the result view and the diagram view. Furthermore, the calculated protection device settings can be exported as a report. Applied calculated setting values are also available in the tabular view.

Network graphic

- The calculated setting values are displayed in the protection device in addition to the existing setting values

Result view

- Listing of all protection devices with status (calculated, manual, none)
- Transfer of the calculated setting values as new actual values for selected protection devices

Diagram view

- Automatically generated grading diagrams in X-t and Z-t for the calculated setting values

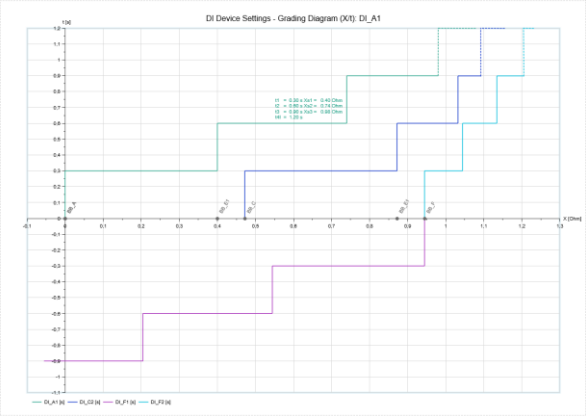


Figure 68: Grading diagram (X-t) shows the zone settings of distance protection devices based on the input data

Tabular view

- The protection device settings values are provided in the tabular view

Report

- The calculated setting values can be exported for further use as a predefined or user-defined report

Protection Security Assessment
(PSA)

The protection security assessment (PSA) module has two functions:
Protection analysis and **Overcurrent time protection check.**

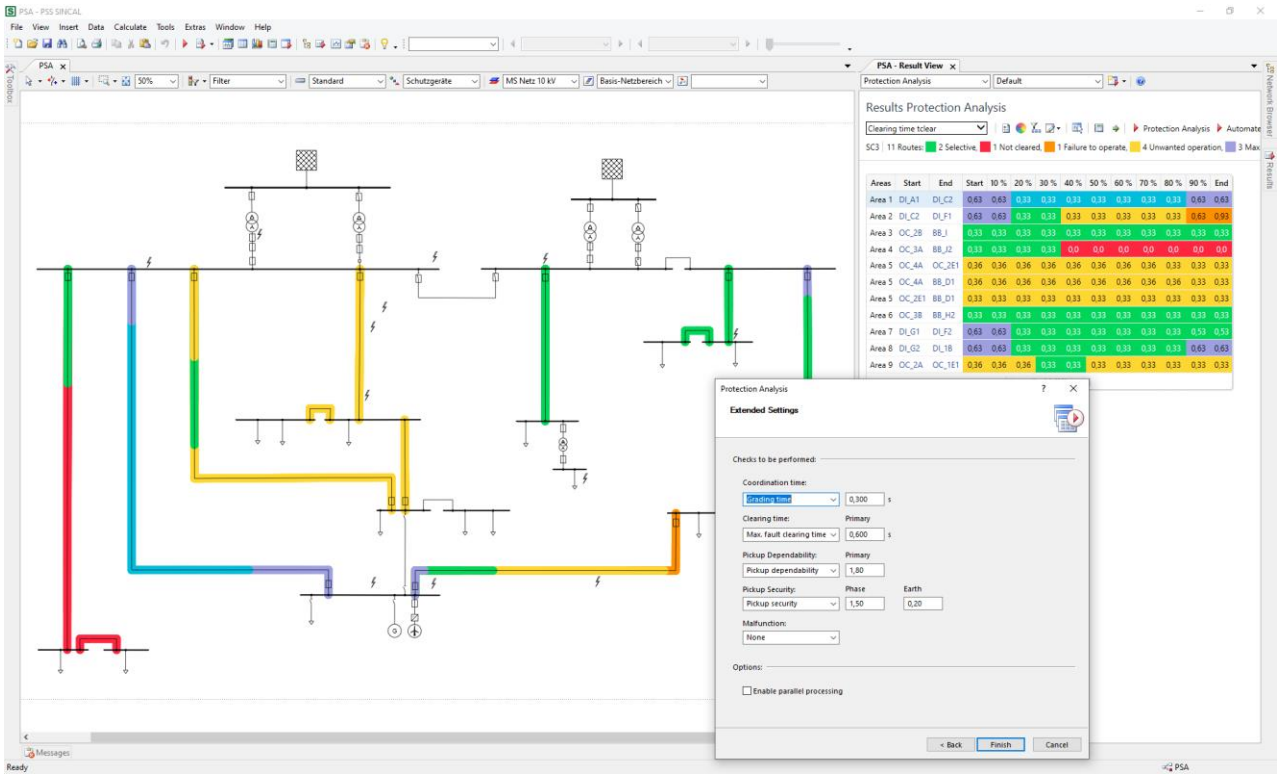


Figure 69: Weak points in the protection system are displayed in a results matrix and in the network graphic as a result of the protection analysis

Protection analysis

Requirements

In meshed networks and in networks with a high penetration of distributed generation, the check of orderly function (selectivity, speed, dependability, security) of the network protection solely based on input data/grading diagrams is often insufficient. In addition to observing specific fault events in the protection simulation, it is therefore necessary to check the protection settings of the entire network protection for all possible fault locations. While this must be done in a time-efficient manner, it is also necessary to identify weak points in the network protection reliable.

The growing number of decentral energy resources (DER) with fluctuating power flow increases the number of switching operations in the network. From the point of view of network operation, this requires a quick check of the entire network protection (e.g. before each switching operation).

Solution

The protection analysis (PSA) in PSS®SINCAL performs an automated check of the setting values of all protection systems present in the network by calculating fault events in the entire network. As a result, weak points in the network protection are visualized, allowing incorrect settings and faulty protection concepts to be detected.

- Automated check and documentation of the selectivity, speed, pickup dependability and pickup security of the network protection for fault events in the entire network
- Weak points in network protection are reliably detected and highlighted in a results matrix
- Start of the protection simulation from the results matrix to recalculate short circuits at specific fault locations and analyze the protection behavior in detail

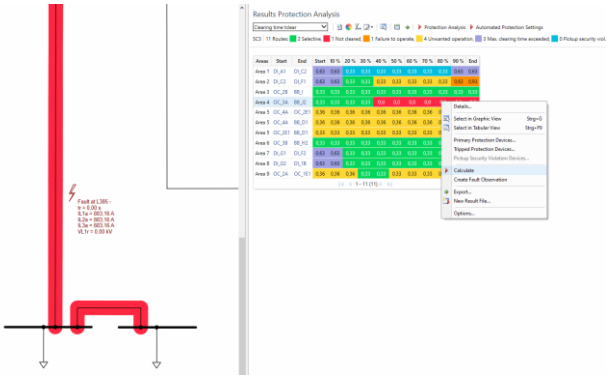


Figure 70: Start of the protection simulation for the in-depth analysis of one fault location directly from the result matrix

- Protection setting check with very little time effort due to automated analysis of the protection behavior fault for fault events in the entire network
- Quality assurance through the improvement of the process for protection coordination (protection concept/setting value calculation/protection analysis/documentation)
- Fast calculation algorithms allow the entire network protection to be checked before each switching operation

Modeling

For the protection analysis the protection devices modeled in the network are used. All protection device types available in PSS®SINCAL are supported. For differential protection and frequency protection, you can set whether they should be considered in the protection analysis.

- Optional manual definition of main protection devices for the consideration of special main protection concepts
- Optional manual definition of backup protection devices for the consideration of special backup protection concepts
- Optional limitation of the area to be checked by a defined network area or existing protection areas limited by protection devices

Calculation

The protection analysis is based on the protection simulation. This involves automated protection simulations throughout the entire network.

- The number of fault simulations/the step size along protection areas can be set flexibly
- Protection analysis for one fault type or for several fault types in parallel (3-, 2-, 1-phase faults)
- Checking of primary protection and backup protection (protection device and circuit breaker failure)
- Determination of backup protection by three possible modes: Default (based on a network trace), extended (based on topology), manual allocation of backup protection devices (highest priority)
- Specification of fault impedances (arc and ground impedances)
- Checking of the selectivity between protection devices with specified selectivity distances or on the basis of the switch-off procedure of the protection system (circuit breaker opening time, protection idle time, release time)
- Checking of defined maximum fault clearing times
- Checking of pickup dependability by setting pickup reliability factors (for main and for backup protection)
- Checking the pickup security by setting pickup security factors (for phase and ground steps)
- Checking the sensitivity by considering fault impedances and covering the worst-case fault locations by performing the protection analysis in the whole network
- Calculation of fault events on lines and busbars
- Calculation of pickup and tripping sequences
- Trip and fault clearing times
- Specification of faulty conductors in asymmetrical networks
- Dynamic protection analysis (RMS)
- User-defined recalculation of individual faults (as protection simulation) from the results of the protection analysis
- Performing the protection analysis for different switching states by the use of multiple calculations
- Configurable automatic distribution of the simulation into multiple processes (to use multiple cores) for the parallelization of the overall simulation task

Results and evaluation options

The results of the protection analysis are shown in the result view and in the network graphic. It is also possible to export the results as a report.

Result view

- Interactive results matrix, containing all calculation results and highlighting critical states (not cleared, underfunction, overfunction...) in color
- Calculation results such as the fault clearing time or the number of protection devices that have not kept to a specified grading distance can be displayed in the result cells
- Display of the results of one fault type or display of the worst-case result from all calculated fault types (3-, 2-, 1-phase faults)

Network graphic

- Highlighting of protection areas in the network graphic by selecting a protection area in the results matrix. Results from the results matrix can thus be quickly assigned to the corresponding protection area in the network graphic
- Coloring the entire network graphic with the statuses from the result matrix
- Start the protection simulation from the results matrix for individual fault locations. Detailed calculation results are then available in the network graphic, which allows a step-by-step analysis of the behavior of the network protection for this fault location

Report

- The results matrix of the protection analysis can be saved in PSS®SINCAL and exported as a report in .pdf format
- The results can be exported as .csv file

Result database

- Storage of the results in an open result database for further analysis

Overcurrent time protection check

Requirements

The selectivity check and the check for reliable pickup (pickup reliability) are two essential checks when observing protection devices with current-dependent tripping characteristics.

Solution

The overcurrent time protection check (PSA) function in PSS®SINCAL performs an automated check of the time and current selectivity as well as the pickup reliability (k factor).

- Checking the current and time selectivity of overcurrent time protection devices and fuses in radial networks

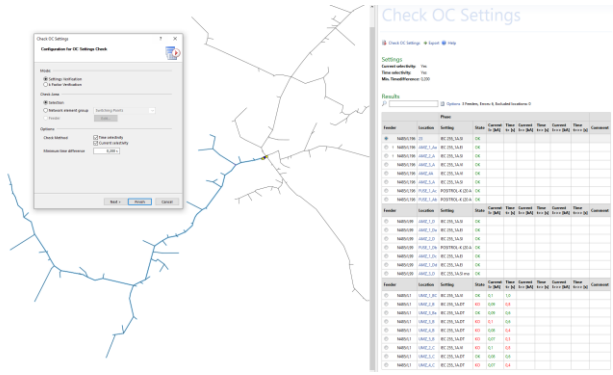


Figure 71: Results of the selectivity check displayed in the result view and the network graphic

- Checking the pickup reliability (k factor) for primary and backup protection as well as output of a setting value recommendation

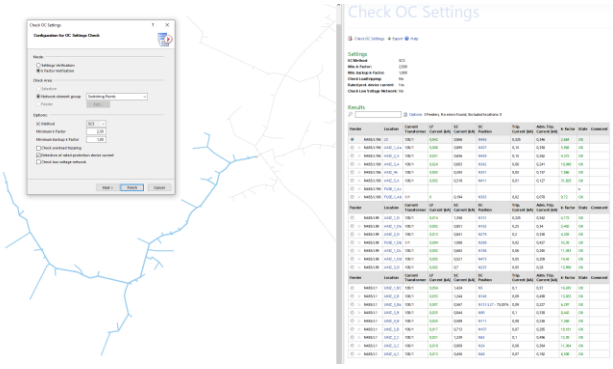


Figure 72: Results of the k factor check displayed in the result view and the network graphic

- E Advanced check of protection devices for the criteria for conductor cross-section, thermal load, thermal destruction and maximum switch off time

Modeling

The protection devices modeled in the network are used for the overcurrent time protection check analysis.

Overcurrent time protection devices, fuses, low-voltage circuit breakers, reclosers, bimetals and miniature circuit breakers are supported. The selectivity check is restricted to radial networks.

The pickup reliability (k factor) check supports overcurrent time protection devices, fuses, low-voltage circuit breakers, reclosers, bimetals, miniature circuit breakers and distance protection devices with current pickup. The pickup reliability check is also available in meshed networks.

- Support of symmetrical and asymmetrical networks
- Optional limitation of the area to be checked to a network area or to specific feeders

Calculation

The checking of current and time selectivity is based on the settings set in the protection devices.

To check pickup reliability, protection simulations are automatically performed in the network to determine the minimum short-circuit current occurring in the network. The k factor (Ikmin/Ipickup) is calculated and checked based on the minimum short circuit current (Ikmin) and the pickup current set in the device.

- Check of the current and time selectivity
- Fault type related (3-, 2-, 1-phase) check of the k factor
- Check of the k factor for primary and backup protection
- Calculation of the maximum permissible setting value for the pickup current dependent on the specified k factor
- Advanced checking of the correct setting of protection devices regarding conductor cross-section, thermal load, thermal destruction and maximum switch off time

Results and evaluation options

The results of the overcurrent time protection check are shown in the result view and in the network graphic. It is also possible to export the results as a report.

Result view

- Output of the results of the selectivity check in a separate results table, non-selectivities are also shown here
- Output of the results of the k factor check in a separate results table, showing whether the specified k factor was adhered, and which maximum pickup current is permissible to be set
- Output of the results of the advanced check (conductor cross-section, thermal load, thermal destruction,

maximum switch-off time) in the results table of the k factor check

Network graphic

- Highlighting of protection areas in the network graphic by selecting a protected area in the result view. Results from the results table can thus be quickly assigned to the corresponding protected area in the network graphic

Report

- The result tables of the OC check can be exported as a report in *.pdf format
- The results can be exported as .csv file

Arc Flash Calculation

(AFH)

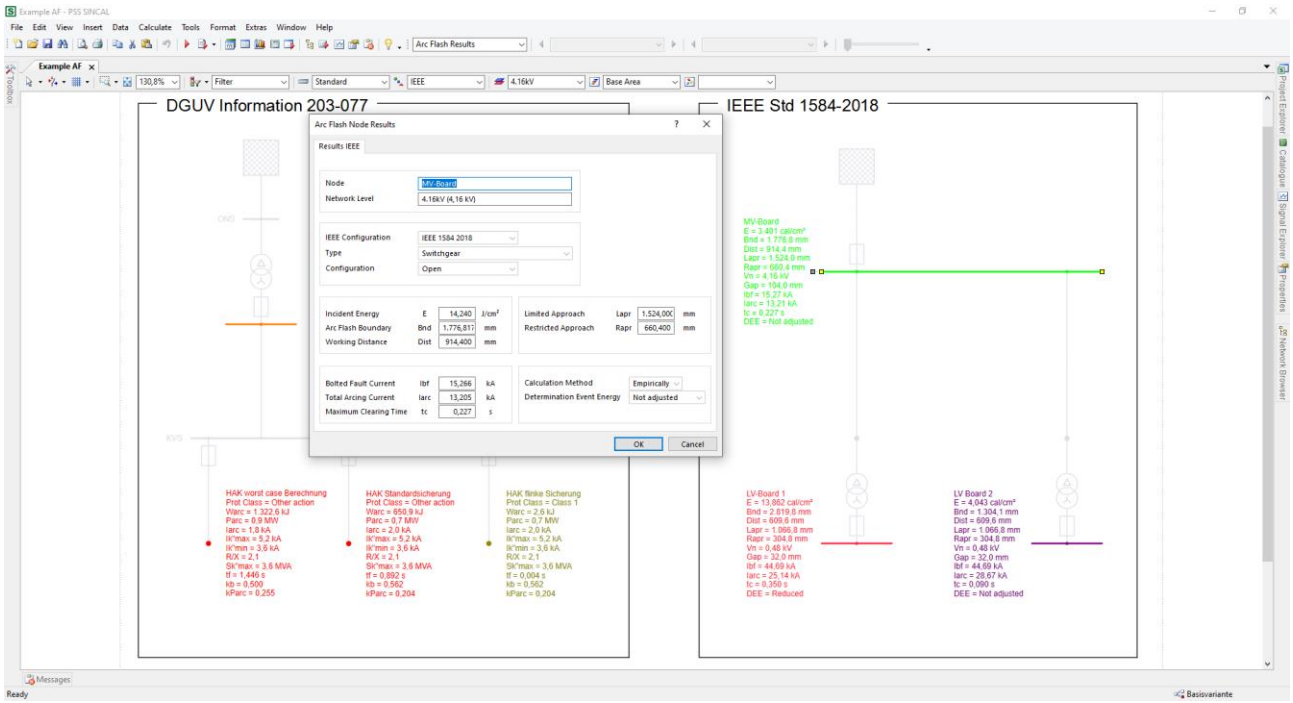


Figure 73: Arc Flash Calculation according to IEEE 1584 or DGUV 203-077

Requirements

Employers are obliged by health and safety laws and electric codes to assess working conditions and take appropriate measures to ensure safe working conditions. When working on or in the vicinity of live system parts, service personnel are exposed to the risk of arc flashes. According to accident statistics, arcing faults and their consequences are major causes of injuries in the electrical industry. The following measures help to reduce risks to persons:

- Risk assessment regarding arc flash events
- Definition of safety distances
- Improvements to the network and protection
- Provision of suitable personal protective equipment
- Affixing of warnings to systems

Solution

The module for arc flash analysis (AFH) in PSS®SINCAL enables the calculation of arc flash energy and other parameters and supports the user in optimizing existing equipment. The typical steps of an arc flash analysis are:

- Calculation based on a network model for 3-phase short-circuit current calculations with detailed simulation of the protection devices and system configurations
- Arc flash calculation and analysis based on current national and international regulations (DGUV Information 203-077 (2020) or IEEE 1584 (2002, 2018) and NFPA 70E)
- Display of results in network plans, reports and user-definable warning signs
- Development of measures for risk minimization based on the calculation results

Modeling

A network model for three-phase short circuit current calculations (SC module) provides the basis for the arc flash analysis. Various standards can be considered for the calculation, such as IEC 60909/VDE 0102 or IEEE C37, in each case with or without initial load. The model is extended by fuses, protection devices and their overcurrent protection setting values, which disconnect arc flashes occurring in the systems under consideration according to the concept. Alternatively, a fault-clearing time can also be specified.

Depending on the analysis method selected (DGUV Information 203-077 or IEEE 1584 and NFPA 70E), further information on the working environment is possible:

- Specific parameters for analysis according to DGUV Information 203-077
  - Electrode distance
  - Transmission factor
  - Working distance

    - If necessary, individual determination of current limiting factor and referenced arcing power
- Specific parameters for analysis according to IEEE 1584 and NFPA 70E
    - Electrode distance and arrangement
    - Enclosure dimensions
    - Working distance
    - Selection of the method for determining the arcing energy

Calculation and analysis

In both procedures, the system parameters are assigned to the observed network nodes (work locations) and the arcing energy occurring is determined from the 3-phase short-circuit current, switch-off time(s) and the system parameters. However, the calculation methods differ fundamentally. The subsequent selection of personal protective equipment against the thermal effects of an arc flash (PPE) is also based on different test methods.

- Analysis according to DGUV Information 203-077
    - Comparison of the calculated arc flash energy with the equivalent arcing energy (protection level of the arc flash PPE)
    - Selection of the appropriate protection class or other measures if the calculated arcing energy exceeds protection class 2 of the arc flash PPE
- Analysis according to IEEE 1584 and NFPA 70E
    - Determination of the arc flash boundary
    - Selection of suitable protective equipment based on the specifications of the current NFPA 70E standard
    - Creation of warning labels with specific information for the on-site identification of installations regarding arc flashes and electric shock

In addition to the consideration of faults on network nodes/busbars, line-side faults on the supply lines with their individual switch-off times can also be taken into account as an option.

Results and evaluation options

The calculation results depend on the selected analysis method:

- Results for analysis according to DGUV Information 203-077
    - Short circuit power and R/X ratio
    - Prospective fault current and minimum fault current
    - Current limiting factor and referenced arcing power
    - Equivalent arc flash energy (class 1 and class 2)
    - Arcing current
    - Arcing time/switch-off time
    - Arcing power and arcing energy
    - Required measure (arc flash PPE protection class or other measure)
- Results of the analysis according to IEEE 1584 and NFPA 70E
    - Bolted fault current
    - Arcing current
    - Arcing time/switch-off time
    - Arcing energy
    - Arcing boundary
    - Limited approach and restricted approach

The results can be displayed in the following ways:

- Calculation results at the observed network nodes in the network graphic including color highlighting
- Displaying of results in result screen forms
- Display of results in tabular view
- Creation of user-defined warning labels with analysis according to IEEE 1584 and NFPA 70E

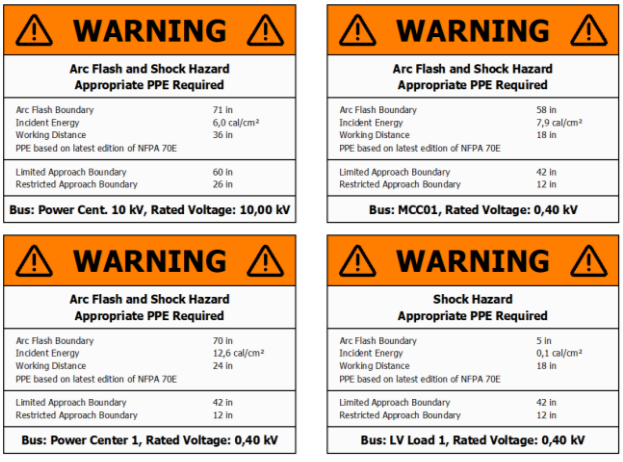


Figure 74: User-defined warning labels with analysis according to IEEE 1584 and NFPA 70E

Fuse Dimensioning

(DN)

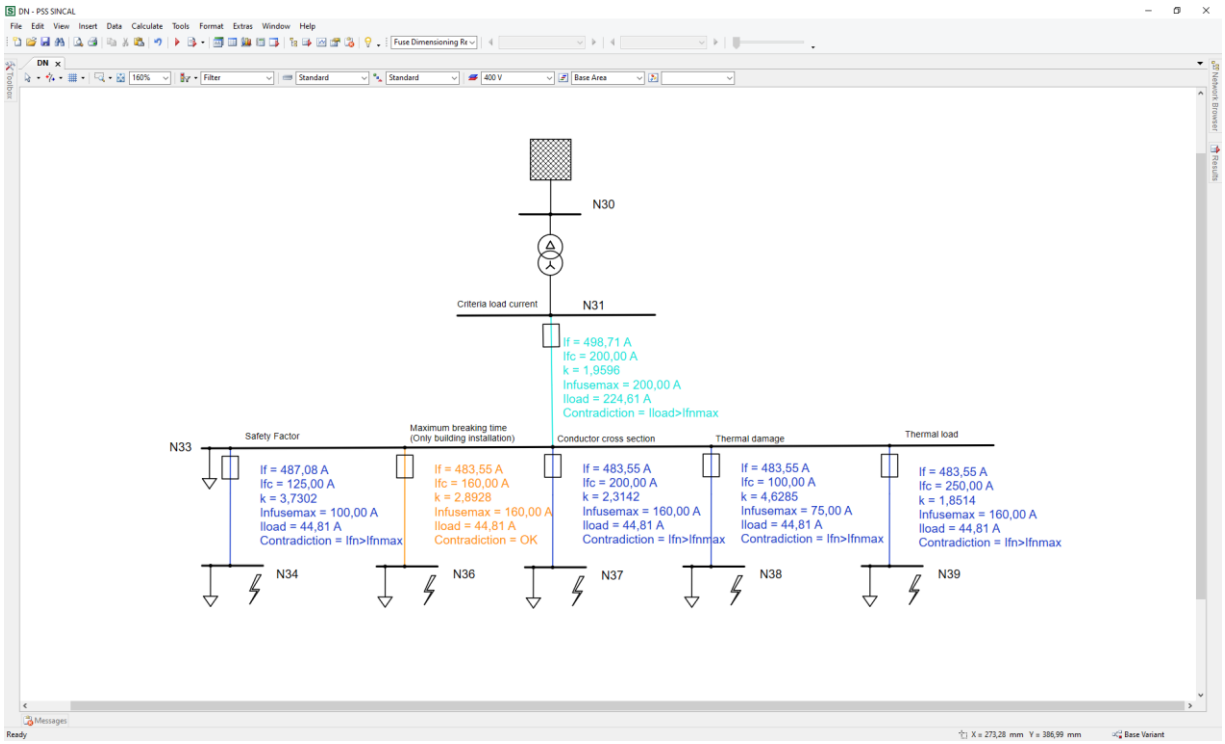


Figure 75: Fuse Dimensioning results including recommendation of fuse size

Requirements

When dimensioning fuses in low-voltage networks, the load current, short-circuit current, conductor cross-section, thermal destruction etc. criteria must be checked. Some of these criteria can be tested without simulation, while others, such as the k-factor test, require extensive simulation. The goal is the automated simulative verification of all these criteria, which leads to a considerable reduction of the workload.

Solution

The Fuse Dimensioning module (DN) in PSS®SINCAL checks the dimensioning of fuses in meshed and radial low-voltage networks.

Checking the correct dimensioning of fuses regarding:

- Load current
- Safety factor (k factor)
- Maximum switch off time (VDE 0100-410)
- Conductor cross section (VDE 0636)
- Thermal destruction
- Thermal load (VDE 0636)

Modeling

Manufacturer-specific fuses can be selected for modeling from the supplied protection device library. It is also possible to create user-defined fuses. The calculation in radial and meshed networks is supported.

- Protection device library with manufacturer-specific fuses
- Possibility to create user-defined fuses by specifying tripping characteristics (via data points or formulas)

Calculation

Various calculations are required to check the criteria.

- Comparison of the calculated load current with the rated fuse current
- The minimum short-circuit current occurring in the network is required for the calculation of the k-factor, fault simulations are automatically carried out for the determination of the minimum current
- Comparison of the occurring switch off time of the fuse from the simulation with the maximum permissible switch off time
- The maximum permissible rated current is determined via the conductor cross-section from a table according to the standard, then the maximum permissible rated current is compared with the rated fuse current
- Comparison of the thermal strength of the line based on the permissible 1s short-circuit current with the calculated Joule integral (thermal effect on the line

at the maximum short-circuit current occurring in the protection area)

- Checking the thermal load based on the thermal limit current of the line and the rated fuse current

Results and evaluation options

The results of the Fuse Dimensioning are provided in the network graphic.

Network graphic

- Fuses for which a criterion is not met are colored differently in the network graphic, depending on the criteria that are violated
- Violated criteria are displayed next to the fuses in the network graphic, further results such as the fault current or the k-factor can also be displayed next to the fuses
- If a criterion is violated, a suitable fuse is proposed with which the criterion can be met

Electrical Networks – PSS®NETOMAC

Eigenvalue/Modal Analysis
(EVA)

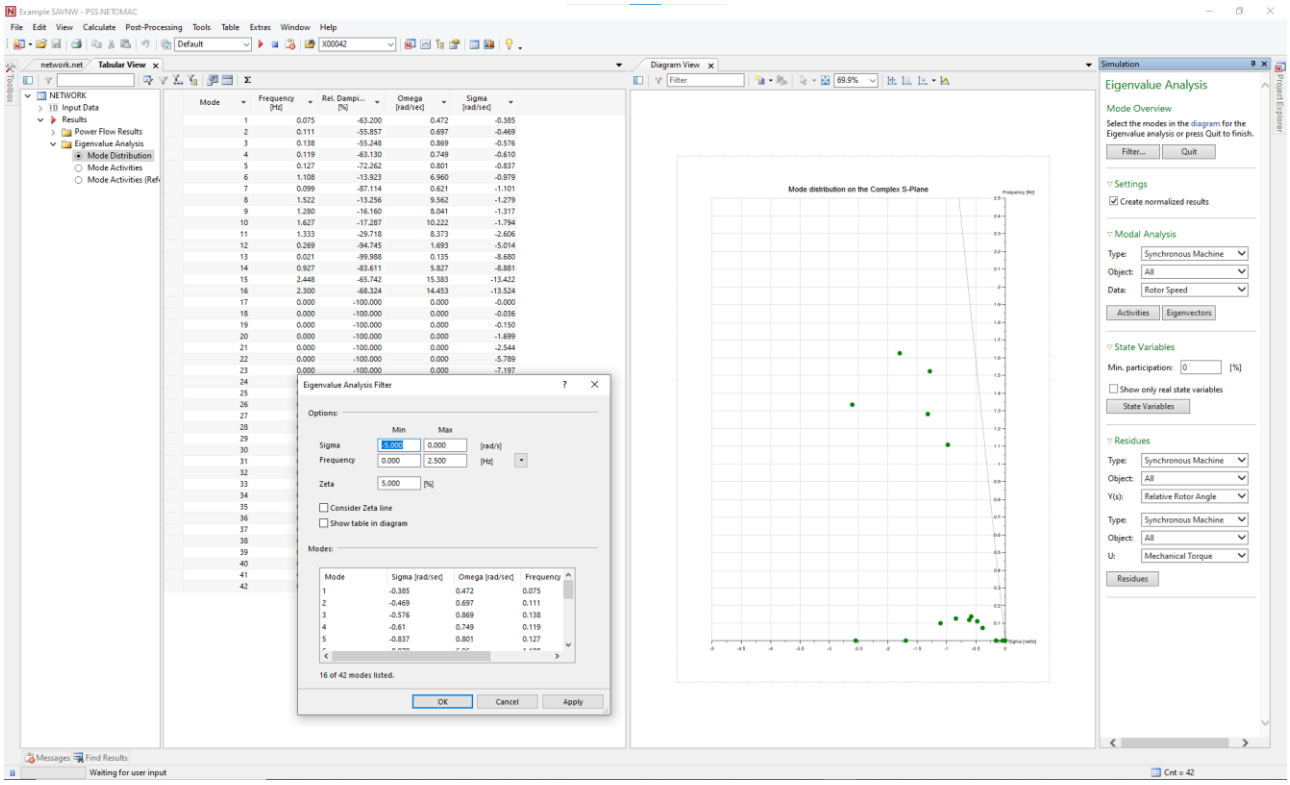


Figure 76: Mode Overview after Determining Model Eigenvalues

Requirements

In power systems, the interaction of all components from generation, transmission and conversion systems is complex, not only in case of fault events. Generators, control devices, HVDCs, FACTS, distributed energy resources and loads interact with each other even in a quasi-steady state, which manifests itself, for example, in the high-energy dominant electromechanical modes and jeopardizes system stability, e.g. through disconnections.

The complexity of the systems is constantly increasing due to digitalization and structural and market-related developments. This situation requires innovative methods that can systematically assess the stability of such systems and support the derivation of effective countermeasures.

If the dynamics of the network are shifted to the network levels subordinate to the transmission network, the complexity of the requirements to the operators of such systems increases.

- Systematic analysis of the small-signal stability of electrical energy systems with a focus on electromechanical modes and interactions with control devices of equipment
- Fast identification of local (local), regional (intra-area) and global (inter-area) electromechanical modes and controller interactions
- Support in the identification of suitable and efficient countermeasures for weakly damped, low-frequency oscillations

Solution

The PSS®SINCAL Platform, with its dynamics engine PSS®NETOMAC, offers the user in this module (EVA) the innovative modal analysis that meets the above-mentioned technical requirements and enables the evaluation of the interaction of all components with the focus on electromechanical modes and controller interactions. In addition to the dynamic models of stability calculation, the engine uses efficient methods for the complete description of the inherent oscillation behavior of an electrical power system.

- Quick and easy identification of weakly damped, dominant modes in the electrical power system and their influencing variables that can jeopardize the stability of the system regarding voltages and synchronism
- Determination of the eigenvalue solution of an entire dynamic network model with machines, controllers, transmission systems as well as loads and thus the inherent electromechanical and controller-induced oscillation capability of a system for a given steady-state case

- Option for simplified eigenvalue screening based on signal excitation and evaluation in the time domain for very large network models
- Support of the user in the search for effective countermeasures for dominant modes

Modeling

Basically, the EVA module uses the same modeling basis as the stability module (ST) due to the strong focus on electromechanical modes. This includes an efficient model handling as in stability calculations as well as the same simplifications in dynamic models of machines. Predefined linearization rules are also used to efficiently transform the network model into the state space and determine the eigenvalues of the model and their eigenvectors based on this definition.

- Models of the machines are considered as state equations. Their state variables are thus included as real state variables in the system matrix
- Models of control devices for machines, for network elements and for other systems are considered at building the state space model, linearized according to their function
- Consideration of converter-based systems like photovoltaic systems, wind turbines, batteries and other storage systems, HVDC, FACTS by generic elements (power, admittance, voltage and current)
- Fundamental frequency model of the network with dynamic phasors of all variables (voltages and currents) and constant impedances
- Loads are treated as constant impedances if they do not get assigned a dynamic model

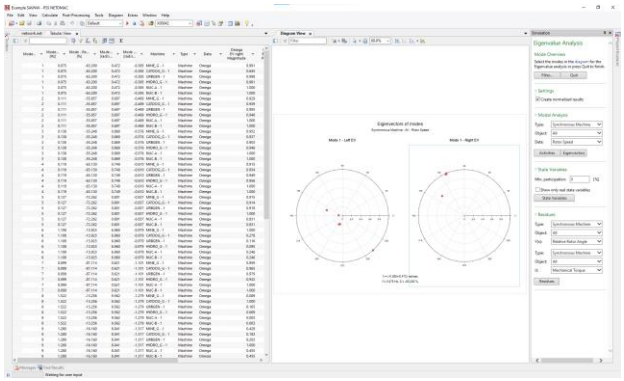


Figure 77: Graphical Representation of Left and Right Eigenvectors

Eigenvalue calculation

The high-performance dynamics engine in the PSS®SINCAL Platform can process even large network models with several thousand state variables and tens of thousands of nodes in eigenvalue calculation. Various methods are used in addition to efficient initialization and linearization.

- Precise and effective initialization of the dynamic models contained in the network model, so that the linearization can be applied to steady-state condition
- Predefined, efficient linearization rules for dynamic models and their blocks
- Linearization of black box models by model identification by excitation signals
- Eigenvalue calculation can optionally be started at a later point of simulation time of the stability calculation to consider the start-up processes of systems (e.g. HVDCs)
- Various powerful solution algorithms (QR, SI, DP) for calculating the eigenvalues of the linearized state space model of the network
  - Complete solution through eigenvalue calculation according to the QR method
  - Efficient methods for a partial solution according to the subspace iteration (SI) and dominant pole (DP) methods
- Use of eigenvalue calculation in the optimization of control devices for the sizing of damping measures (OPT module)
- A simplified method of eigenvalue screening based on signal excitation and evaluation in the time domain can be used optionally
  - Individually characterizable, sequential signal excitation in all machine models of the network model (e.g. in torques, slip, excitation voltage etc.)
  - Evaluation of the respective system responses by the Matrix-Pencil method with the result of dominant modes and their residues
  - Estimation of the relevant modal range for the network model for the application of solution algorithms for partial solutions in the state space model (SI, DP)

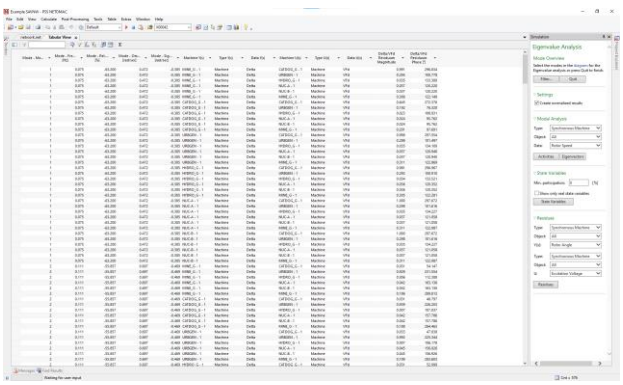


Figure 78: Evaluation of Residues in Modal Analysis

Modal analysis

The modal analysis for a network model that follows the eigenvalue calculation is divided into basic and advanced functions.

- The basic analysis includes, in addition to the functions for selecting relevant modes, the determination of all eigenvectors of this selection in relation to the selected state variables. This enables the identification of dominant modes and their main observation and control variables
  - Interactive scaling in the mode overview to filter the eigenvalues considered in the basic analysis
  - Advanced filter functionality based on damping, frequency and relative damping ratio
  - Normalization of the eigenvectors to the largest value or with respect to each participation vector
  - Calculation of the left and right eigenvectors by inverse iteration as well as the participation factors for certain or all state and auxiliary variables
  - Display of the eigenvectors in tabular or vector chart view
- The advanced analysis offers the user the possibility to evaluate countermeasures for dominant modes and to find an optimal strategy
  - Determination of the eigenvalue-specific residues for an excitation function in node, branch, machine or controller variables and the response in all state and auxiliary variables

Results and evaluation options

The program provides the following options for evaluating the results.

- Useful filter functions in tables for eigenvalues, eigenvectors and residues
- Grouping of results according to modes, state variables and other variables
- Advanced evaluation options in global evaluation models (GMB module) with structured output to files

Identification and Optimization
(OPT)

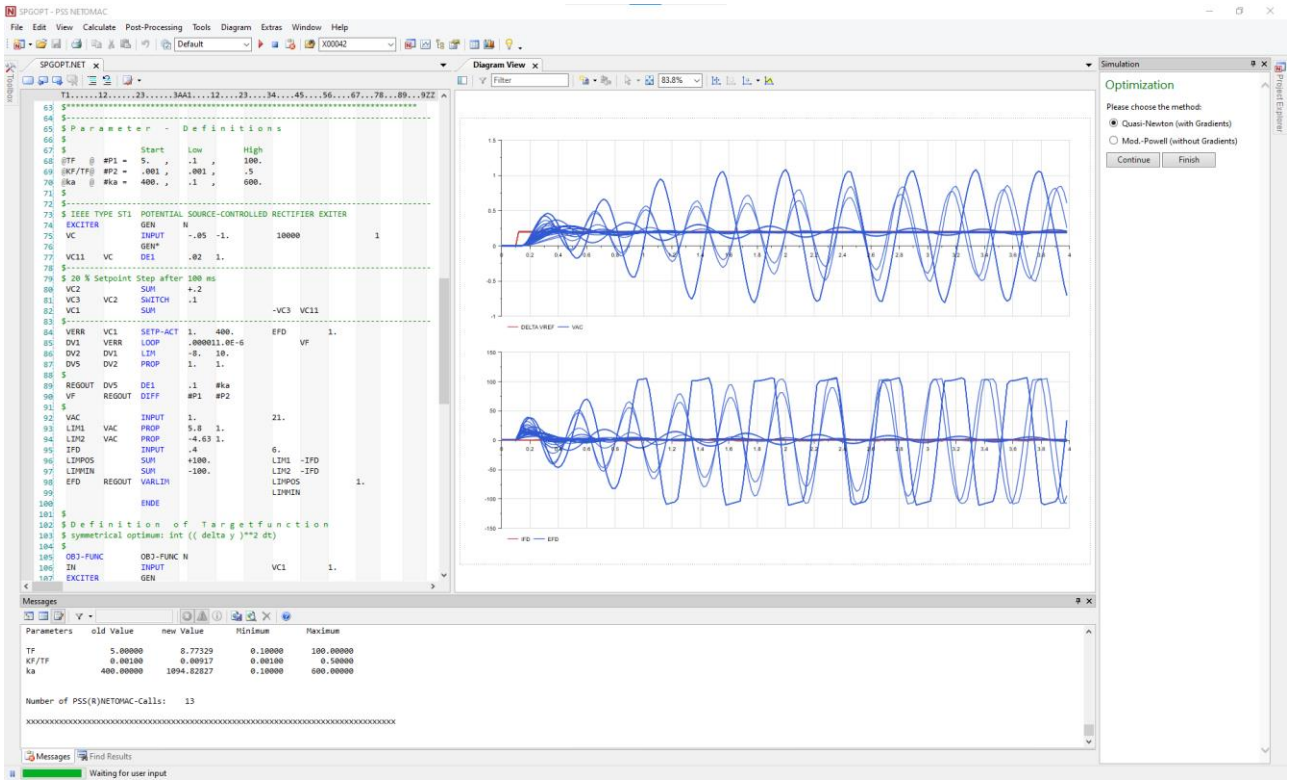


Figure 79: Optimization of Controller Parameters

Requirements

The analysis of electrical networks requires not only the development of models but also their parameterization. In the complex data collection phase, the user sometimes has access to the information provided by the system manufacturers (nameplate and data sheets). Furthermore, measured values are provided or determined by local measurements, from which the parameters for different types of models must be derived.

- Determination of the equivalent circuit diagram sizes of asynchronous and synchronous machines
- Identification of equipment model parameters based on measured values
- Determination of dynamic equivalent networks
- Reduction of the models of dynamic loads
- Determination of set values of controller parameters in open and closed control loops

When dimensioning components and control devices, their rating and parameterization should also be optimized regarding specified objectives. This requires efficient algorithms for the formulation of optimization targets, secondary conditions and the variables to be changed.

- Optimization of any parameter of the network model or control devices regarding a target function
- Definition of secondary conditions, which are considered in the optimization besides the target function
- Consideration of the optimization functions in different calculations of the time and frequency domain

Solution

The optimization algorithms (OPT) of the PSS®NETOMAC dynamics engine are used within the native user interface (ExpMode) both to identify parameters from measured values and to determine optimal settings and dimensioning values in various calculation types based on target functions.

- Identification of the equivalent circuit diagram values of asynchronous machines from basic data and provided torque-speed characteristics as well as the output of the machine definition
- Parameterization of network models and their dynamic equipment as well as control devices from measured values in the time and frequency domain
- Optimization of parameters of network elements, dynamic equipment and models with regard to a target function and secondary conditions in the calculations power flow (PF module), stability (ST module), electromagnetic transients (EMT module), active and passive frequency response (FRD module) and in the eigenvalue calculation EVA module)

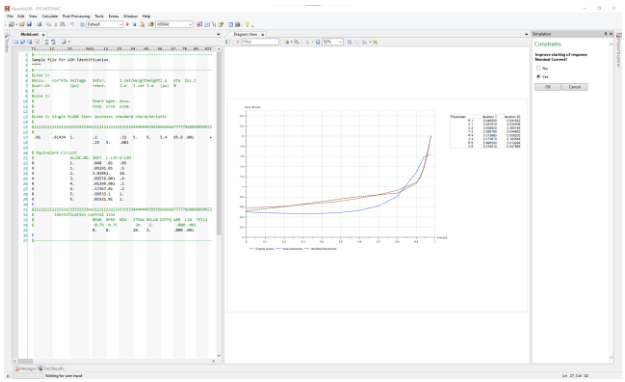


Figure 80: Identification of Asynchronous Machine Parameters

Identification and optimization

To determine the parameters based on the user specifications, various numerical methods are used, for which the convergence behavior can be adapted to the individual task. The identification or optimization includes the triggering of the relevant calculation procedures as selected by the user and the results are compared to the specifications by measured values or by functions.

- Consideration of reference results in the identification during time domain simulation (ST, EMT modules) and frequency response calculation (FRD module)
  - Provided torque-speed characteristic and basic data of asynchronous machines
  - Reference time curves of signals
  - Reference frequency response of signals
  - Consideration of weighting functions to prioritize specific ranges of measured values over others
- Consideration of a target function and secondary conditions in the optimization during power flow calculation (PF module), time domain simulation (ST, EMT modules), frequency response calculation (FRD module) and eigenvalue analysis (EVA module)
  - Definition of a main target function for which the result value is minimized. The function can have a linear or non-linear behavior depending on the task
  - Sum consideration of target function values if applying in combination with variants
  - Definition of any number of secondary conditions, which must be fulfilled in the optimization task
  - Consideration of any signals of a calculation by input blocks in the models of the optimization
- Free definition of parameters to be identified for use in network elements, dynamic equipment or other models, considering initial values and value ranges
- Numerical algorithms for handling the identification or optimization task with parameterizable convergence behavior
  - Quasi Newton method with gradients
  - Modified Powell algorithm
  - Least squares method
  - Adjustable accuracies for the target function as well as the convergence thresholds for parameters and changing the target function
  - Specification of the number of iterations, after which the identification task is aborted
- Combinatorial use of the numerical algorithms by sequential use of results and starting values for the iterations

Results and output options

The program provides the following options for evaluating the results and the output.

- The result of the identification or optimization outputs the numerical identifiers of the algorithm together with the deviation of the target variables
- The results of the identification can then be used as input definition in the network model data
- Following an identification or optimization in the time and frequency domain, the user can perform calculations directly with the identified or optimized parameters
- Both the results of the individual iteration steps of a single method and the intermediate results of the combined method application can be evaluated
- For the identification of the equivalent circuit diagram values of asynchronous machines, the characteristic curves from optimized parameters are compared with the characteristic curves determined with the initial parameters (or the previously used ones if the methods are used in combination)

Frequency Domain and Resonances (FRD)

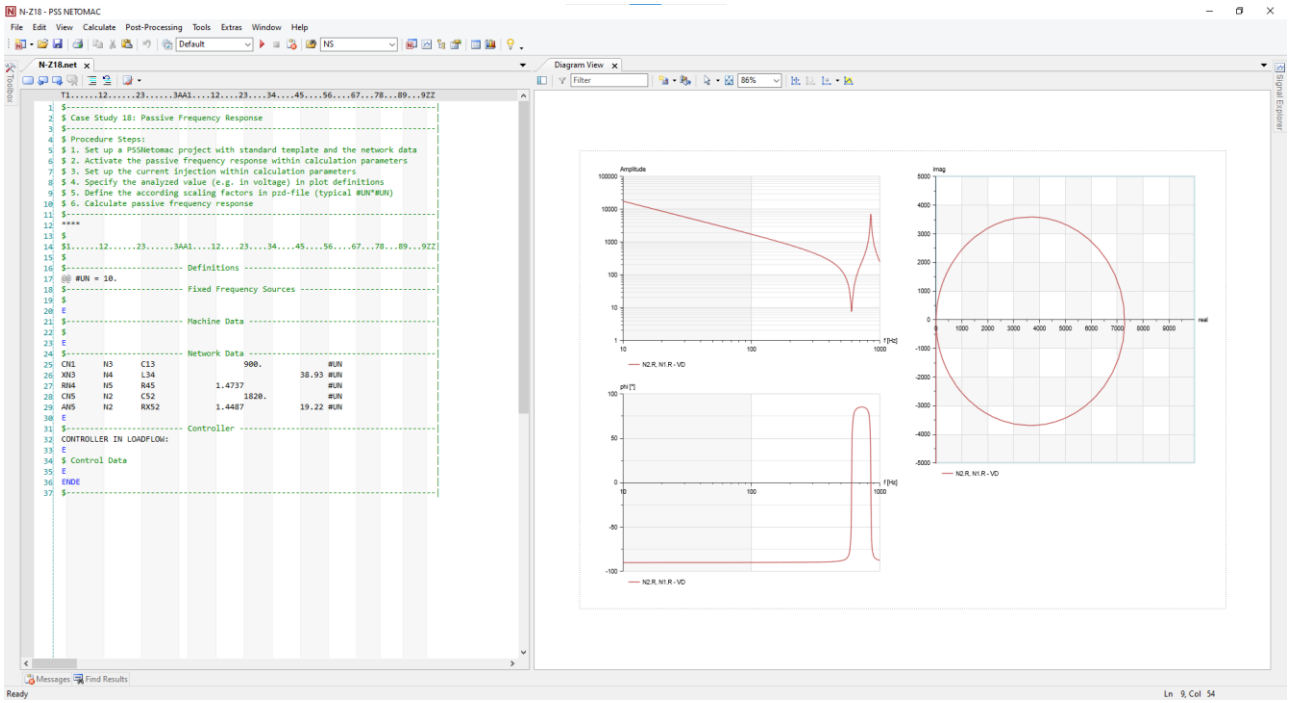


Figure 81: Determination of Frequency Response of Passive Networks

Requirements

When dimensioning equipment in electrical power systems, it is necessary to efficiently determine potential resonance points of the network as well as of the active network elements over a broadly defined frequency range. This makes it possible to prevent possible damage caused by resonances in network operation through passive and active countermeasures.

- Analysis of the frequency response of passive network elements to determine electrically induced resonance points
- Support in the sizing of filters based on the results of the frequency response determination
- Consideration of dynamic equipment such as machines, their drive trains, their control devices and controllable network elements in the frequency response
- Consideration of the operating point in the linearized response of the frequency response of a nonlinear system

Solution

In addition to the harmonics (OB) module, the expert mode (ExpMode) of the PSS®NETOMAC transient engine allows the passive (ST, EMT modules) and active (EMT module) system behavior in the frequency domain to be analyzed by this module (FRD). It supports the user in the detection of potential resonance points and in the development of appropriate countermeasures in dimensioning and parameterization.

- Quick and easy identification of resonance areas of the network
- Use of proven and successfully validated models and simulation methods of the PSS®NETOMAC transient engine, taking the torsion data (TOR module) and used models into account
- Application of efficient linearization rules for model blocks to determine the frequency response
- Consideration of models for network elements in the passive frequency response
- Support in the sizing of filters to suppress or shift resonance ranges

Modeling and calculation

The frequency domain (FRD) module uses the modeling basis of the ST, EMT and TOR modules to simulate the network, the machines and the drive shafts of the machine sets. This modeling basis is enhanced by linearization rules for model blocks.

- Definable frequency range for excitation in passive and active frequency response
  - Definition of the variable step width by start value, minimum and maximum difference value and rate of change
  - Start and end value of the frequency range in Hz
- Passive frequency response for passive network elements

  - Consideration of all passive elements of the network model
  - Additional consideration of user-defined models for network elements in the passive network model (GMB module)
  - Automatic conversion of dynamic machine data into suitable passive network elements
  - 3-, 2- or 1-phase excitation of the passive network model by a current source at defined nodes
- Active frequency response for network models with machines, definition of drive shafts and regulating devices
  - Consideration of the entire transient network model including extended network element models, machine data, torsion data (TOR module) and regulating devices as well as their linearization
  - Excitation of the active network model in any model (e.g. excitation system model)

Results and evaluation options

The program provides the following options for evaluating the results:

- Evaluation of the frequency response of defined electrical quantities in the passive frequency response
- Evaluation of the frequency response of defined electrical quantities in the active frequency response
- Any signal can be written out from user-defined models in ASCII character-based formats according to a user-defined structure

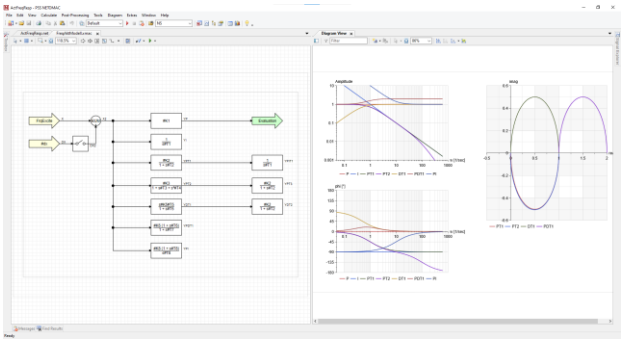


Figure 82: Analysis of Frequency Response from Controller Models

Torsional Analysis

(TOR)

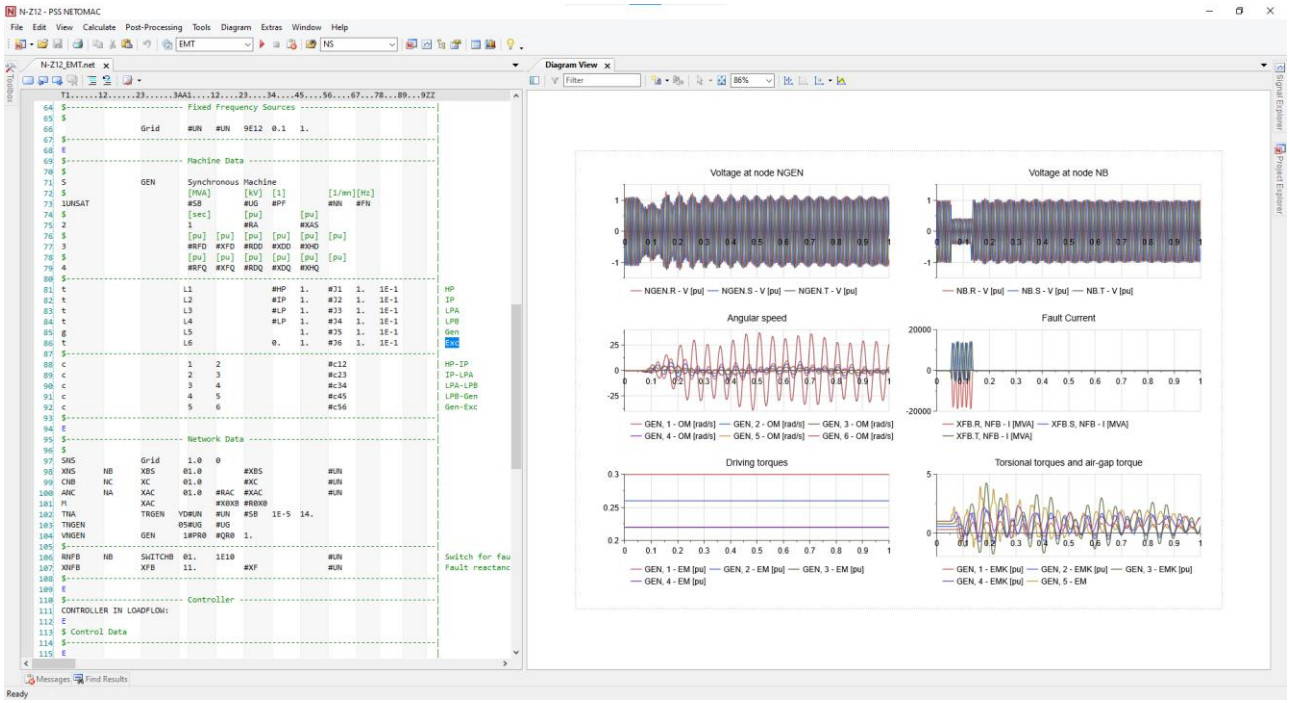


Figure 83: Analysis of Subsynchronous Resonances (SSR)

Requirements

The use of series compensation in order to increase transmission capacity and to stabilize grid operation can lead to the phenomenon of subsynchronous resonances (SSR) with drive shafts of conventional generating plants and thus can lead to damage of shafts and protection tripping. Converter-based technologies can also lead to subsynchronous interactions (SSTI) with the drive shafts. These dangers must be assessed already in the planning phase of such systems, but also when the resonances are detected during operation, and necessary counter-measures must be taken in order to avoid damages and fatigue.

- Assessment of the inherent tendency of drive shafts with several turbine stages, machines and excitation systems to oscillate, which can be excited by series compensation and converter-based technologies (HVDC, FACTS etc.)
- Evaluation of the mechanical stresses on drive shafts in power plants in case of faults
- Assessment of life expectation of drive shafts under regular stress due to torsional oscillations
- Analysis of the electromagnetic compensation processes associated with the resonances occurring and their effects

Solution

Based on the transient engine PSS®NETOMAC, the expert mode in this module (TOR) allows the extension of the models of the machines by the definition of the drive shaft in order to consider the influence of turbine stages and excitation system in the mechanical part of a power plant. On the one hand, this supports the user in the assessment of mechanical stresses on the drive shafts when subsynchronous resonances (SSR) and interactions (SSTI) occur and in the development of appropriate countermeasures when dimensioning and commissioning a plant. On the other hand, it enables the user to evaluate the electromagnetic effects of the compensation processes.

- Use of proven and successfully validated models and simulation methods of the PSS®NETOMAC transient engine
- Support of detailed mass definitions for realistic representation of turbine stages
- Various possibilities for modeling the drive shaft by distributing masses, torques and the Park transformation angle
- Possibility to use torsional data in the active frequency response (FRD module)

Modeling

The torsional analysis module uses the modeling basis of the EMT module for the simulation of the network. It adds the mechanical system of drive shafts with the different turbine stages (high, medium and low pressure), the machine rotors and the rotating excitation systems to this consideration. The connection to models containing the thermodynamic simulation of the generating plant can

consider the drive torque distribution and behavior in relation to each mass. The module also offers a high degree of modeling freedom on the machine side to represent the real system behavior

- Native simulation of the transient behavior of machines (synchronous and asynchronous machines) as well as the multi-phase network topology by means of differential equations based on principles of the EMT module
- Representation of turbine stages, machine rotors and rotating excitation systems by cylindrical masses on drive trains which are coupled together by spring constants
  - Individual distribution of a constant or controlled drive torque to the turbine stages by factors or a connection to a model which contains and simulates the individual drive torques of the turbine stages
  - Distribution of the air gap torque to several generator masses by factors or weighted according to the moments of inertia
  - Definition of the park transformation angle for a given mass or by a weighted angle, based on the moments of inertia of the generator masses
- Consideration of the real damping in the simulation in modal form from measured values
  - Direct input of the modal damping for the respective torsional modes
  - Input of the logarithmic decrement determined for the respective modes, which is converted into modal damping
- Support of the input of a large number of masses and thus an exact simulation of moment of inertia distributions (e.g. consideration of conical shapes)
- Extension of the inherent model by user-defined non-linear representation in simulation, influencing mass- or modal-based parameters as inertias, spring constants and damping

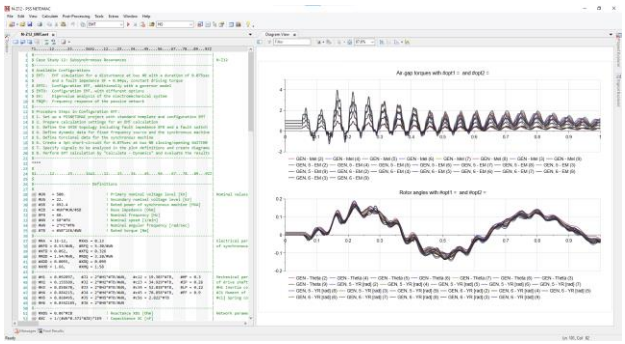


Figure 84: Extensive Access to all Mass- and Modal-based Signals

Calculation

The torsional analysis module basically uses the high-performance and robust simulation method of the EMT module with the extension of the models described above. It thus enables the connection between electromagnetic and mechanical transients on shafts

- Precise and fast initialization of the torsion model, so that the simulation can start in the steady-state condition without initial transients
- Calculation of active frequency response due to instantaneous excitation on the shaft and the effects of the excitation on machine and network variables (FRD module)

Results and evaluation options

In addition to the results and evaluation possibilities of the EMT module, the torsion analysis offers the output of the essential values for the evaluation of torsional torques and for the characterization of shafts

- Output of all mechanical variables from the torsion calculation as well as all network variables
  - Instantaneous values as well as their determined magnitudes, angles and frequencies as well as the quantities derived from the EMT calculation
  - Output of torsional and drive torques, angles, angular velocities and accelerations of the defined masses on the drive train
  - Output of modal torsional signals
  - Output of the determined modal coupling matrix, transformation matrix, spring constants, damping factors and eigenfrequencies
- Analysis in intuitive diagrams, export options and the possibilities of user-defined evaluations in models as well as in the EMT module
- Fourier analysis of the simulation results

Pipe Network – Calculation Modules

The calculation modules for pipe networks offer engineers in planning and operational planning of district heating networks, district cooling networks, gas networks as well as water supply networks a solution for steady-state hydraulic network calculation as well as operating point and time series calculations and contingency analysis.

Requirements

- Planning of district heating networks or district cooling networks in the supply area of energy supply companies, quarters and campus facilities, industrial plants or in the vicinity of conveyor systems and support in operational planning
- Planning of district and supply networks for gas, in the supply area of energy supply companies, quarters and campus facilities, industrial plants or in the vicinity of conveyor systems and support in operational planning
- Planning of water supply networks in residential water engineering for extensive transport networks or in the connection area of supply companies and support in the operational planning, planning and analysis of the fire water supply
- Calibration and validation of the digital network model with measurement data from the operation
- Increasing the supply security and reliability of the networks
- Support in operational planning by analysis of operating point and time series observations, derivation of operational measures to reduce losses and utilization of the media-specific storage possibilities of pipe networks
- Calculation of coupled networks for comprehensive system analysis between electrical and heat networks or gas networks
- Use of a diameter planning and analysis tool in the company with the same user interface and architecture

Solution

The PSS®SINCAL Platform offers calculation modules for heating networks, cooling networks, calculation modules for gas networks and calculation modules for water supply networks across any number of pressure levels in radial and meshed networks.

- Steady-state hydraulic calculation, operating and (quasi-dynamic) time series calculation as well as contingency analysis for supply and return pipes of heating and cooling networks
- Steady-state hydraulic calculation, operating and (quasi-dynamic) time series calculation and contingency analysis for gas networks
- Steady-state hydraulic calculation, operating and (quasi-dynamic) time series calculation and contingency analysis as well as fire water observations and calculation of the filling and emptying of water tanks and reservoirs

Gas - Steady-State

(GS)

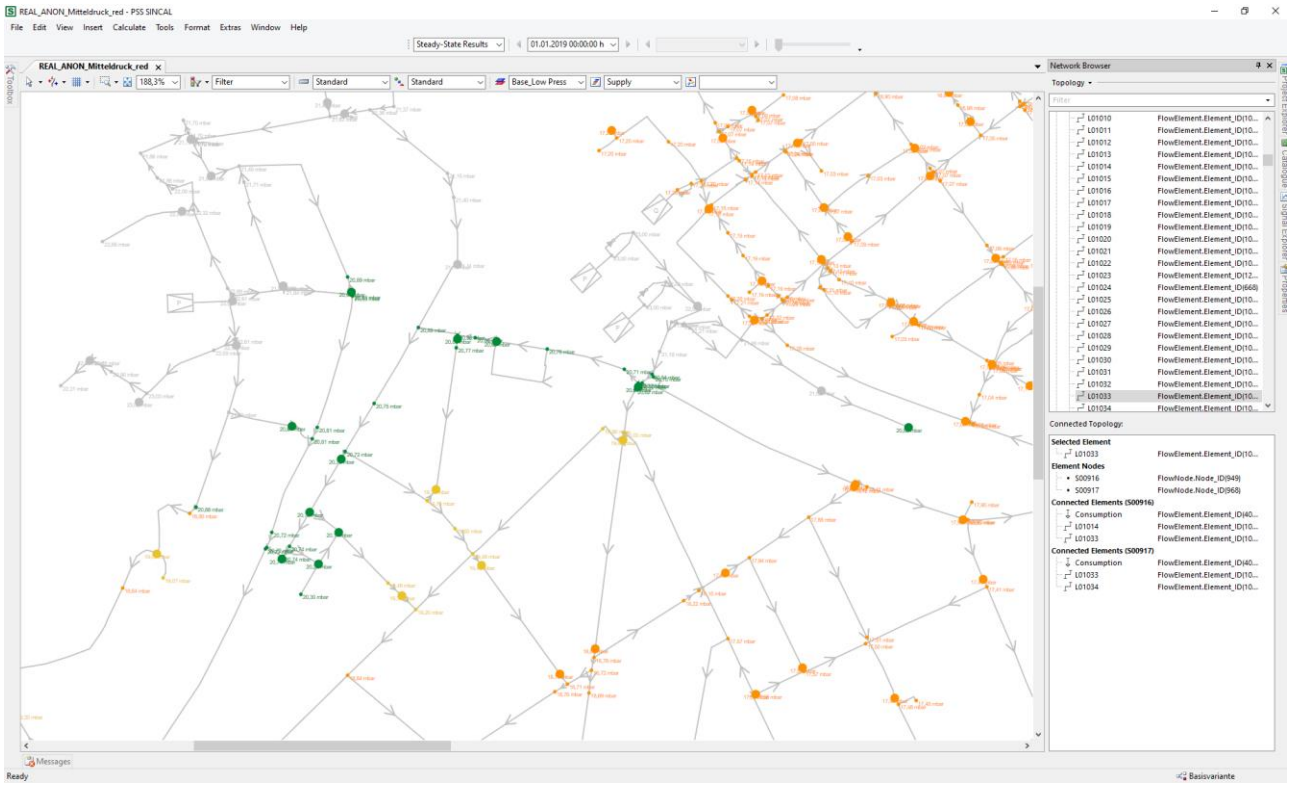


Figure 85: Steady-state calculation results in gas network visualized in the network graphic (colored according to pressure values)

Requirements

Steady-state network calculation for observing the operating states of a network is required in the target network planning, the planning of new network areas or network optimizations and reinforcements of existing gas district and large area supply networks.

- Documentation of the network topology, the network elements and network coupling points in graphical and schematic view
- Assessment of the steady-state pressure and volume distribution as well as the flow velocity in any meshed networks with different pressure levels
- Determination of network content, the usage of the networks buffer capabilities and its losses
- Assessment of the consumption behavior in relation to pressure, temperature and simultaneity
- Assessment of the mixing ratio and the flow times when supplied from different sources
- Assessment of the transport capacities
- Assessment of connection requests at network coupling points

Solution

The module for the steady-state calculation for gas networks (GS) in the PSS®SINCAL Platform is the basic module and enables the modeling of a gas pipe network, the steady-state calculation and the appropriate options for evaluating the results.

- Comprehensive modeling of branch and node elements as well as characteristic curves for the behavior
- Calculation of the steady-state pressure, volume and flow distribution in any meshed networks
- Consumer modeling depending on the ambient temperature
- Automatic redistribution of supply depending on the selected limit values of the generators and calculation of the supply shares from different sources at network nodes as well as the flow time
- Hydraulic head diagrams for user-defined routes considering the geodetic height

Modeling

In order to model a gas network, many predefined elements are provided to simulate a network of nodes and node and branch elements.

- Consideration of the geodetic height (elevation above sea level) of the nodes
- Flow or pressure feed as supplying network element
  - Flow supply for constant, pressure-independent supply quantity under consideration of limit values in quantity-controlled networks
  - Pressure supply to compensate the sum of all delivered quantities with constant overpressure (balance nodes) in pressure-controlled networks
- Modelling of pipes with static parameters and time-dependent change of diameter and roughness
  - Consideration of internal roughness, length and diameter manipulation factors, zeta value and leakage rate
  - Annual change of the roughness and reduction of the diameter can be modelled
  - Creation and use of pipes from user-defined type databases
- Sliding valve for bidirectional flow limitation or non-return valve for unidirectional flow limitation
- Pressure controller with flexible setpoint and feedback for modelling pressure control regulators or compressor stations
  - Setpoint for output pressure as constant value or with a characteristic curve dependent on the flow rate
  - Control of the increase or reduction of pressure at any defined network node due to the flexible feedback loop definition
  - Specification of the response pressures of the pressure monitors and pressure limiters
- Branch element (connecting of two nodes) with constant pressure drop
  - Drop in pressure between two nodes
  - Independent of flow and pressure at the inlet node
- Branch element (connecting of two nodes) with constant flow rate
  - Constant flow rate between two nodes
  - Independent of flow and pressure at the inlet node
- Compressor for pressure increase
  - Pressure increase between two nodes
  - Control of the pressure increase at any definable network node
- Simulation of a gas container as pressure buffer
  - Filling volume change by flow into or out of the buffer according to a user-defined pressure buffer characteristic
- Modeling of different consumer types
  - Modeling of the consumption from the supply pipes as volume or energy quantity
  - Modeling of reduced consumption by consumers with a pressure difference below the limit to simulate undersupply
  - Modeling of the temperature-dependent consumption with temperature consumption characteristic (ambient temperature of the network level)
- Simulation of leakage points in the network as leakage rate of the pipes or leakage element at nodes
- Specification of the gas properties by common parameters (e.g. specific density, viscosity, energy content, Sutherland constant, adiabatic exponent)

Calculation

The calculation iteratively determines the steady-state operating state of the network.

- Calculation of the steady-state pressure, volume and flow distribution in any meshed networks with different pressure levels
  - Hardy-Cross procedure and Kirchhoff's 2nd law
  - Lambda calculation with formula according to Nikuradse, Prantl-Colebrook or Unger and Prantl-Colebrook
  - Convergence debug interface for the detailed analysis of convergence problems
  - Common and combined calculation of any definable pressure levels (high, medium and low pressure)
  - Mass flows in the pipes
- Calculation of the relative and absolute pressure considering the geodetic height (elevation above sea level) of the nodes and the entire network
- Redistribution of the supply quantity between different sources within their specified limits
- Determination of the steady-state mixing ratio and the flow times at each node
  - Network tracing at a node to determine the percentage shares of the supply quantity from the different supplies
  - Respective flow time (end time) of the fluid between the individual supplies and the selected node
- Simulation of snapshots with time series data located in an open and generic external database (e.g. metering or forecasting data) with the time series data interface (module TSDI) without additional transfer of input data

- Checking the operating points and limits of pumps, sliding valves and network groups
- Steady-state calculation for the targeted analysis of malfunctions of individual elements

Results and evaluation options

The program provides the following options for evaluating the results.

- Provision of the results for the elements in graphics, table and database as well as other result views and reports
- Provision of results for network levels, network areas and the entire network
  - Pipe length, gas volume and pipe volume of the entire network, network levels and network areas
  - Total of all consumption and supplies in the entire network as well as balances of the individual network levels and areas
  - Total of all outputs of leakages
  - Minimum pressure in the network, maximum flow rate
  - Transferred volume between the defined network areas
- Network tracing at nodes to determine the supply shares from different sources and their flow time up to the node
  - Determination of the supplied gas quantities from the different feeders to the selected node
  - Determination of the flow time from the individual feeders up to the selected node
- Display of hydraulic head diagrams along any route in the network
  - Freely definable routes for the determination of hydraulic head diagrams and automatic generation of the corresponding diagram
  - Display of relative or absolute pressure and pressure height
  - Display of the values over the distance of the selected nodes

Gas - Operating/Time Series

(GL)

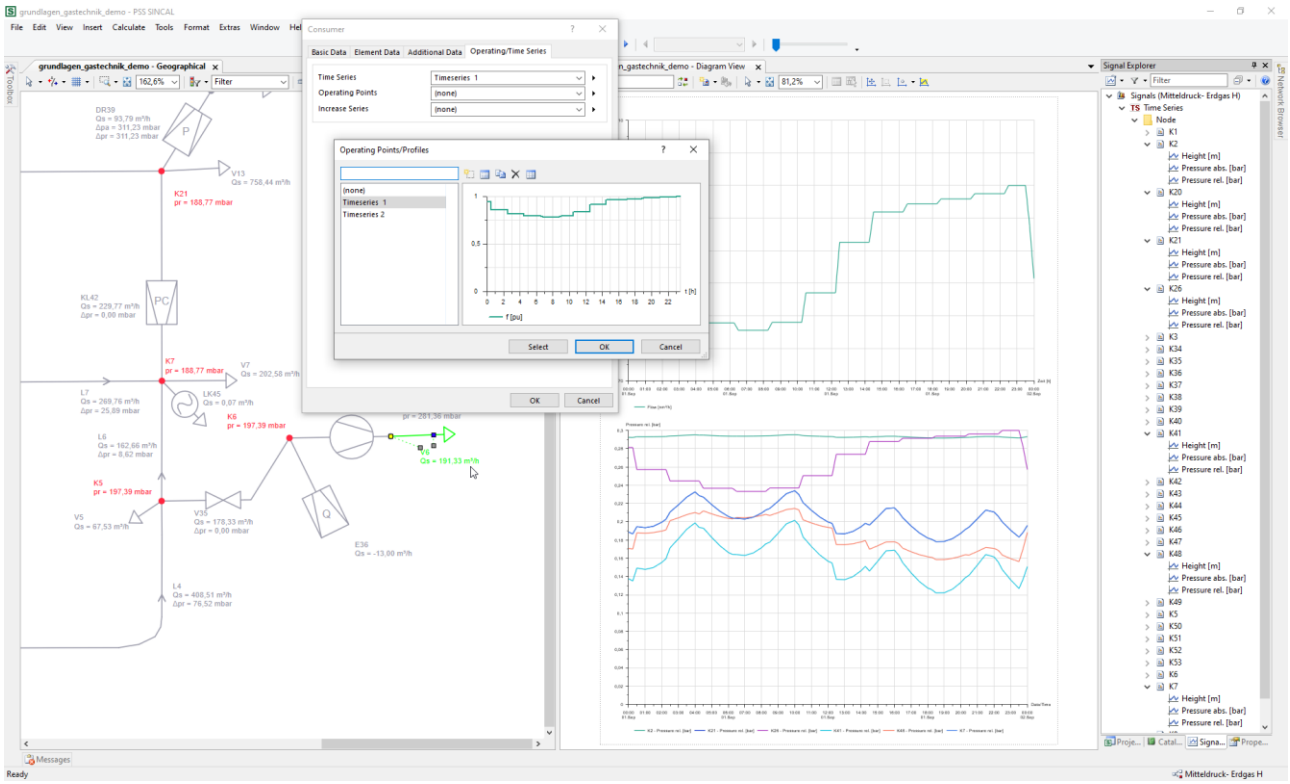


Figure 86: Time series calculation in a gas network

Requirements

Many individual steady-state calculations are required to analyze the effects of changes in operating state in relation to temperatures, consumption patterns and valve states of the gas network over a historical or predicted time period.

A validation of a planning model with measured values is required but also the determination of energy and volume quantities over short, medium or long-term periods.

- Analysis of the daily and seasonal dependent pressure conditions in the network based on historical operation with measured data from time series measurements
- Refinement and validation of the network model (calibration)
- Analysis of increase and reduction rates of supply or consumption in medium and long-term forecast periods
- Analysis of the change of the internal pipe roughness and reduction of the diameter
- Determination of average and extreme values
- Determination of transported quantities over a selected period

Solution

Based on a network model for steady-state calculations, PSS®SINCAL enables quasi-dynamic time series calculations (GL) over a time period or at specific operating points.

- Calculation of user-defined operating points and operating states
- Time series calculation based on steady-state calculations with user-defined time step
- Calculation based on user-defined increase rates
- Calculation with meter data and measured values determined during operation

Modeling and calculation

Advanced modeling options and parameters are available for extending a network model with time series or operating points for calculation.

- Calculation of operating points to represent stationary operating states of the network
  - Definition of any number of steady-state operating points with multiplication factors for the rated values/states of the elements to represent typical operating states of the network
  - Modelling of global or regional simultaneity

    - Individual assignment of the operating points to the respective elements or global assignment for the individual network levels
    - Calculation of all operating points with steady-state calculation for each individual operating point as an operating series
- Time series calculation based on steady-state calculations to simulate operating states in time periods of minutes, hours up to several days or years
    - Individual definition or import of factor profiles with user-defined time step
    - Use of standard load profiles as consumer profiles
    - Cyclical handling of profiles
    - Individual assignment of the time series/profiles to the respective elements or global assignment for the individual network levels
    - Time step for the duration of the individual stationary condition can be set
    - Steady-state calculation at all points in time within the simulation period
- Calculation based on user-defined increase rates to simulate operating states for the long-term (several years) periods
    - Definition of any number of increase profiles with multiplication factors for the rated values/states of the elements for modelling changes in generation and consumption over the long term
    - Individual assignment of the increase rates to the respective elements or global assignment for the individual network levels
    - Calculation of the selected time points at which changes result from the defined increase or consumption
- Simulation of snapshots or time series with time series data located in an open and generic external database (e.g. metering or forecasting data) with the time series data interface (module TSDI) without additional transfer of input data

Results and evaluation options

The program provides the following options for evaluating the results.

- Provision of the results for the elements for each time step in graphics, table and database as well as other result views and reports
- Automatically calculated average, maximum and minimum values
- Display of the results in user-defined diagrams over the calculation period
- Generation of diagrams of the operating behavior (flow-pressure) of the defined operating groups

Gas - Contingency Analysis
(GCA)

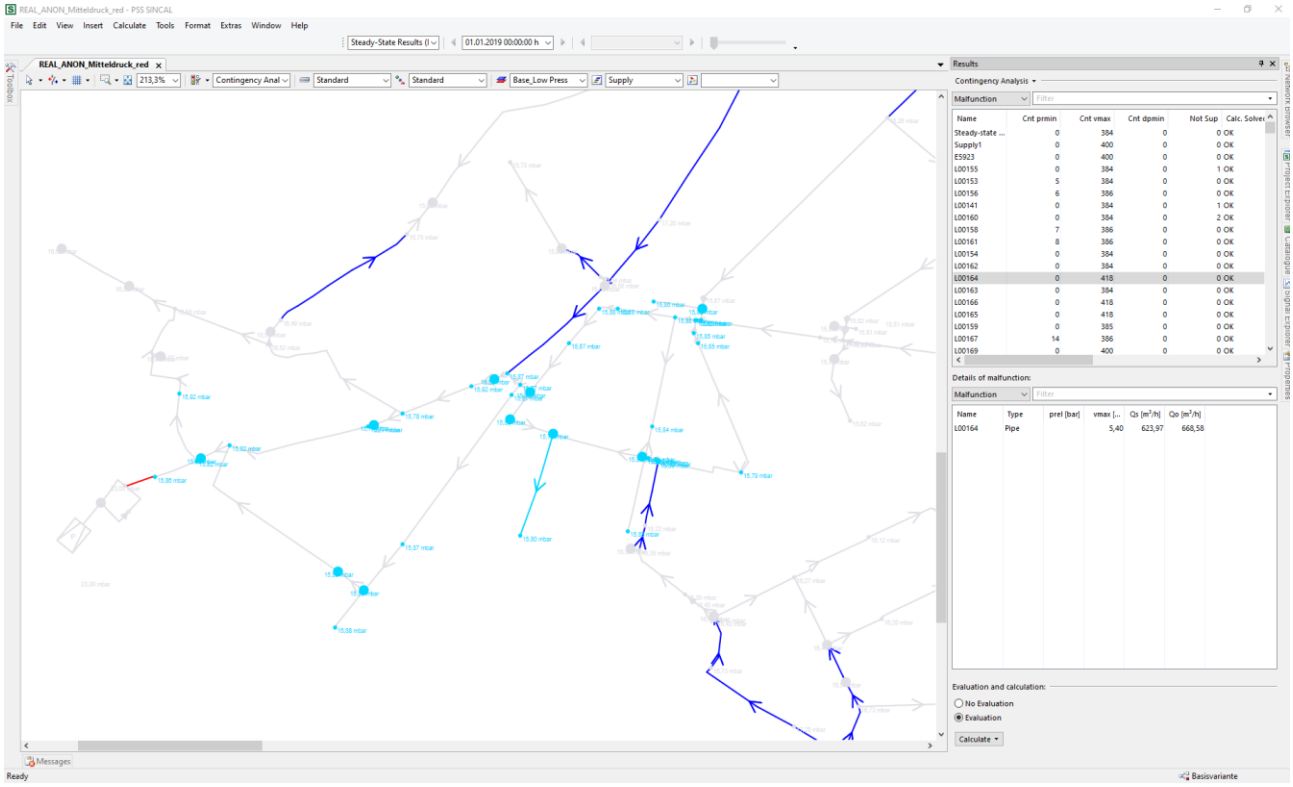


Figure 87: Analysis of the effects of a pipe malfunction (or maintenance) in the network graphic

Requirements

In order to increase the reliability of the gas supply and transport as well as operational safety, it is useful to analyze the effects of malfunctions, contingencies and planned maintenance measures at individual elements or of entire element groups.

- Assessment of the flow conditions in case of malfunction (or maintenance) of individual network elements and generators or element groups as well as the caused malfunction of further elements due to the contingency
- Consideration of all possible malfunction combinations or specific analysis of the malfunction of elements groups
- Analysis of the operational safety and analysis of weak points in the network as well as the derivation of countermeasures to increase the security of supply and reliability

Solution

The structured combinatorial generation and calculation of all configurations is possible with the module for contingency analysis (GCA) and is based on the high-performance calculation of individual stationary conditions.

- Automatic generation of all possible malfunction combinations in the network and consideration of user-defined groups
- Steady-state calculation for each combination, considering the elements that failed unconditionally as well as conditional malfunctions (caused malfunctions) that occur during the calculation according to defined conditions

Modeling

The user has the possibility to define function and malfunction groups in order to consider typical malfunctions, where several elements in a network fail or are switched off at the same time.

- User-defined malfunction groups for elements that are considered together
- User-defined function groups that are only in operation together
- Setting of the malfunctions individually for the network areas

Calculation

The malfunction calculation generates all possible malfunction scenarios and those that are user-defined and calculates each one in a stationary condition. The network model is only changed during the individual calculation iterations and is unchanged after the calculation.

- Automatic generation of all combinatorically possible malfunction combinations
  - Malfunction of the individual elements
  - Malfunction of all elements, excluding the pipes or elements where limit violations occur
  - Consideration of function and malfunction groups
- Automatic steady-state calculation of all individual combinations after analysis start with only a temporary change of the network model
  - Unconditional combinatorial or user-defined generated malfunctions as the initial state for the calculation
  - Conditional further malfunctions (caused malfunctions) of elements when a user-defined flow rate is exceeded during the calculation

Results and evaluation options

The program provides the following options for evaluating the results.

- Display of malfunction combinations in the result browser for contingency analysis
  - Detailed information about the failure in tree structure
  - Elements at which limit values are violated, unsupplied elements, connected and disconnected elements as well as elements at which the maximum values of the results are obtained
  - Localization, marking and editing in the network graphic
- Display of the results by color coding
- Results in tabular view in the results view with direct link to the graphical view, filter functions as well as options for generating reports and exporting the results

Water - Steady-State

(WS)

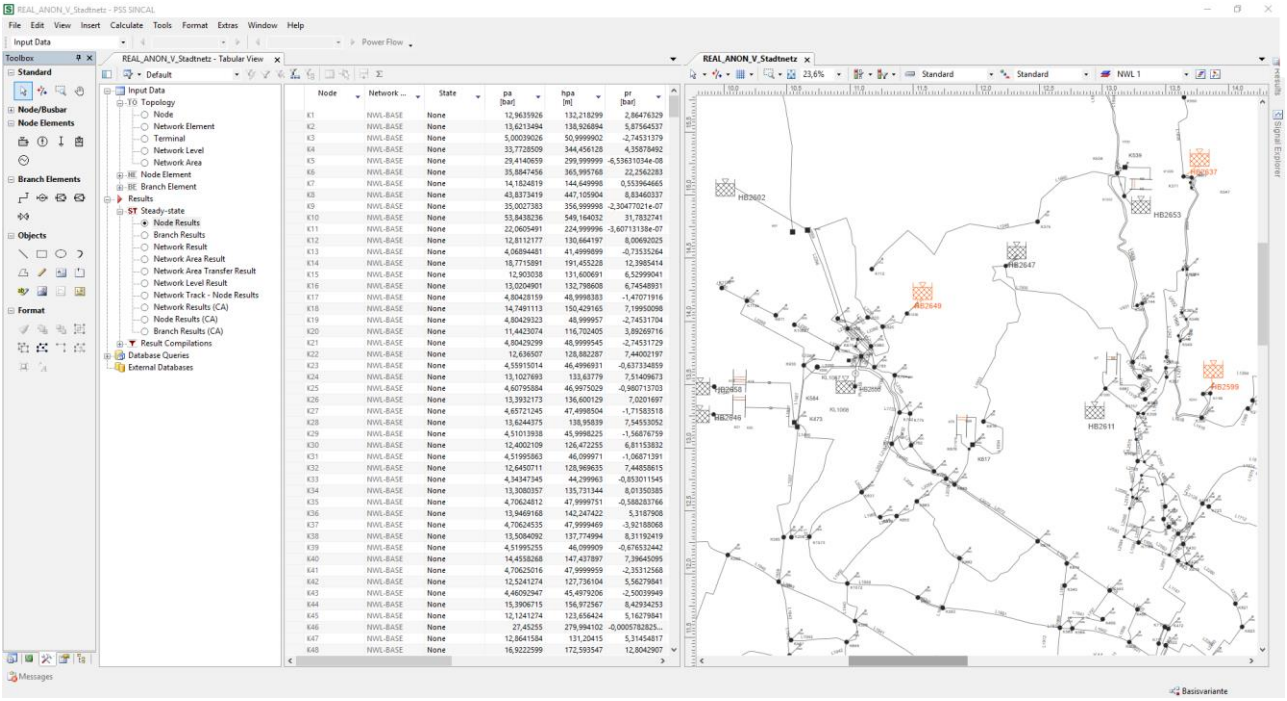


Figure 88: Steady-state calculation results in water network visualized in the network graphic (colored according to pressure values)

Requirements

In order to ensure a high level of supply security, an interconnected system is aimed at the technical planning of the water supply (distribution and storage) in residential water engineering for new network areas and in the reinforcement or dismantling of existing networks as well as in target network planning.

The coverage of future requirements through the reinforcement, dismantling or optimization of existing networks requires powerful and flexible network modeling and calculation in order to observe the current operating states of the network and those designed in scenarios.

- Planning and routing of district and transport pipelines and district water distribution networks (branched, meshed or ring networks)
- Pump sizing and pipe dimensioning
- Calculation of the supply pressure (minimum overpressure at the customer load) at all connection points
- Consideration of long-term roughness changes and diameter reductions
- Expansion or reinforcement in case of increased demand as well as optimization in case of oversized pipe networks
- Determination of the water age at the consumption nodes
- Provision of the fire water demand at defined points in the network and creation of fire water plans
- Documentation of the network topology in graphical and schematic view

Solution

The steady-state calculation for water networks (WS) in the PSS®SINCAL Platform is the basic module and enables the modeling of a network, the steady-state hydraulic calculation and the appropriate options for evaluating the results.

- Comprehensive modeling of branch and node elements as well as characteristic curves for their behavior
- Calculation of the steady-state pressure distribution and the flow as well as water losses in any meshed networks across different pressure zones
- Consumer modeling depending on the ambient temperature
- Calculation of the available fire water (hydrants) at the network nodes
- Hydraulic head diagrams for user-defined routes considering the geodetic height (elevation about sea level)

Modeling

In order to model a water supply network, many predefined elements are provided to simulate a network of nodes and connections as well as elements that are inserted at the nodes.

- Consideration of the geodetic height (elevation above sea level) of the nodes
- Modeling of supply into the network as water storage or pump
  - Water tanks (water reservoir) with constant pressure to compensate the supply from pumps and the consumption by consumers
  - Reciprocating pump with constant output flow from a water reservoir or parent network, assumed to be unlimited
  - Centrifugal pump with output flow in relation to the user-defined pump characteristics from a water reservoir or parent network, assumed to be unlimited
  - Any combined supply from the various elements
- Modeling of the pipes with user-defined diameters
  - Consideration of internal roughness, length and diameter manipulation factors, zeta value and leakage rate
  - Annual change of the roughness and reduction of the diameter can be modeled
  - Creation and use of pipes from user-defined type databases
- Sliding valve for limiting bidirectional flow limitation or non-return valve for unidirectional flow limitation
  - Sliding valve with valve position, opening degree and diameter
  - Non-return valve for preventing bidirectional flow in a pipe
- Pressure controller with setpoint input for increasing or reducing the pressure between two nodes
  - Setpoint setting as a fixed value or with a characteristic curve dependent on the flow rate to simulate a constant head and pressure
  - Control of the increase or reduction of pressure at any defined network node
  - Specification of the response pressures of the pressure monitors and pressure limiters
- Branch element (connecting of two nodes) with constant pressure drop
  - Drop in pressure between two nodes
  - Independent of flow and pressure at the inlet node
- Branch element (connecting of two nodes) with constant flow
  - Constant flow rate between two nodes
  - Independent of flow and pressure at the inlet node
- Pumps to increase pressure between inlet and outlet nodes
  - Centrifugal pump for output flow according to the pump characteristic curve
  - Reciprocating pump for constant output flow
- Pressure buffer as water reservoir with overflow
  - Filling volume change by flow into or out of the buffer according to a user-defined pressure buffer characteristic
  - Removal (overflow) when a limit value is violated in order not to exceed this maximum pressure value
- Modeling of consumer or extraction points
  - Constant consumption
  - Modeling of reduced consumption by consumers in case of an undercut of the minimum pressure difference to simulate undersupply
  - Modeling of the temperature-dependent consumption with temperature consumption characteristic
- Modelling of hydrants and leaks in the network
  - Leakage rate of the pipes
  - Leakage element at nodes with constant output
  - Hydrant element as combined element with pipe parameters, internal pressure head and parameters for fire water quantity, pressure and time at the hose connection
- Specification of the water via the specific density and viscosity as an ideal, incompressible fluid in completely filled pipes

Calculation

The calculation iteratively determines the steady-state operating state of the network.

- Calculation of the steady-state pressure, volume and flow distribution in any meshed networks with different pressure levels/zones
  - Hardy-Cross procedure and Kirchhoff's 2nd law
  - Convergence debug interface for the detailed analysis of convergence problems
  - Common and combined calculation of any definable pressure levels/zones
- Calculation of the relative and absolute pressure considering the geodetic height (elevation above sea level) of the nodes and the entire network
- Redistribution of the supply quantity between different sources within their specified limits

- Determination of the steady-state mixing ratio and the flow times at each node
  - Network tracing at a node to determine the percentage shares of the supply quantity from the different supplies
  - Respective flow time (end time) of the fluid between the individual supplies and the selected node
- Simulation of snapshots with time series data located in an open and generic external database (e.g. metering or forecasting data) with the time series data interface (module TSDI) without additional transfer of input data
- Checking the operating points and limits of pumps, sliding valves and network groups
- Steady-state calculation for the targeted analysis of malfunctions of individual elements
- Fire water calculation at network nodes with hydrants
  - Calculation of individual hydrants or all hydrants in the network simultaneously
  - Calculation of the fire water quantity for a given fire water pressure of the hydrant
  - Calculation of the pressure at all network nodes and fire water pressure for a given amount of fire water

Results and evaluation options

The program provides the following options for evaluating the results.

- Provision of the results for the elements in graphics, table and database as well as other result views and reports
- Provision of results for network levels, network areas and the entire network
  - Pipe length, pipe volume of the entire network, network levels and network areas
  - Total of all consumptions and supplies in the entire network, as well as balances of the individual network levels and areas
  - Total of all losses and leakages
  - Minimum pressure in the network, maximum flow velocity
  - Transferred volume between the defined network areas
- Provision of results of the fire water calculation in the graphic for the creation of fire water plans
- Network tracing at nodes
  - Determination of the delivered quantities from the different supplies to the selected node
  - Determination of the flow time from the individual supplies up to the selected node
- Display hydraulic head diagrams along any route in the network
  - Freely definable routes for the determination of hydraulic head diagrams, automatic generation of the corresponding diagram
  - Display of relative or absolute pressure and height
  - Display of the values over the distance of the selected nodes

Water - Operating/Time Series
(WL)

Requirements

Many individual steady-state calculations are required to analyze the effects of changes in operating state in relation to consumption patterns and valve states of the water network over a historical or forecast period.

A validation of a planning model with measured values is also required but also the determination of flow rates, as well as losses over short, medium or long-term periods (e.g. daily pattern).

- Analysis of different defined operating states in only one calculation
- Analysis of the daily and seasonal dependent pressure distributions in the network
- Refinement and validation of the network model (calibration)
- Analysis of increase and reduction rates of supply or consumption in medium and long-term forecast periods
- Determination of average and extreme values
- Determination of transported quantities and losses over a selected period

Solution

Based on a network model for steady-state calculations, PSS®SINCAL enables quasi-dynamic time series calculations (WL) over a time period or at specific operating points.

- Calculation of user-defined operating points and operating states
- Time series calculation based on steady-state calculations with user-defined time step
- Calculation based on user-defined increase rates
- Calculation with meter data and measured values determined during operation
- Results for average, maximum and minimum values

Modeling and calculation

Advanced modeling options and parameters are available for extending a network model with time series or operating points for calculation.

- Calculation of operating points to represent stationary operating states of the network
  - Definition of any number of steady-state operating points with multiplication factors for the rated values/states of the elements to represent typical operating states of the network
  - Modelling of global or regional simultaneity
  - Individual assignment of the operating points to the respective elements or global assignment for the individual network levels
  - Calculation of all operating points with steady-state calculation for each individual operating point as an operating series
- Time series calculation based on steady-state calculations to simulate operating states in time periods of minutes, hours up to several days or years
  - Individual definition or import of factor profiles with user-defined time step
  - Cyclical handling of profiles
  - Individual assignment of the time series/profiles to the respective elements or global assignment for the individual network levels
  - Time step for the duration of the individual steady states can be set
  - Steady-state calculation at all points in time within the simulation period
- Calculation based on user-defined increase rates to simulate operating states for the long-term (several years) periods
  - Definition of any number of increase profiles with multiplication factors for the rated values/states of the elements to represent changes in generation and consumption over the long term
  - Individual assignment of the increase rates to the respective elements or global assignment for the individual network levels
  - Calculation of the selected time points at which changes result from the defined increase or consumption
- Pipes with roughness changes and diameter reductions
- Simulation of snapshots and time series with time series data located in an open and generic external database (e.g. metering or forecasting data) with the time series data interface (module TSDI) without additional transfer of input data

Results and evaluation options

The program provides the following options for evaluating the results.

- Provision of the results for the elements for each point in time graphics, table and database as well as other result views and reports
- Automatically calculated average, maximum and minimum values
- Display of the results in user-defined diagrams over the calculation period

Water Tanks

(WH)

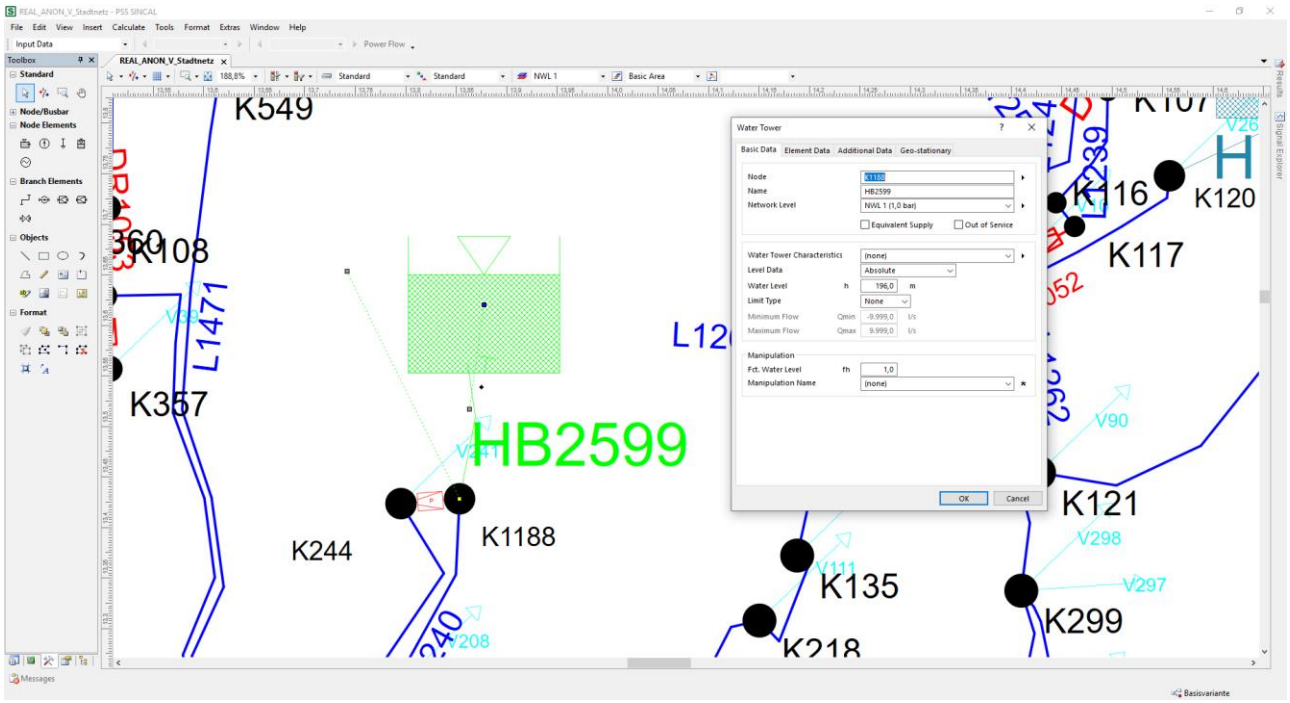


Figure 89: Modelling of water tanks / reservoirs

Requirements

In order to connect the locations where the water is extracted and the water supply area, tanks (ground elevated tanks, water tower, reservoirs) are existing. This enables constant flow rates for the pumps and constant pressure conditions in the network as well as a temporal decoupling of the flow rate from the consumption rate.

- Rating and sizing and positioning of new tanks
- Determination of the required filling level of existing tanks depending on the state of the network and consumption patterns of the consumers
- Validation of the tank sizing by simulation-based verification with consumption data

Solution

Based on the time series calculation in PSS®SINCAL, it is possible to calculate the filling levels of water tanks (WH) and the extended display of the levels in the diagrams.

- Calculation of the water tank filling levels at each point in time of the simulation period
- Graphical display of the filling level in diagrams

Modeling

Water tanks in the network model are modeled as storages with supply and outflow.

- Water tank with volume and level as geodetic height
- Reference height of the tank absolute (elevation about sea level) or relative (node elevation)
- Characteristic curve to model the filling level in relation to the filling volume
- Optional limit values for maximum supply and outflow
- Individual time series and operating points for the water tanks

Calculation

Based on the time series calculation, the water tank is considered as a storage system in the calculation.

- Calculation of the filling level at each point in time of the time series calculation
- Filling of the water tank via up to three independently operating pumps (simulation of the supply)
- Outflow from the water tank through the connected pipe of the network
- Abort of the calculation when tank is completely emptied at the current point in time

Results and evaluation options

The program provides the following options for evaluating the results.

- Additional display option of the level and the outflow/filling over the selected period in the diagram view

Water - Contingency Analysis
(WCA)

Requirements

In order to increase the reliability of the water supply, it is useful to analyze the effects of pipe breaks, malfunctions, contingencies and planned maintenance measures at individual elements or of entire element groups.

- Assessment of the flow and pressure in case of malfunction (or maintenance) of individual network elements and generators as well as the caused malfunction of further elements due to the fault
- Consideration of all possible malfunction combinations or specific analysis of the malfunction of elements groups
- Analysis of the supply safety and analysis of weak points in the network as well as the derivation of countermeasures to increase the security of supply and reliability

Solution

The structured combinatorial generation and calculation of all configurations is possible with the module for contingency analysis (WCA) and is based on the high-performance calculation of individual stationary conditions.

- Automatic generation of all possible malfunction combinations in the network and consideration of user-defined groups
- Steady-state calculation for each combination, considering the elements that failed unconditionally as well as conditional malfunctions (caused malfunctions) that occur during the calculation according to defined conditions

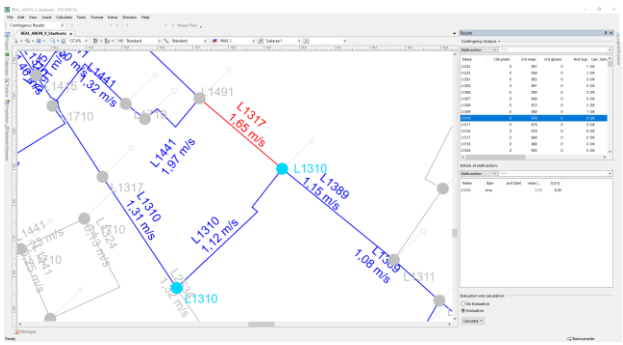


Figure 90: Analysis of the effects of a pipe malfunction (or maintenance) in the network graphic

Modelling

The user has the possibility to define function and malfunction groups in order to consider typical malfunctions, where several elements in a network fail or are switched off at the same time.

- User-defined malfunction groups for elements that are considered together
- User-defined function groups that are only in operation together
- Setting of the malfunctions individually for the network areas

Calculation

The malfunction calculation generates all possible malfunction scenarios and those that are user-defined and calculates each one in a stationary condition. The network model is only changed during the individual calculation iterations and is unchanged after the calculation.

- Automatic generation of all combinatorically possible malfunction combinations
  - Malfunction of the individual elements
  - Malfunction of all elements, excluding the pipes or elements where limit violations occur
  - Consideration of function and malfunction groups
- Automatic steady-state calculation of all individual combinations after analysis start
  - Unconditional combinatorial or user-defined generated malfunctions as the initial state for the calculation
  - Conditional further malfunctions (caused malfunctions) of elements when a user-defined flow rate is exceeded during the calculation

Results and evaluation options

The program provides the following options for evaluating the results.

- Display of malfunction combinations in the result browser for contingency analysis
  - Detailed information about the failure in tree structure
  - Elements at which limit values are violated, unsupplied elements, connected and disconnected elements as well as elements at which the maximum values of the results are obtained
  - Localization, marking and editing in the network graphic
- Display of the results by color coding
- Results in tabular view in the results view with direct link to the graphical view, filter functions as well as options for generating reports and exporting the results

Heating/Cooling - Steady-State
(FS)

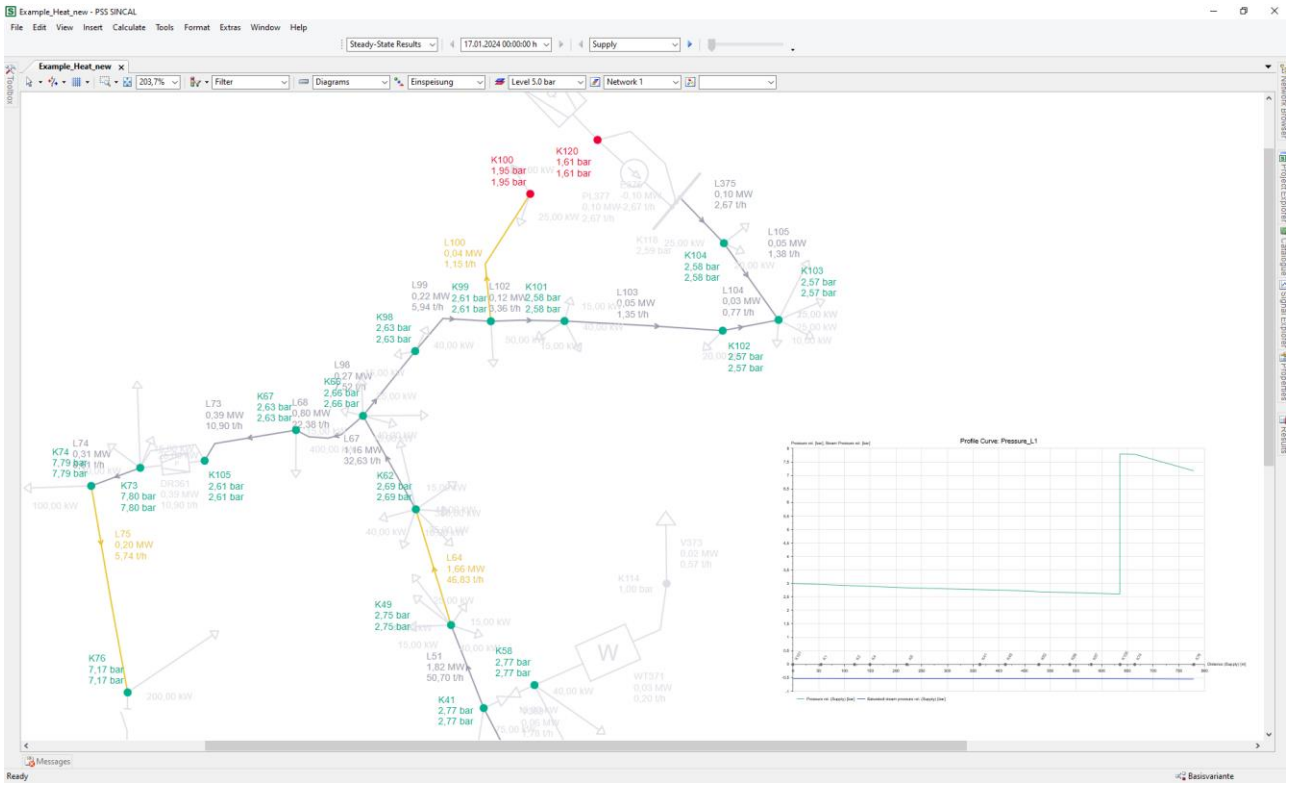


Figure 91: Steady-state calculation results in flow line of network and pressure diagram along line

Requirements

The planning of new or reinforcement of existing heating or cooling networks requires studies and calculations with hydraulic and energetic considerations based on the connected consumers to be supplied and the supply facilities.

Performant and flexible network modeling and calculation are required in order to consider the operating states of the network when planning the target network, the reinforcement or optimization of existing networks.

- Documentation of the network topology in graphical and schematic view
- Hydraulic sizing of network and pumps, route planning and pipe dimensioning of supply and return pipes
- Selection of suitable supply and return temperatures
- Estimation of the heat losses or heating of the cooling medium
- Estimation of the consumption behavior in relation to pressure, temperature and simultaneity
- Assessment of exchange between different network areas
- Assessment of connection or supply requests

Solution

The steady-state calculation for heating and cooling networks (FS) in the PSS®SINCAL Platform is the basic module and enables the modeling of a network, the steady-state hydraulic calculation and the appropriate options for evaluating the results.

- Comprehensive modeling of branch (pipes) and node elements with optional characteristics for their behavior
- Separate or combined modeling of supply and return pipes with user-defined diameters
- Calculation of the steady-state pressure, volume and temperature distribution and losses in radial or arbitrarily meshed networks
- Consumer/consumption modeling depending on the ambient temperature
- Automatic redistribution of supply depending on the selected limit values of the generators and calculation of the supply shares from different sources at network nodes as well as the flow time
- Hydraulic head diagrams for user-defined routes considering the geodetic height

Modeling

For the modelling of a heating or cooling network, many predefined elements are provided to model a network of nodes and connections as well as elements that are inserted at the nodes.

- Consideration of the geodetic height (elevation above sea level) of the nodes
- Modeling of supply systems as pressure, power or pump supply
  - Pressure supply with constant supply pressure at the supply point irrespective of the consumption volume in the network
  - Power supply with constant supply volume or output irrespective of pressure with specified supply temperature (supply) or temperature difference (supply-return)
  - Supply with pressure control with different pressure control types for supply and return
  - Pump supply as a centrifugal pump with characteristic curve in supply or return pipe
  - Supply from different sources with different supply temperatures
- Separate modeling of pipes as supply and return pipes with user-defined diameters or combined
  - Separate or combined modeling of supply and return pipes
  - Modeling of several parallel pipes for supply and return pipes or a bypass
  - Consideration of internal roughness, length and diameter manipulation factors, zeta value and leakage rate
  - Calculation of losses based on temperature difference and thermal conductivity of the insulation
  - Creation and use of pipes from user-defined type databases
- Heat exchanger for hydraulic decoupling or power exchange
  - Hydraulic uncoupling of subnetworks by extraction from the primary network and supply with pressure control in the secondary network, taking efficiency into account
  - Power supply or exchange for the coupling of network areas or subnetworks that are not hydraulically coupled
- Sliding valve for limiting bidirectional flow limitation or non-return valve for unidirectional flow limitation
  - Sliding valve with valve position, opening degree and diameter
  - Non-return valve for preventing bidirectional flow in a pipe
- Pressure controller with setpoint input for increasing or reducing the pressure between two nodes
  - Setpoint setting as a fixed value or with a characteristic curve dependent on the flow rate to simulate a constant head and pressure
  - Control of the increase or reduction of pressure at any definable network node
  - Specification of the response pressures of the pressure monitors and pressure limiters
  - Differential pressure control
- Connection element with constant pressure drop
  - Drop in pressure between two nodes
  - Independent of flow and pressure at the inlet node
- Connection element with constant flow
  - Constant flow rate between two nodes
  - Independent of flow and pressure at the inlet node
- Pumps to increase pressure between inlet and outlet nodes
  - Centrifugal pump for output flow according to the pump characteristic curve
  - Reciprocating pump for constant output flow
- Temperature controller for supply or return pipe temperature
  - Removal from supply or return
  - Control of the supply or return temperature at any definable network node
- Simulation of a storage as a pressure buffer and overflow
  - Filling volume change by flow into or out of the buffer according to a user-defined pressure buffer characteristic
  - Prevention of a limit value (maximum pressure value) violation by removal (overflow)
- Modeling of different consumer or consumption types
  - Constant consumption quantity according to the specification of a temperature difference or a return pipe temperature (with optional pressure-dependent reduction)
  - Constant consumption (as power equivalent) according to the specification of a temperature difference or a return pipe temperature (with optional pressure-dependent reduction)
  - Modeling of reduced consumption by consumers with a pressure difference below the limit to simulate undersupply
  - Modeling of the temperature-dependent consumption with temperature consumption characteristic

- Simulation of leaks in the network
  - Leakage rate of the pipes
  - Leakage element at nodes
- Specification of the cooling/heating medium (fluid) via the specific heating capacity as an ideal, incompressible fluid in completely filled pipes

Calculation

The calculation iteratively determines the steady-state operating state of the network.

- Calculation of the steady-state pressure, volume and temperature distribution in any meshed networks with different pressure levels
  - Hardy-Cross procedure and Kirchhoff's 2nd law
  - Common and combined calculation of any definable pressure levels
  - Convergence debug interface for the detailed analysis of convergence problems
- Calculation of the relative and absolute pressure considering the geodetic height (elevation above sea level) of the nodes and the entire network
- Redistribution of the supply quantity between different sources within their specified limits
- Determination of the steady-state mixing ratio and the flow times at each node
  - Network tracing at a node to determine the percentage shares of the supply quantity from the different supplies
  - Respective flow time (end time) of the fluid between the individual supplies and the selected node
- Simulation of snapshots with time series data located in an open and generic external database (e.g. metering or forecasting data) with the time series data interface (module TSDI) without additional transfer of input data
- Checking the operating points and limits of pumps, sliding valves and network groups
- Steady-state calculation for the targeted analysis of malfunctions of individual elements

Results and evaluation options

The program provides the following options for evaluating the results.

- Provision of the results for the elements in graphics, table and database as well as other result views and reports
- Provision of results for network levels, network areas and the entire network
  - Pipe length, pipe volume of the entire network, network levels and network areas
  - Total of all consumptions and supplies in the entire network, as well as balances of the individual network levels and areas
  - Total of all losses or excesses of leakages
  - Minimum pressure in the network, maximum flow velocity
  - Transferred volume between the defined network areas
- Network tracing at nodes
  - Determination of the delivered quantities from the different supplies to the selected node
  - Determination of the flow time from the individual supplies up to the selected node
- Display of hydraulic head diagrams along any route in the network
  - Freely definable routes for the determination of hydraulic head diagrams, automatic generation of the corresponding diagram
  - Display of relative or absolute flow pressure, steam pressure, temperature and hydraulic head
  - Display of the values over the distance of the selected nodes

Heating/Cooling - Operating/Time Series (FL)

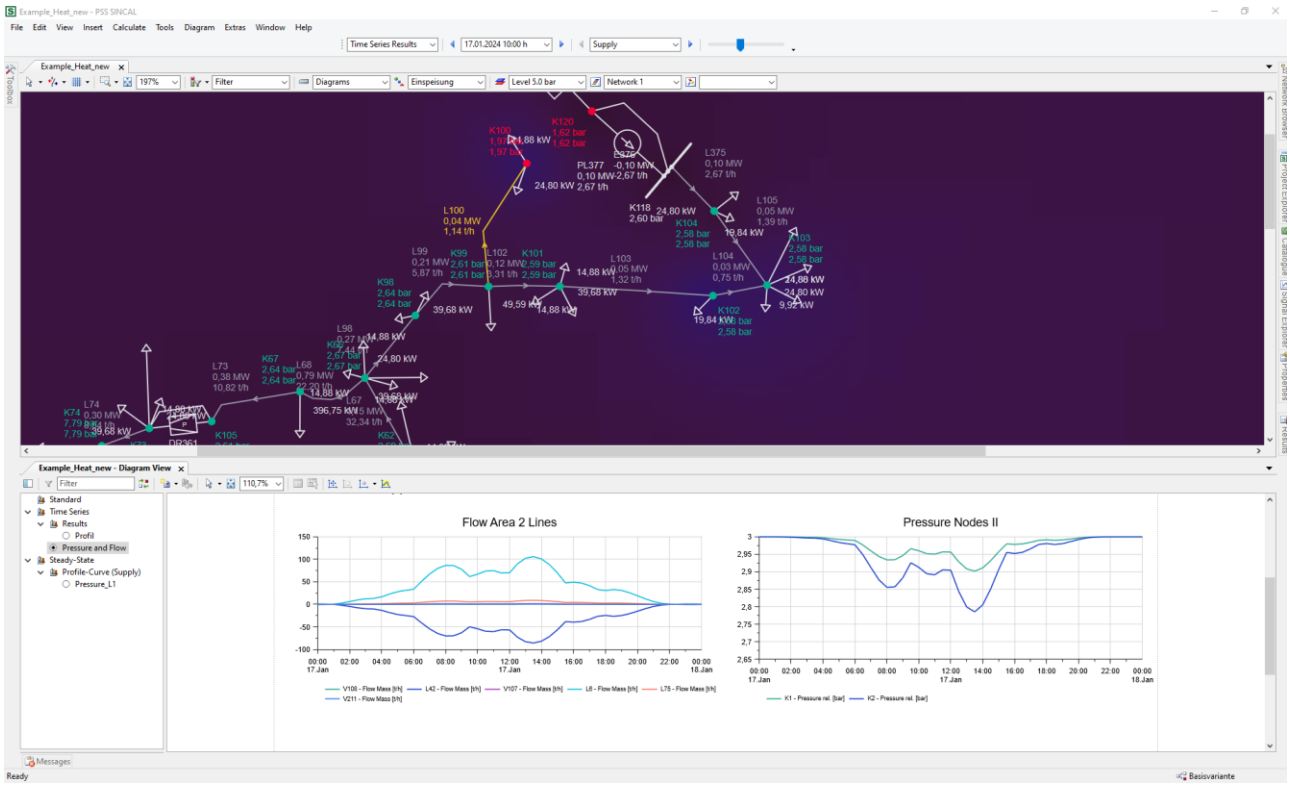


Figure 92: Time series calculation in a district heating network

Requirements

Many individual steady-state calculations are required to analyze the effects of changes in operating state in relation to temperatures, consumption patterns and valve states of the heating or cooling network over a historical or predicted period.

A validation of a planning model with measured values is also required but also the determination of energy and volume quantities, as well as losses over short, medium or long-term periods.

- Analysis of the daily and seasonal dependent pressure conditions in the network based on historical operation with measured data
- Refinement and validation of the network model (calibration)
- Analysis of increase and reduction rates of supply or consumption in medium and long-term forecast periods
- Determination of average and extreme values
- Determination of transported quantities and losses over a selected period

Solution

Based on a network model for steady-state calculations, PSS®SINCAL enables quasi-dynamic time series calculations (FL) over a time period or at specific operating points.

- Calculation of user-defined operating points and operating states
- Time series calculation based on steady-state calculations with user-defined time step
- Calculation based on user-defined increase rates
- Calculation with meter data and measured values determined during operation

Modeling and calculation

Advanced modeling options and parameters are available for extending a network model with time series or operating points for calculation.

- Calculation of operating points to represent stationary operating states of the network
  - Definition of any number of steady-state operating points with multiplication factors for the rated values/states of the elements to represent typical operating states of the network
  - Modelling of global or regional simultaneity
  - Individual assignment of the operating points to the respective elements or global assignment for the individual network levels

    - Calculation of all operating points with steady-state calculation for each individual operating point as an operating series
- Time series calculation based on steady-state calculations to simulate operating states in time periods of minutes, hours up to several days or years
    - Individual definition or import of factor profiles with user-defined time step
    - Cyclical handling of profiles
    - Individual assignment of the time series/profiles to the respective elements or global assignment for the individual network levels
    - Time step (interval between the individual stationary points in time) can be set user defined
    - Steady-state calculation at all points in time within the simulation period
- Calculation based on user-defined increase rates to simulate operating states for the long-term (several years) periods
    - Definition of any number of increase profiles with multiplication factors for the rated values/states of the elements to model changes of generation and consumption over the long term
    - Individual assignment of the increase rates to the respective elements or global assignment for the individual network levels
    - Calculation of the selected point in times at which changes result from the defined increase or consumption
- Simulation of snapshots and time series with time series data located in an open and generic external database (e.g. metering or forecasting data) with the time series data interface (module TSDI) without additional transfer of input data

Results and evaluation options

The program provides the following options for evaluating the results.

- Provision of the results for the elements for each calculated point in time in graphics, table and database as well as other result views and reports
- Automatically calculated average, maximum and minimum values
- Display of the results in user-defined diagrams over the calculation period

Heating/Cooling - Contingency Analysis (FCA)

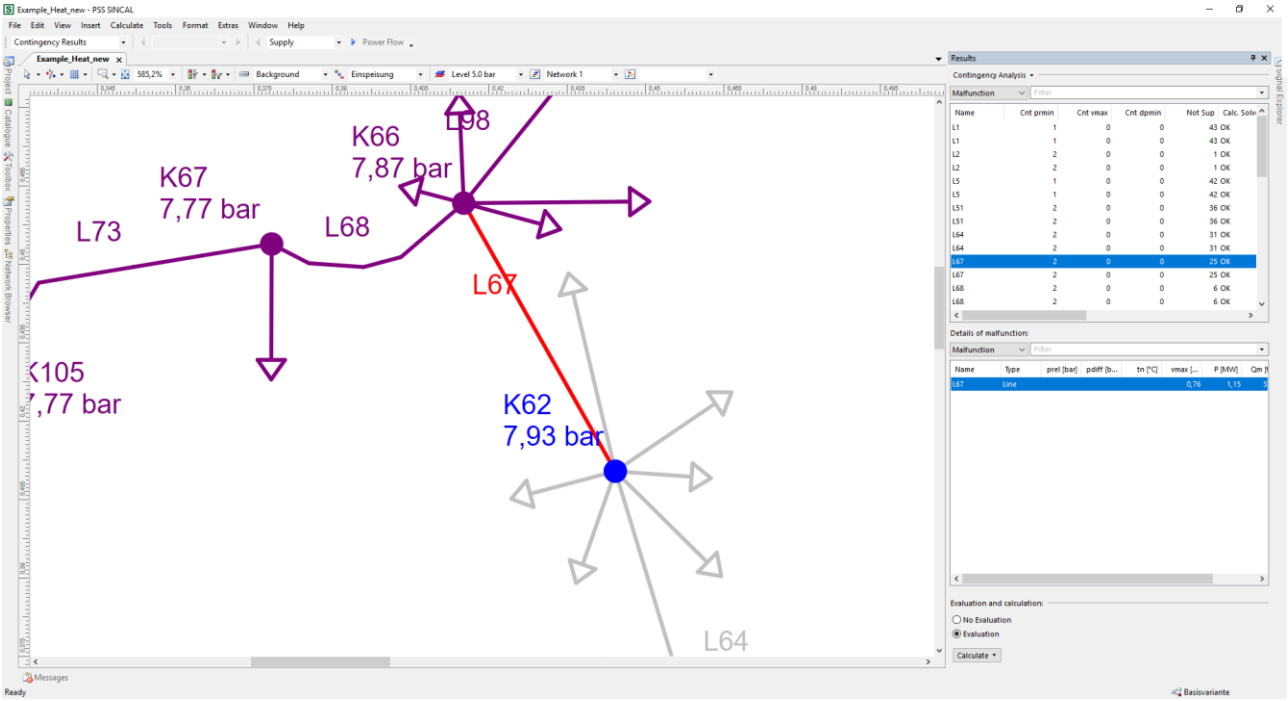


Figure 93: Analysis of the effects of a pipe malfunction (or maintenance) in the network graphic

Requirements

In order to increase the reliability of the heating or cooling supply and the operational safety of the network, it is useful to analyze the effects of malfunctions, contingencies and planned maintenance measures at individual elements or of entire element groups.

- Assessment of the flow conditions in case of malfunction (or maintenance) of individual network elements and generators as well as the caused malfunction of further elements due to the fault
- Consideration of all possible malfunction combinations or specific analysis of the malfunction of elements groups
- Analysis of the operational safety and analysis of weak points in the network as well as the derivation of countermeasures to increase the security of supply and reliability
- Determination of suitable network nodes for emergency supplies

Solution

The structured combinatorial generation and calculation of all configurations is possible with the module for contingency analysis (FCA) and is based on the high-performance calculation of individual stationary conditions.

- Automatic generation of all possible malfunction combinations in the network and consideration of user-defined groups
- Steady-state calculation for each combination, considering the elements that failed unconditionally as well as conditional malfunctions (caused malfunctions) that occur during the calculation according to defined conditions

Modeling

- The user has the possibility to define function and malfunction groups in order to consider typical malfunctions, where several elements in a network fail or are switched off at the same time.
- User-defined malfunction groups for elements that are considered together
- User-defined function groups that are only in operation together
- Setting of the malfunctions individually for the network areas

Calculation

The malfunction calculation generates all possible malfunction scenarios and those that are user-defined and calculates each one in a stationary condition. The network model is only changed during the individual calculation iterations and is unchanged after the calculation.

- Automatic generation of all combinatorically possible malfunction combinations
  - Malfunction of the individual elements
  - Malfunction of all elements, excluding the pipes or elements where limit violations occur
  - Consideration of function and malfunction groups
- Automatic steady-state calculation of all individual combinations after analysis start
  - Unconditional combinatorial or user-defined generated malfunctions as the initial state for the calculation
  - Conditional further malfunctions (caused malfunctions) of elements when a user-defined flow rate is exceeded during the calculation

Results and evaluation options

The program provides the following options for evaluating the results.

- Display of malfunction combinations in the result browser for contingency analysis
  - Detailed information about the failure in tree structure
  - Elements at which limit values are violated, unsupplied elements, connected and disconnected elements as well as elements at which the maximum values of the results are obtained
  - Localization, marking and editing in the network graphic
- Display of the results by color coding
- Results in tabular view in the results view with direct link to the graphical view, filter functions as well as options for generating reports and exporting the results

Network Planning Tools (Pipe Networks)

Network Planning Tools

The network planning tools of PSS®SINCAL provide extended functions for pipe networks to support various planning and evaluation tasks in the network model.

- Modeling tools for fast and systematic manual modeling in the network graphic
- Route calculations to determine shortest or optimized routes between nodes in the network
  - Shortest route
  - Shortest route following the maximal pipe diameters
- Functions for determining the pipe or route data (e.g. pipe volume) of the selected network elements
- Functions for automatic disconnection or merging of pipes

Model Management – GIS Interfaces

Smallworld GIS – PSS®SINCAL Interface

provided by Mettenmeier

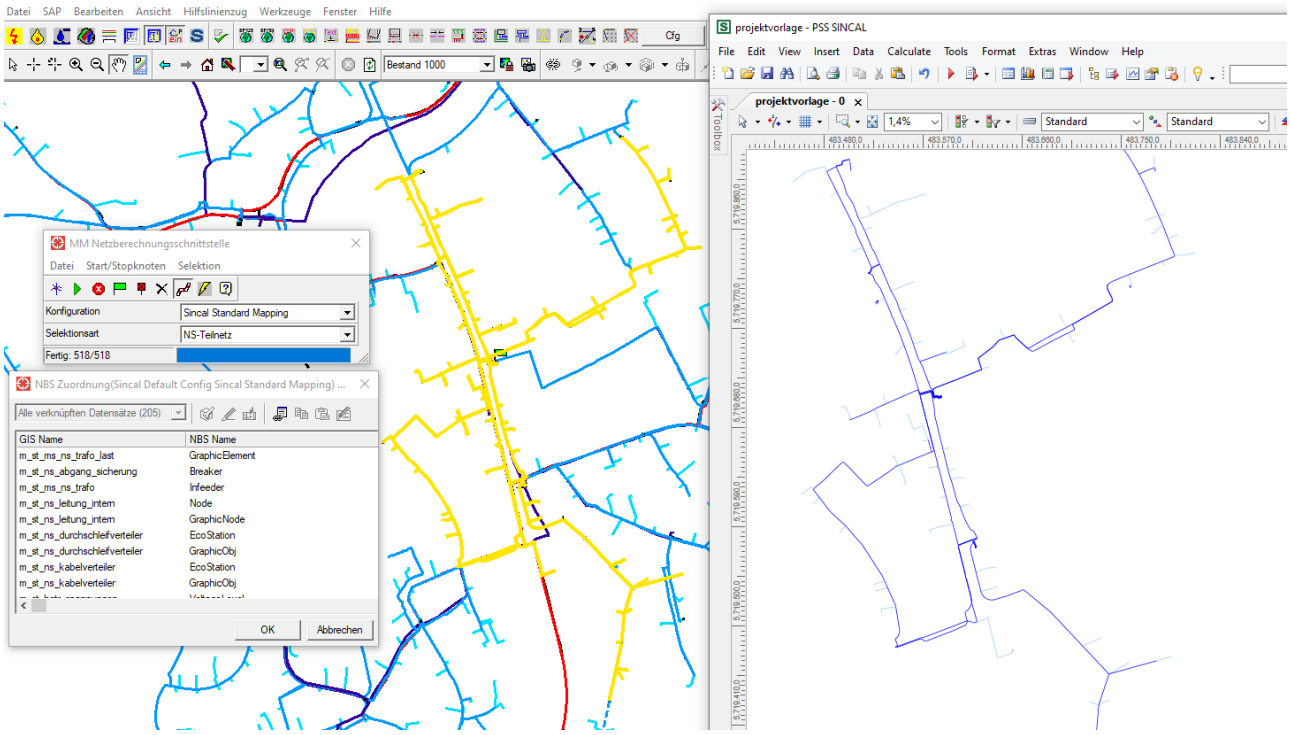


Figure 94: Smallworld GIS – PSS®SINCAL Interface

Requirements

The GIS offers enormous support within the entire planning process. The core task of the GIS is the acquisition and maintenance of extensive and complex network data.

With a consistent topological representation of the network, from network infeeders to consumer or DER connection points, the grid simulation and analysis is supported by the GIS.

- Alignment of data streams and workflows between the GIS and the grid simulation tool to reduce time consuming and redundant manual data cleaning and conversion tasks to a minimum (model continuity)
- Conversion of Smallworld GIS NRM network data to a PSS®SINCAL network model with a flexible and customized configuration

Solution

The Mettenmeier Smallworld™ GIS PSS®SINCAL interface enables the transfer of the Smallworld GIS NRM data into PSS®SINCAL projects without media changes. This is achieved by the following features:

- Interface is based on a mature interface framework which is integrated as a tool into the Smallworld GIS application.
- Customizable configuration of the interface in the Smallworld application UI with the possibility to integrate Smallworld Magik code
- Direct conversion of the Smallworld data into a PSS®SINCAL network model without transformation into other intermediate formats such as CIM or Shape

GIS data requirements

The following requirements exist with respect to the implemented GIS system:

- GIS NRM data must be topologically correct (TN-status OK) and traceable
- GIS NRM data must provide either technical data or type information e.g. line types
- Selection and preparation of the Smallworld GIS NRM data
- Mapping of the Smallworld GIS NRM database into the target data structures of PSS®SINCAL

Functions

The interface is provided as a plug-in in the GIS system with an own UI and offers the following functionalities among others:

- Automatic network tracing in the GIS database according to a defined selection variant
- Preparation and refinement of the network data, also generation of data not available in the GIS

- Configuration with GIS tools
- Generation and transfer of object and geometry data into a PSS®SINCAL network model including unit and coordinate transformation
- Transfer of maps, e.g. overview map, schematic map, stations' internals into the PSS®SINCAL network graphics
- Error logging and interactive error handling in the GIS editor
- Ability to automate the interface engine

Results and evaluation options

The interface generates ready-to-use PSS®SINCAL network models corresponding to the network selected in the GIS. By opening the PSS®SINCAL network model the data can then directly be edited without an explicit import process

MIF – PSS®SINCAL Interface

(MIF2SIN)

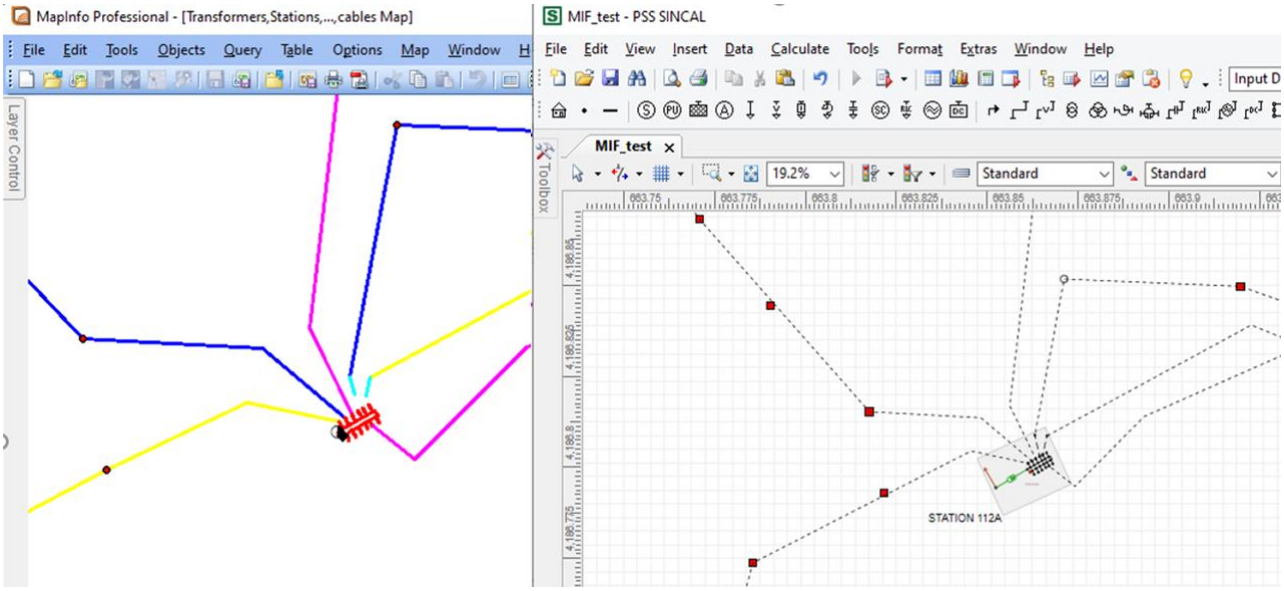


Figure 95: MIF – PSS®SINCAL Interface

Requirements

MapInfo Interchange Format (MIF) is an ASCII based map and database export format of MapInfo and other GIS systems. It can therefore serve as data basis for a network model for grid simulation use cases.

- Import of MapInfo Interchange Format (MIF) based network models with a flexible and customized configuration
- Alignment of data streams and workflows between the GIS and the grid simulation tool to reduce time consuming manual data cleaning and conversion tasks to a minimum
- Reuse of geographical information for topology creation

Solution

The MIF-PSS®SINCAL interface (MIF2SIN) creates a PSS®SINCAL network model based on the graphical structure of the MIF data.

- Interface as an add-on application with an own graphical user interface to launch, configure and start the network model creation
- Fully automated creation of a topological and graphical PSS®SINCAL network model based on the parsed MIF data (element coordinates)
- Customization of data conversion rules (*.xml-based) with user-defined parameters and options
- Capability to integrate customized plug-ins to extend the functionality

GIS data requirements

The interface requires certain file types as well as specific type and quality of the GIS data export for the later PSS®SINCAL network model creation. Real utility GIS solutions may have different data models, but the following properties are preconditioned:

- Existence of “Graphical topology”
- Line/Polyline layers representing cables and overhead lines
- Symbol type layers representing node type elements (busbars, stations, transformers, breakers, protection devices, etc.)
- Data objects with additional linked technical data
- MIF export file pair with *.mid and *.mif extension

Functions

The configuration of the interface is necessary for the first setup of the interface. Only if additional data types are inserted into the GIS system or shall be used the configuration has to be adapted later.

- Mapping of source data with the object type definition (from *.xml parameter file) to the attributes of the PSS®SINCAL network elements
- Conversion rules in *.xml parameter file

After configuration of the interface the model creation is automatically performed. The interface application creates the network topology (element connections) based on the elements’ coordinates (e.g. if two lines have the same end position, the lines will be connected to each other in the PSS®SINCAL network model). In addition, as well the network graphic for the network model is created.

- Creation of network topology and network graphic
- Completion of network topology with additional nodes for lacking node elements at the line's end position in MIF
- Add-on functionalities for automated substation model creation as well as splitting, merging, and smoothing of lines:
  - Substation creation from source data
  - Merging of station objects into one station node with option to trigger the creation by the size of the station
  - Magnifying station graphic
  - Splitting of complex lines, merging of lines with similar line type, deletion of orphan lines
  - Line smoothing with an angle limit of line's buckle positions differing from the straight direction
- User defined default values and graphical representation
- Capability to integrate customized plug-ins to extend the functionality

Results and evaluation options

The result of the automated creation is a PSS®SINCAL network model containing the topology and graphic.

- Database system SQLite or MS Access
- New line types inserted into the linked PSS®SINCAL standard type database
- Optional error and/or log file creation with error messages indicating serious functional problems and warning messages for not serious problems
- Optional log file creation with:
  - Information about the software and hardware environment of the application
  - GUI parameters
  - Summary information about internal processes
  - Summary information about the inserted elements
  - Number of errors and warnings
  - Process duration

ESRI ArcMap – PSS®SINCAL Interface

(ArcMap2SIN)

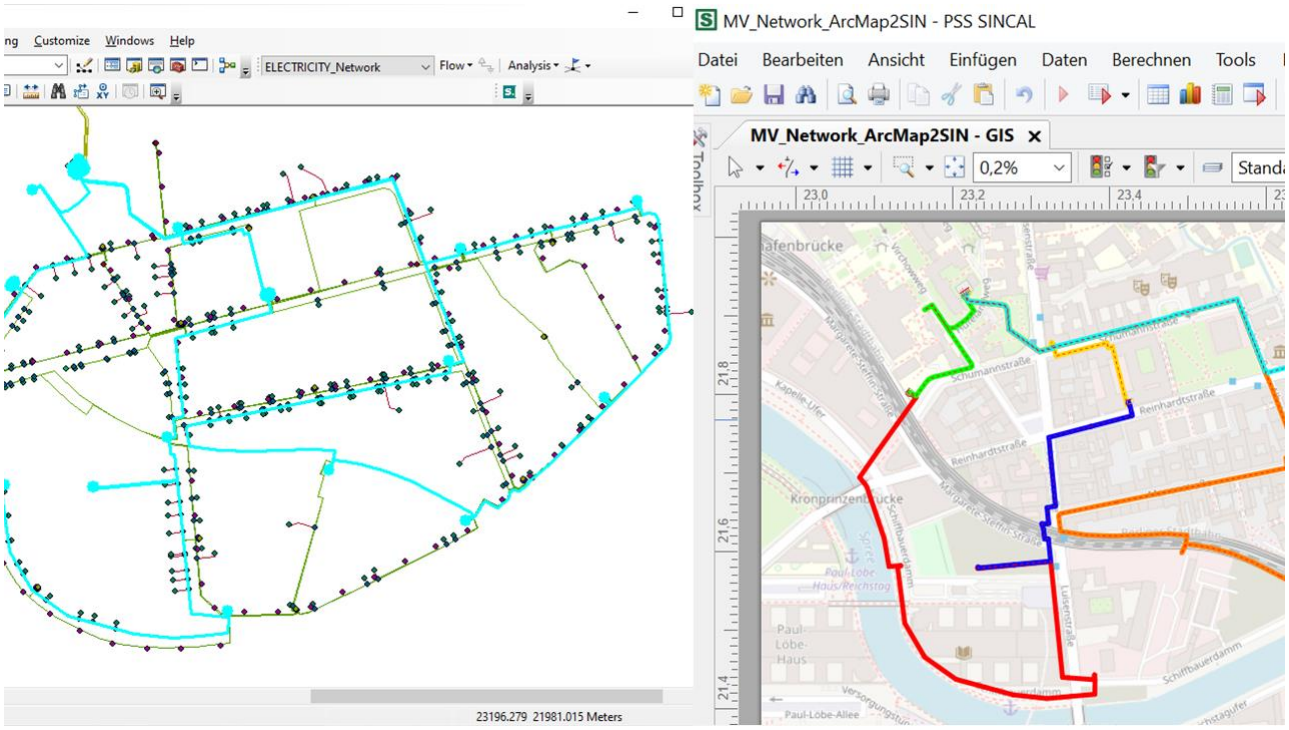


Figure 96: ESRI ArcMap – PSS®SINCAL Interface

Requirements

ESRI ArcMap as a GIS system can serve as data basis for a network model for grid simulation use cases.

- Model conversion from GIS system to network model with flexible and customizable configuration
- Alignment of data streams and workflows between the GIS and the grid simulation tool to reduce time consuming manual data cleaning and conversion tasks to a minimum
- Reuse of geographical information for model creation

Solution

ESRI ArcMap – PSS®SINCAL standard interface is an extension (plug-in) within ESRI ArcMap.

- Application as plug-in in the ArcMap graphical user environment with toolbar and icon
- Partial conversion of selected network areas in the GIS selection (based on the ordinary GIS network selection mode)
- Network topology based on ESRI Geometric Network
- Customization of data conversion rules (*.xml-based) with user-defined parameters and options

GIS data requirements

The interface requires certain data format as well as specific type and quality of the GIS data for the later PSS®SINCAL network model creation. Real utility GIS solutions may have different data models, but the following properties are preconditioned:

- Network objects must be connected to Geometric Network
- Line/Polyline layers representing cables and overhead lines
- Symbol type layers representing node type elements (busbars, stations, transformers, breakers, protection devices, etc.)
- Data objects with additional linked technical data

Functions

The configuration of the interface is necessary for the first setup of the interface. Only if additional data types are inserted into the GIS system or shall be used, the configuration must be adapted.

- Mapping of source data with the object type definition (from *.xml parameter file) to the attributes of the PSS®SINCAL network elements
- Conversion rules in *.xml parameter file

After configuration of the interface the model creation is automatically performed. The interface application creates

the network topology (element connections) based on Geometric Network.

Beyond the one-to-one data conversion, the interface has the following functionalities:

- Partial conversion of only selected network areas in the GIS selection (based on the ordinary GIS network selection mode)
- Transform symbol-based GIS transformer objects into branch-based PSS®SINCAL transformer objects
- Default load element creation at the seconder side of distribution transformers
- Creation of complex busbar structures if the target busbar shape is a polyline (and not a straight line)
- Automatic standard type creation (line, cable, and transformer types) in a PSS®SINCAL standard type database
- Merging of similar lines
- Magnify station graphic representation
- Storage of GIS IDs in PSS®SINCAL Master Resource

Results and evaluation options

The result of the automated creation is a PSS®SINCAL network model containing the topology and graphics.

- Database system SQLite or MS Access
- New line, cable and transformer types inserted into the linked PSS®SINCAL standard type database
- Optional error and/or log file creation with error messages indicating serious functional problems and warning messages for not serious problems
- Optional log file creation with:
  - Information about the software and hardware environment of the application
  - GUI parameters
  - Summary information about internal processes
  - Summary information about the inserted elements
  - Number of errors and warnings
  - Process duration

ESRI ArcGIS Pro Utility Network (UN) JSON – PSS®SINCAL Interface

(AGProJSON2SIN)

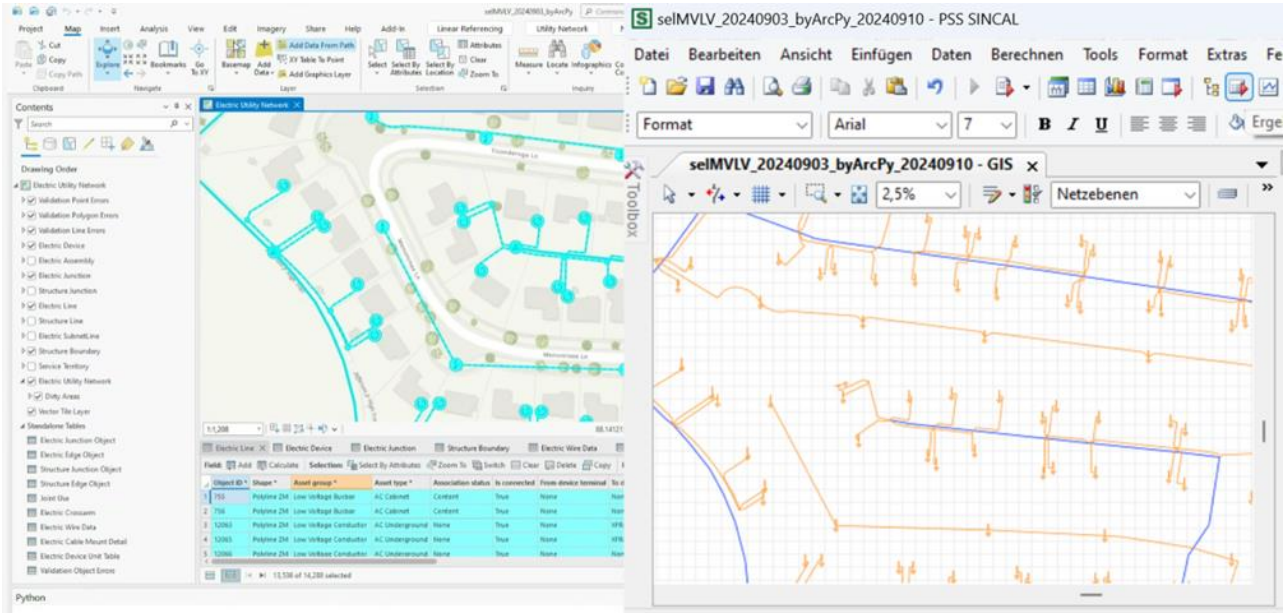


Figure 97: ESRI ArcGIS Pro UN JSON – PSS®SINCAL Interface

Requirements

ESRI ArcGIS Pro as a GIS system together with the Utility Network as a functionality framework, can serve as data basis for a network model for grid simulation use cases.

- Model conversion from GIS system (UN) to network model with flexible and customizable configuration
- Alignment of data streams and workflows between the GIS and the grid simulation tool to reduce time consuming manual data cleaning and conversion tasks to a minimum
- Reuse of geographical information for model creation

Solution

ESRI ArcGIS Pro UN JSON – PSS®SINCAL standard interface (AGPROJSON2SIN) creates a PSS®SINCAL network model based on the UN trace export to JSON file.

- Interface as an add-on application with an own graphical user interface to launch, configure and start the network model creation
- Network topology based on the UN network connectivity exported to JSON file
- Customization of data conversion rules (*.xml-based) with user-defined parameters and options
- Capability to integrate customized plug-ins to extend the functionality

GIS data requirements

The interface requires certain data format as well as specific type and quality of the GIS data for the later PSS®SINCAL network model creation. Real utility GIS solutions may have different data models, but the following properties are preconditioned:

- The JSON file containing the UN trace export must contain:
  - Feature elements and needed feature attributes
  - Connectivity
  - Associations
  - Graphical representation
- Electric lines representing cables and overhead lines
- Electric devices representing transformers, breakers, feeders, consumers, etc.

Functions

The configuration of the interface is necessary for the first setup of the interface. Only if additional data types are inserted into the GIS system or shall be used, the configuration must be adapted.

- Mapping of source data with the object type definition (from *.xml parameter file) to the attributes of the PSS®SINCAL network elements
- Conversion rules in *.xml parameter file

After configuration of the interface, the model creation is automatically performed. The interface application creates the network topology (element connections) based on UN connectivity, present in the JSON trace export.

Beyond the one-to-one data conversion, the interface has the following functionalities:

- Transform symbol-based GIS transformer objects into branch-based PSS®SINCAL transformer objects
- Default load element creation at the seconder side of distribution transformers
- Creation of complex busbar structures if the target busbar shape is a polyline (and not a straight line)
- Automatic standard type creation (line, cable, and transformer types) in a PSS®SINCAL standard type database
- Merging of similar lines
- Storage of GIS IDs in PSS®SINCAL Master Resource

Results and evaluation options

The result of the automated creation is a PSS®SINCAL network model containing the topology and graphics.

- Database system SQLite or MS Access
- New line, cable and transformer types inserted into the linked PSS®SINCAL standard type database
- Optional error and/or log file creation with error messages indicating serious functional problems and warning messages for not serious problems
- Optional log file creation with:
  - Information about the software and hardware environment of the application
  - GUI parameters
  - Summary information about internal processes
  - Summary information about the inserted elements
  - Number of errors and warnings
  - Process duration

ESRI Shape – PSS®SINCAL Interface (Electrical)

(SHP2SIN)

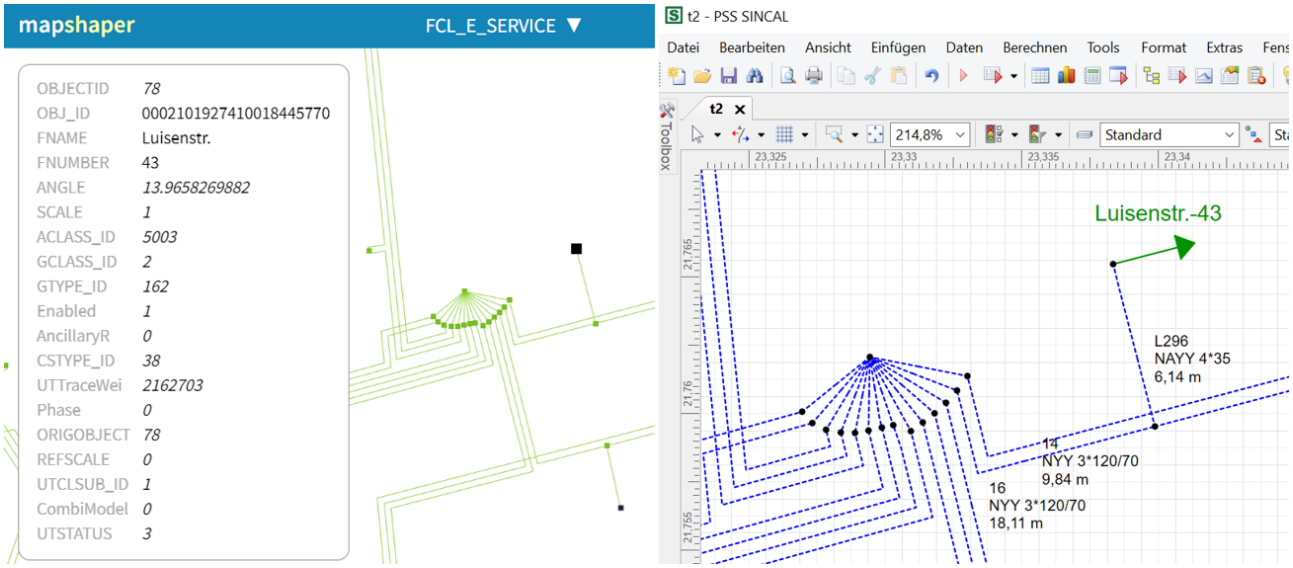


Figure 98: ESRI Shape – PSS®SINCAL Interface (Electrical)

Requirements

The ESRI Shape format is defined and maintained by ESRI. The format structure is open and supported by many applications. It can therefore serve as data basis for a network model for grid simulation use cases.

- Import of ESRI Shape based network models with a flexible and customized configuration
- Alignment of data streams and workflows between the GIS and the grid simulation tool to reduce time consuming manual data cleaning and conversion tasks to a minimum
- Reuse of geographical information for topology creation

Solution

The ESRI Shape – PSS®SINCAL standard interface (SHP2SIN) creates a PSS®SINCAL network model based on the graphical structure of the ESRI Shape data.

- Interface as an add-on application with an own graphical user interface to launch, configure and start the network model creation
- Fully automated creation of a topological and graphical PSS®SINCAL network model based on parse ESRI Shape data (element coordinates)
- Customization of data conversion rules (*.xml-based) with user-defined parameters and options
- Capability to integrate customized plug-ins to extend the functionality

GIS data requirements

The interface requires certain file types as well as specific type and quality of the GIS data export for the later PSS®SINCAL network model creation. Real utility GIS solutions may have different data models, but the following properties are preconditioned:

- ESRI Shape file structure must be complete
- Existence of “Graphical or stored topology”
- Line/Polyline layers representing cables and overhead lines
- Symbol type layers representing node type elements (busbars, stations, transformers, breakers, protection devices, etc.)
- Data objects with additional linked technical data

Functions

The configuration of the interface is necessary for the first setup of the interface. Only if additional data types are inserted into the GIS system or shall be used, the configuration has to be adapted.

- Mapping of source data with the object type definition (from *.xml parameter file) to the attributes of the PSS®SINCAL network elements
- Conversion rules in *.xml parameter file

After configuration of the interface the model creation is automatically performed. The interface application uses the stored topology from the source database or creates the network topology (element connections) based on the elements’ coordinates (e.g. if two lines have the same end position, the lines will be connected to each other in the

PSS®SINCAL network model). In addition, as well the network graphics for the network model are also created.

- Creation of network topology and network graphic
- Completion of network topology with additional nodes for lacking node elements at the line's end position in ESRI Shape
- Add-on functionalities for automated substation model creation as well as splitting, merging, and smoothing of lines:
  - Substation creation from source data
  - Merging of station objects into one station node with option to trigger the creation by the size of the station
  - Magnifying station graphic
  - Splitting of complex lines, merging of lines with similar line type, deletion of orphan lines
  - Line smoothing with an angle limit of line's buckle positions differing from the straight direction
- User defined default values and graphical representation
- Capability to integrate customized plug-ins to extend the functionality

Results and evaluation options

The result of the automated creation is a PSS®SINCAL network model containing the topology and graphics.

- Database system SQLite or MS Access
- New line types inserted into the linked PSS®SINCAL standard type database.
- Optional error and/or log file creation with error messages indicating serious functional problems and warning messages for not serious problems
- Optional log file creation with:
  - Information about the software and hardware environment of the application
  - GUI parameters
  - Summary information about internal processes
  - Summary information about the inserted elements
  - Number of errors and warnings
  - Process duration

ESRI Shape – PSS®SINCAL Interface (Pipe)

(SHP2SINFlow)

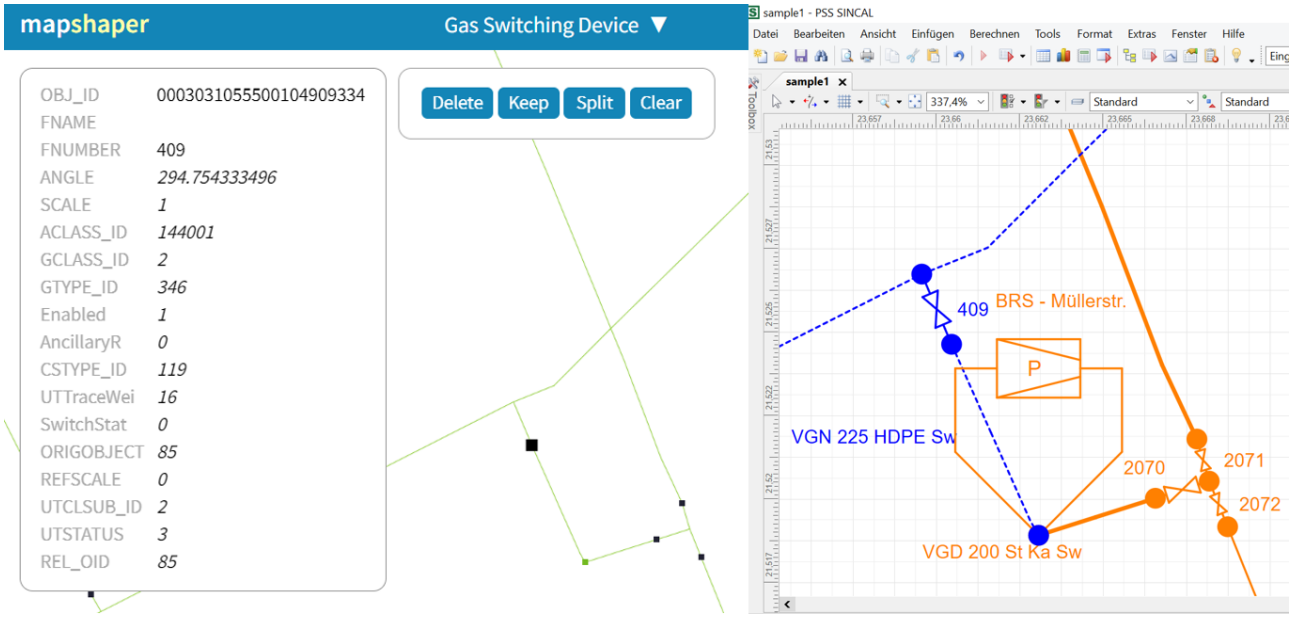


Figure 99: ESRI Shape – PSS®SINCAL Interface (Pipe)

Requirements

The ESRI Shape format is defined and maintained by ESRI. The format structure is open and supported by many applications. It can therefore serve as data basis for a pipe (gas, heating/cooling, water) network model for simulation use cases.

- Import of ESRI Shape based pipe network models with a flexible and customized configuration
- Alignment of data streams and workflows between the GIS and the grid simulation tool to reduce time consuming manual data cleaning and conversion tasks to a minimum
- Reuse of geographical information for topology creation

Solution

The ESRI Shape – PSS®SINCAL standard interface (SHP2SINFlow) creates a PSS®SINCAL pipe network model based on the graphical structure of the ESRI Shape data.

- Interface as an add-on application with an own graphical user interface to launch, configure and start the network model creation
- Fully automated creation of a topological and graphical PSS®SINCAL network model (gas, heating/cooling, water) based on parse ESRI Shape data (element coordinates)
- Customization of data conversion rules (*.xml-based) with user-defined parameters and options
- Capability to integrate customized plug-ins to extend the functionality

GIS data requirements

The interface requires certain file types as well as specific type and quality of the GIS data export for the later PSS®SINCAL network model creation. Real utility GIS solutions may have different data models, but the following properties are preconditioned:

- ESRI Shape file structure must be complete
- Existence of “Graphical topology”
- Line/Polyline layers representing pipes
- Symbol type layers representing node type elements (pressure regulators, pressure buffers, valves, leakages, etc.)
- Data objects with additional linked technical data

Functions

The configuration of the interface is necessary for the first setup of the interface. Only if additional data types are inserted into the GIS system or shall be used the configuration has to be adapted.

- Mapping of source data with the object type definition (from *.xml parameter file) to the attributes of the PSS®SINCAL network elements
- Conversion rules in *.xml parameter file

After configuration of the interface the model creation is automatically performed. The interface application creates the network topology (element connections) based on the elements’ coordinates (e.g. if two pipes have the same end position, the pipes will be connected to each other in the PSS®SINCAL network model). In addition, as well the network graphics for the network model are also created.

- Creation of network topology and network graphic
- Completion of network topology with additional nodes for lacking node elements at the line's end position in ESRI Shape
- Add-on functionalities for model creation
  - Magnifying station graphic
  - Splitting of complex pipes, merging of pipes with similar pipe type, deletion of orphan pipes
  - Line smoothing with an angle limit of line's buckle positions differing from the straight direction
- User defined default values and graphical representation
- Capability to integrate customized plug-ins to extend the functionality

Results and evaluation options

The result of the automated creation is a PSS®SINCAL network model containing the topology and graphics.

- Database system SQLite or MS Access
- New pipe types inserted into the linked PSS®SINCAL standard type database
- Optional error and/or log file creation with error messages indicating serious functional problems and warning messages for not serious problems
- Optional log file creation with:
  - Information about the software and hardware environment of the application
  - GUI parameters
  - Summary information about internal processes
  - Summary information about the inserted elements
  - Number of errors and warnings
  - Process duration

Spatial Database – PSS®SINCAL Interface
(SPDB2SIN)

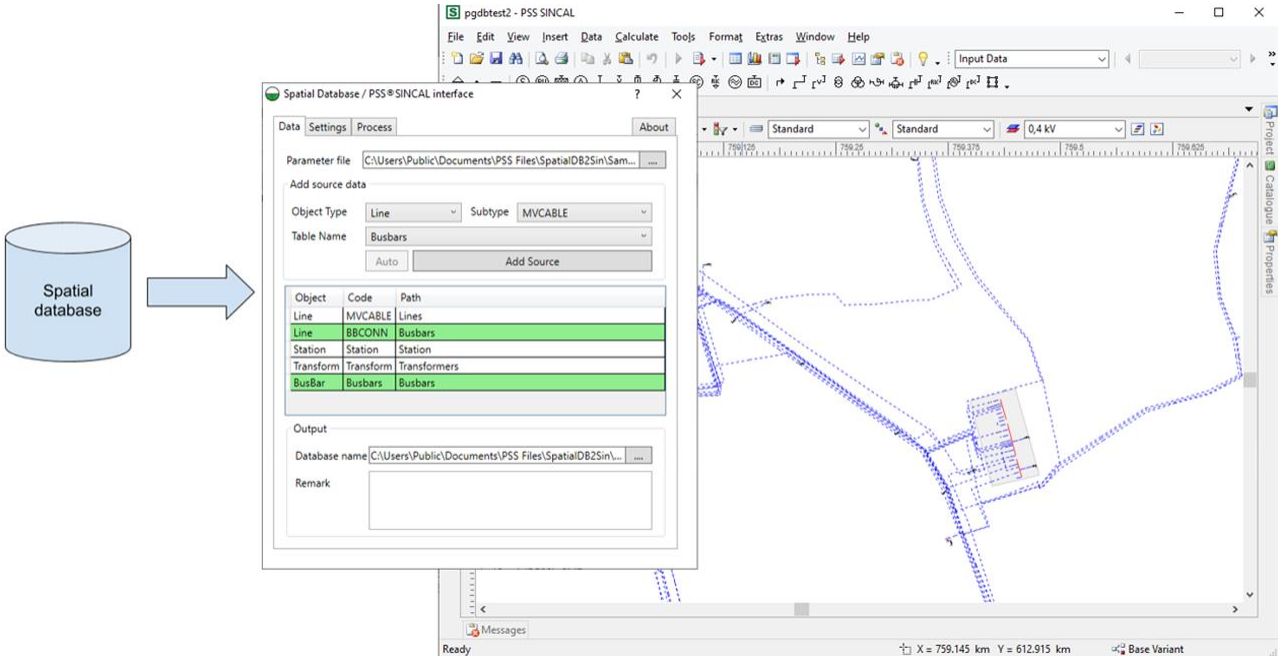


Figure 100: Spatial Database – PSS®SINCAL Interface

Requirements

Several RDBMS (Relational Data Base Management Systems) support the storage of spatial data natively and the connected software can use this feature to store graphical representation of the objects. In this case the data tables have a special column type for the geometry (the geographical network representation).

- Import of data from spatial databases, like
  - Oracle Spatial
  - PostgreSQL/PostGIS
  - ESRI Personal Geodatabase
  - ESRI File Geodatabase
- Alignment of data streams and workflows between the GIS and the grid simulation tool to reduce time consuming manual data cleaning and conversion tasks to a minimum
- Reuse of geographical information for topology creation

Solution

The Spatial Database – PSS®SINCAL standard interface (SPDB2SIN) creates a PSS®SINCAL network model based on the graphical structure of spatial database. The main features are:

- Interface as an add-on application with an own graphical user interface to launch, configure and start the network model creation
- Fully automated creation of a topological and graphical PSS®SINCAL network model based on sparse ESRI Shape data (element coordinates)
- Customization of data conversion rules (*.xml-based) with user-defined parameters and options
- Capability to integrate customized plug-ins to extend the functionality.

GIS data requirements

The interface requires certain file types as well as specific type and quality of the GIS data export for the later PSS®SINCAL network model creation. Real utility GIS solutions may have different data models, but the following properties are preconditioned:

- Proper geometry definition
- Existence of “Graphical or stored topology”
- Line/Polyline layers representing cables and overhead lines
- Symbol type layers representing node type elements (busbars, stations, transformers, breakers, protection devices, etc.)
- Data objects with additional linked technical data

Functions

The configuration of the interface is necessary for the first setup of the interface. Only if additional data types are inserted into the GIS system or shall be used the configuration has to be adapted.

- Mapping of source data with the object type definition (from *.xml parameter file) to the attributes of the PSS®SINCAL network elements
- Conversion rules in *.xml parameter file

After configuration of the interface the model creation is automatically performed. The interface application uses the stored topology from the source database or creates the network topology (element connections) based on the elements' coordinates (e.g. if two lines have the same end position, the lines will be connected to each other in the PSS®SINCAL network model). In addition, as well the network graphics for the network model are also created.

- Creation of network topology and network graphic
- Completion of network topology with additional nodes for lacking node elements at the line's end position in spatial database
- Add-on functionalities for automated substation model creation as well as splitting, merging, and smoothing of lines:
  - Substation creation from source data
  - Merging of station objects into one station node with option to trigger the creation by the size of the station
  - Magnifying station graphic
  - Splitting of complex lines, merging of lines with similar line type, deletion of orphan lines
  - Line smoothing with an angle limit of line's buckle positions differing from the straight direction
  - User defined default values and graphical representation

Results and evaluation options

The result of the automated creation is a PSS®SINCAL network model containing the topology and graphics.

- Database system SQLite or MS Access
- New line types inserted into the linked PSS®SINCAL standard type database
- Optional error and/or log file creation with error messages indicating serious functional problems and warning messages for not serious problems
- Optional log file creation with:
  - Information about the software and hardware environment of the application
  - GUI parameters
  - Summary information about internal processes
  - Summary information about the inserted elements
  - Number of errors and warnings
  - Process duration

Smallworld CIM15 – PSS®SINCAL Interface

(swCIM2SIN)

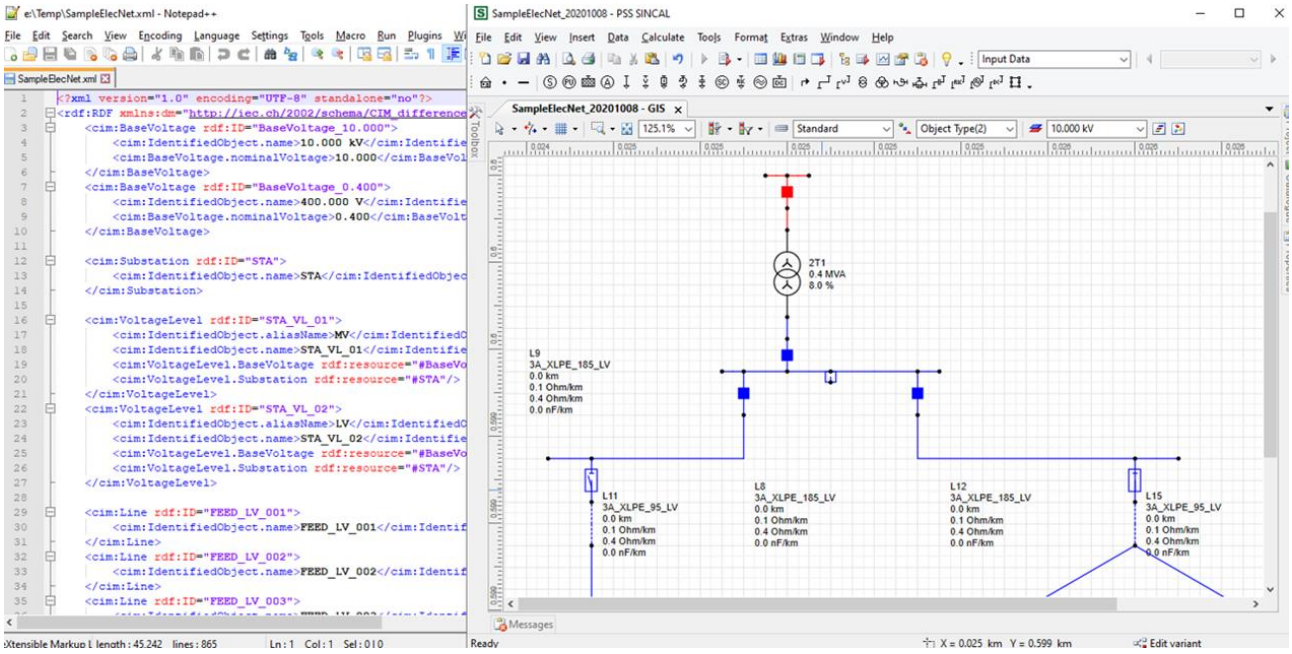


Figure 101: Smallworld CIM15 – PSS®SINCAL Interface

Requirements

The Common Information Model (CIM) is developed as standard data interchange format for electrical networks models in different versions.

GE Smallworld Electric Office application can export its database into CIM 15 format with additional graphic description.

- Import of Smallworld CIM15 based network models with a flexible and customized configuration
- Alignment of data streams and workflows between Smallworld GIS and the grid simulation tool to reduce time consuming manual data cleaning and conversion tasks to a minimum
- Reuse of geographical information for topology creation

Solution

The Smallworld CIM15 – PSS®SINCAL standard interface (swCIM2SIN) creates a PSS®SINCAL network model based on the structure of the exported CIM 15 data.

- Interface as an add-on application with an own graphical user interface to launch, configure and start the network model creation
- Command line mode to enable the background operation
- Fully automated creation of a topological and graphical PSS®SINCAL network model based on CIM 15 data
- Coordinate transformation during the import
- Optional graphic representation transfer from CIM 15 or additional GML

CIM data requirements

The exported CIM 15 data have the following preconditions:

- CIM version is 15
- Created (exported) by Smallworld Electric Office
- Common ID system between CIM XML and GML

Functions

The main options of the conversion are defined in the parameter file (*.xml), which is selected by the user. After configuration of the interface the model creation is automatically performed.

- One or more input source(s) can be chosen for the data conversion process
- Creation of a new PSS®SINCAL network model (database) with the processed data
- The solution offers additional optional functionalities for the import process:
- Reference database definition to setup own default values and graphical representation for the created PSS®SINCAL elements
- Matching of the types (if available in the source data) with the defined types of the PSS®SINCAL standard type database

Results and evaluation options

The result of the automated creation is a PSS®SINCAL network model containing the topology and graphics.

- Database system SQLite or MS Access
- New line types inserted into the linked PSS®SINCAL standard type database
- Optional error and/or log file creation with error messages indicating serious functional problems and warning messages for not serious problems
- Optional log file creation with:
  - Information about the software and hardware environment of the application
  - GUI parameters
  - Summary information about internal processes
  - Summary information about the inserted elements
  - Number of errors and warnings
  - Process duration

Synergi – PSS®SINCAL Interface

(Syn2Sin)

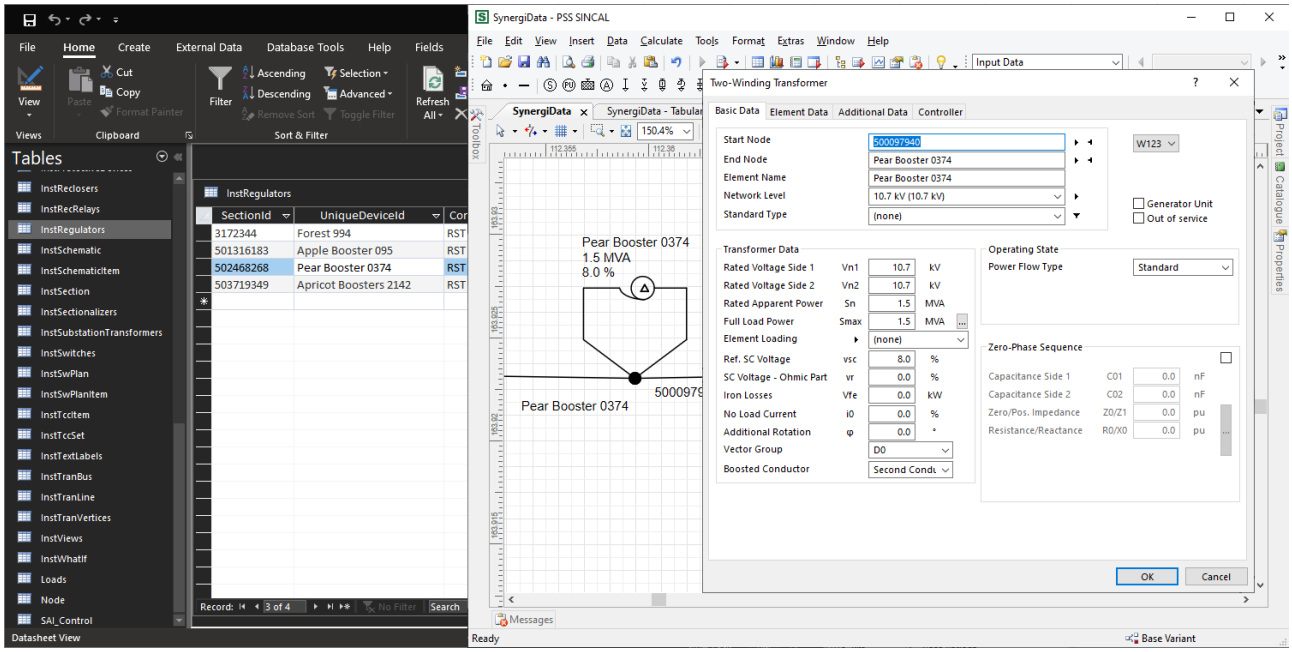


Figure 102: Synergi – PSS®SINCAL Interface

Requirements

Synergi Electric (SynerGEE Electric before) is a network simulation software for power systems among others.

- Import of Synergi network models (MS Access based) with a flexible and customized configuration
- Alignment of data streams and workflows with another grid simulation tool to reduce time consuming manual data capturing and conversion tasks to a minimum
- Leverage the enhanced functionalities of the grid simulation software PSS®SINCAL

Solution

The Synergi – PSS®SINCAL standard interface (SYN2SIN) creates a PSS®SINCAL network model based on the structure of the Synergi data.

- Interface as an add-on application with an own graphical user interface to launch, configure and start the network model creation
- Fully automated creation of a topological and graphical PSS®SINCAL network model based on the parsed Synergi data
- Customization of data conversion rules (*.xml-based) with user-defined parameters and options
- Capability to integrate customized plug-ins to extend the functionality

Synergi data requirements

To assure a smooth import of the Synergi model, the following preconditions are existing:

- Network and warehouse databases required
- Database format MS Access

Functions

The main options of the conversion are defined in the parameter file (*.xml), which must be selected by the user. After configuration of the interface the model creation is automatically performed.

- Data conversion process using a reference database to define user specific default values of the elements and graphic representation
- Conversion of non-metric lengths (Synergi) to metric lengths during the import
- Inbuild rules to handle differences between the Synergi and PSS®SINCAL data modelling convention (e.g. load connection at the branch center)

The current version of the application supports the following additional functionalities:

- Merging rules for lines
  - with similar type
  - at the marked node connection
  - with same name
  - with no opened terminal

    - without added breaker or protection device
- Deletion of orphan lines

The application can be extended with plug-ins for additional functionalities.

Results and evaluation options

The result of the automated creation is a PSS®SINCAL network model containing the topology and graphics.

- Database system SQLite or MS Access
- New line types inserted into the linked PSS®SINCAL standard type database
- Optional error and/or log file creation with error messages indicating serious functional problems and warning messages for not serious problems
- Optional log file creation with:
    - Information about the software and hardware environment of the application
    - GUI parameters
    - Summary information about internal processes
    - Summary information about the inserted elements
    - Number of errors and warnings
    - Process duration

TSDB Manager (Electrical)

(TSDBM)

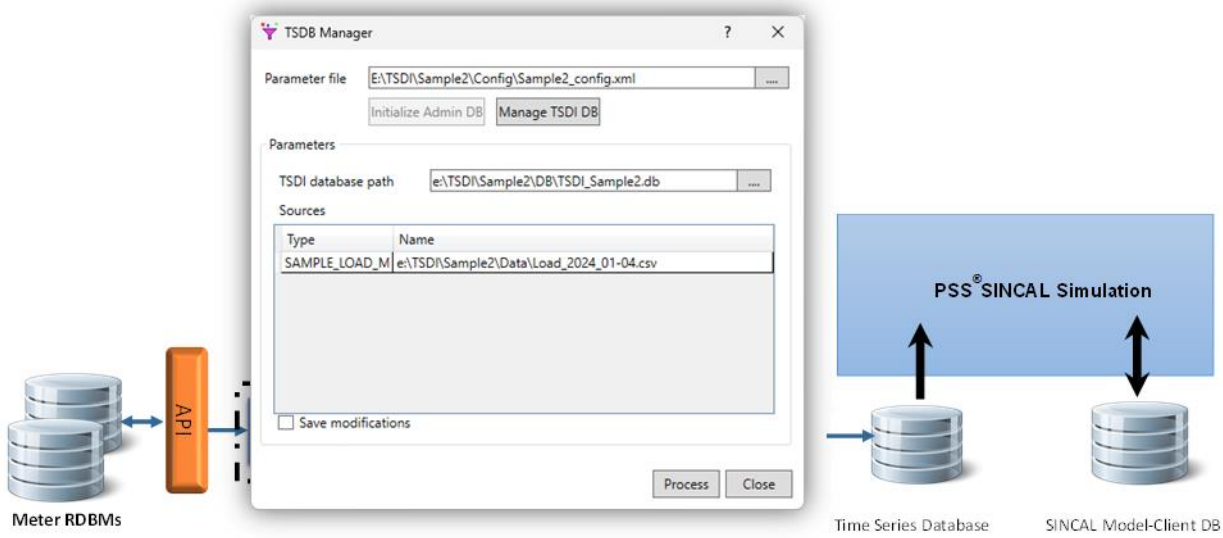


Figure 103: TSDB Manager

Requirements

PSS®SINCAL can use time series databases, which contain measurements of electric network components at certain moments of time for network calculation.

The measurement data can originate from different systems, which can provide different data formats and structures. TSDB Manager transfers these formats and structures to a unified database (SQLite database) which is readable by PSS®SINCAL simulation.

Solution

TSDB Manager is a standalone application, which can start independently from PSS®SINCAL user interface.

The interface has form based and command line-based variants.

The data transfer rules are defined in the parameter file (XML). This file is needed to run the application.

The application creates and uses an administrator database, where information about the transferred data sources is saved. This database helps to follow the data transfer history and to avoid processing the same source file again.

The GUI does not support setting all parameters of the data transfer process, which are saved in the parameter XML.

Source Data Requirements

The current version of the application supports the following input data formats:

- CSV files
- ORACLE database table
- SQL Server database table

There are limitations at the data structure level also. The following structures are supported:

- Daily measurements
- Measurement at certain time
- Measurement place ordered data

Functions

The configuration of the interface is necessary for the first setup of the interface.

The configuration file is in XML format and stores the rules of the data conversion. Filling this file correctly is essential for successful data transfer.

The configuration XML structure supports optionally creating parallel configurations in one XML file, but in this case the command-line version usage is needed; GUI based version does not support this feature.

The data transfer process only inserts new records; never updates any existing records.

The application can combine more measurement values, if all these values are in same processing run (In case of CSV files, this means all related values must be in same CSV file.)

Each data transferring process should extend the time frame of the TSDI database, because dates older than maximal date of the TSDI database will not be processed.

Results and evaluation options

The result of the automated creation is a PSS®SINCAL conform time series database with the transferred measurements in SQLite database format.

- Database system is SQLite
- TSDB manager works with the time series database only and object's ID relation with a PSS®SINCAL database is not checked.
- Optional TSDI database separation by object connection to a station.
- Optional measurement separation by an auxiliary definition (CSV format). [This function is useful, when the measurement data contains aggregated values.]
- Optional ID translation by an auxiliary mapping file (CSV format).
- Optional time frame definition for the TSDI database, which guarantees the maximum difference between the minimum and maximum date in the database. (The measurements are deleted, which are older than latest date minus defined time frame.)

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