ENGINEERING
TOMORROW

VACON 1000

Negative sequence compensation

L3 Webinar

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MV Drives
Overview



Classified as Business

Danfoss MV drives family



VACON® 3000 Drive Kit

A modular MV drive that offers a new dimension of application engineering for industrial applications to our channel partners.

VACON® 3000 Enclosed Drive

Robust, state of the art and ready to run enclosed drive solution for End Customers and EPCs based on the VACON® 3000 Drive Kit.

VACON® 1000 Enclosed Drive

A multi-level variable speed drive for general purpose applications focusing on variable torque loads.

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The VACON® 3000 series

VACON® 3000 Drive Kit



- 340 A - 1230 A
- 2430 - 7060 kVA
- 3300 V, 4160 V
- IP00

VACON® 3000 Enclosed Drive



- 340 A - 1230 A
- 2430 - 7060 kVA
- 3300 V, 4160 V
- IP54

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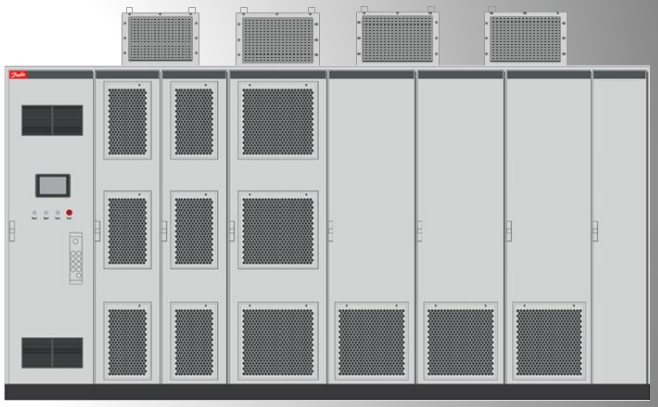
The VACON® 1000 series

VACON® 1000 Stand-alone



- 36 A - 215 A
- 150 - 2570 kVA
- 2300 V...6900 V
- IP31, IP42

VACON® 1000 Line-up



- 230 A - 680 A (36-680 A for 10 and 11 kV)
- 960 - 12[illegible]0 kVA
- 230[illegible]...11000 V
- [illegible]31, IP42

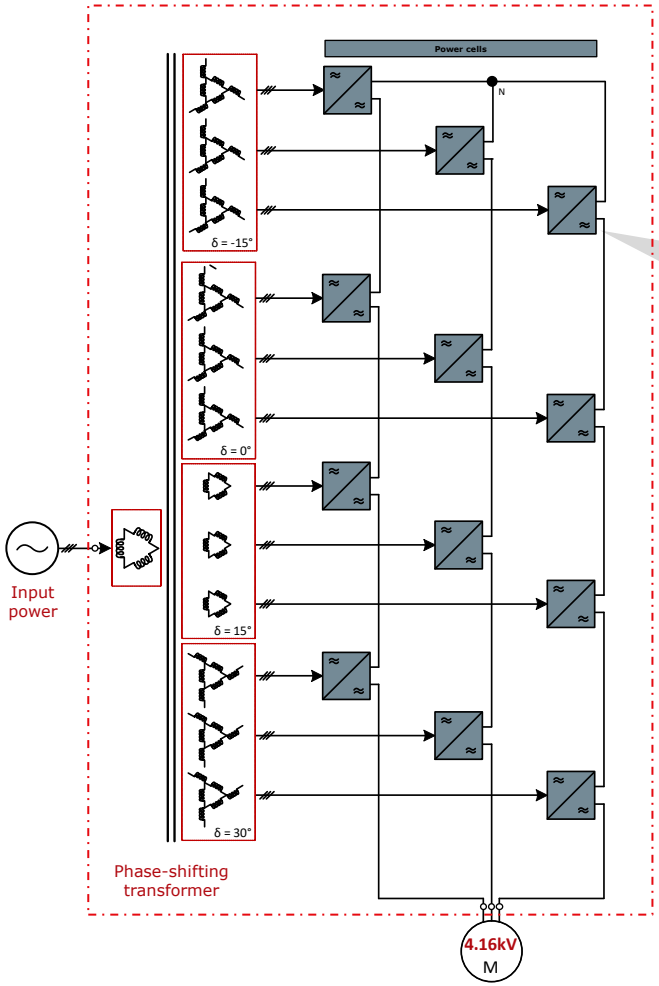
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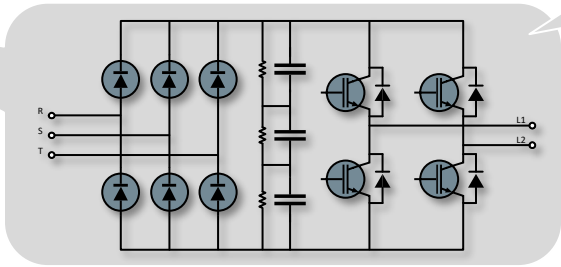
VACON 1000
Product details



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Multi-level Cascaded Inverter







- Modular design
- Series connected power cells
- Multi-level output voltage
- IGBT based power cell bypass (optional)
- N+1 redundant design (optional)
- System bypass (optional)

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Stand-alone design structure



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Bypass possibilities

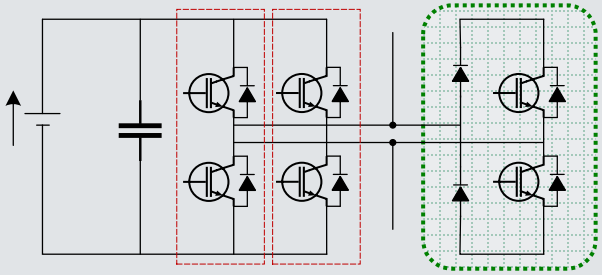
Bypass type	Bypass device	Drive reactions
No cell bypass		Trip
Power cell bypass (+PPCB)	IGBT circuit	Continuous operation with voltage drop
Power cell redundancy (+PPCR)	As +PPCB, and additional power cell per phase	Continuous operation without voltage drop
System bypass Manual (+PMBP) Auto (+PABP) Synchronous (+PSBP)	 Manual disconnector Vacuum contactor Vacuum contactor	Possibility to transfer the load the grid, allowing DOL

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VACON 1000 Power cell bypass **(+PPCB)**

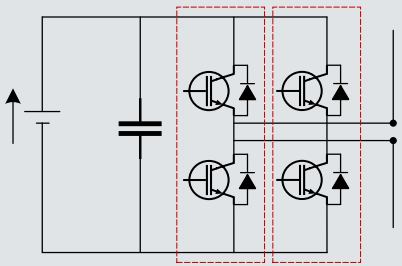
- Depends on power cell bypass availability
- IGBT type power cell bypass technology - **1ms bypass time**

With power cell bypass



PCU-A_HA-xxx-006+PPCB

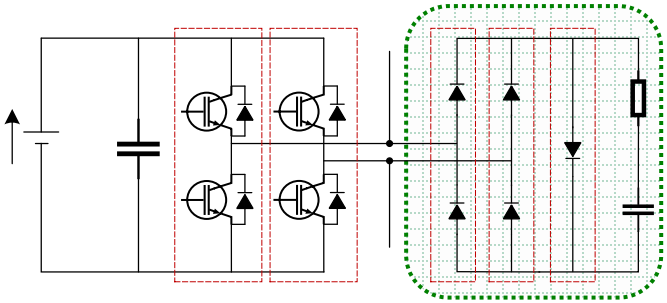
Without power cell bypass



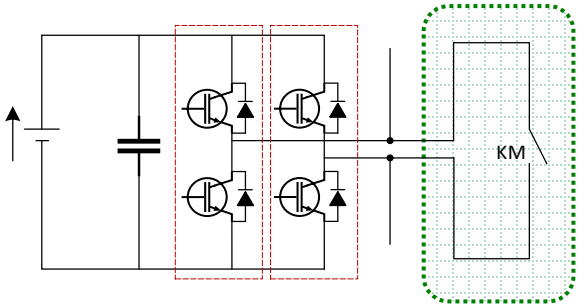
PCU-A_HA-xxx-006

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Power cell bypass comparison



SCR bypass (electronic type)

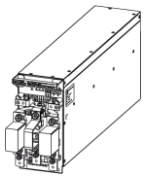
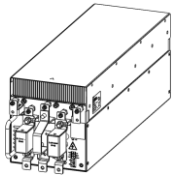
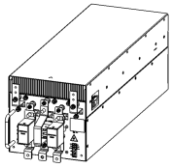
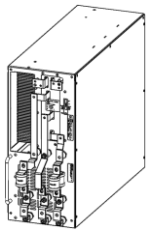
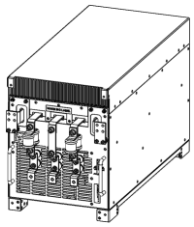


Contactor bypass (mechanical type)

Method of bypass	Contactor bypass	SCR bypass	IGBT bypass
Type of bypass	Mechanical	Electronic	Electronic
Reacting time	Slow	Fast	Fast
Reliability	Low	Mid	High
Remark	Easy to be polluted by dust	Low dV/dt endurance	High dV/dt endurance

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Power cells details

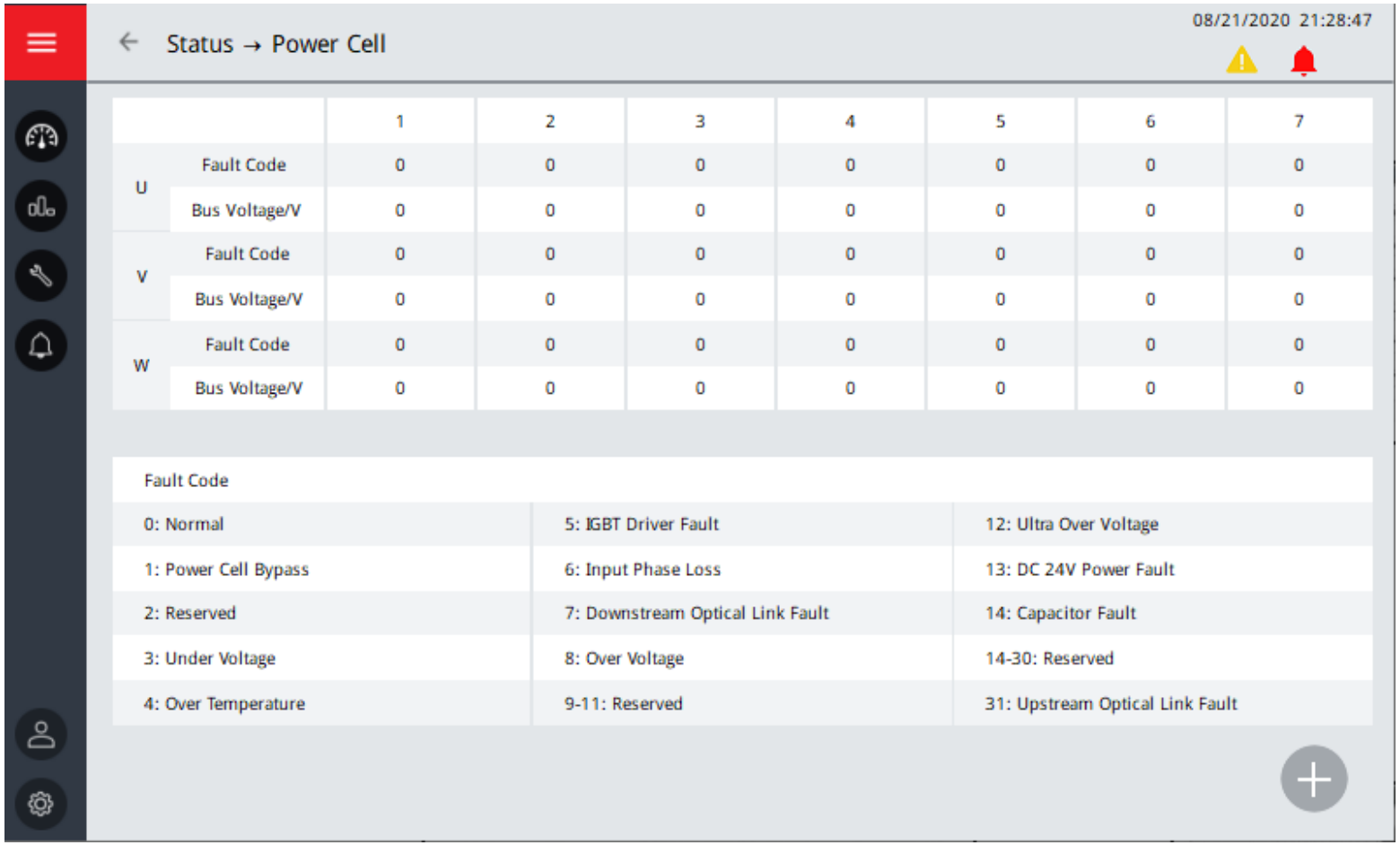
Type PCU-A2_LA-_ _ _-006 Dimensions	036 050 070	100 140	180 215	250 305 350	438 560 680
Height [in]	8.6	8.3	8.3	21.9	18.6
Width [in]	4.4	6.5	7.5	9.7	14
Depth [in]	22.5	24.6	26.6	30.2	33.5
Weight [lb]	46.3 | 48.6 | 50.8	70.6 | 72.8	88.2 | 92.6	187.4	242.6 | 264.6 | 286.7
Current [A]	36 | 50 | 70	100 | 140	180 | 215	250 | 305 | 350	438 | 560 | 680

Stand-alone

Line-up

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HMI Operation Interface
Power Cells Monitoring



		1	2	3	4	5	6	7
U	Fault Code	0	0	0	0	0	0	0
	Bus Voltage/V	0	0	0	0	0	0	0
V	Fault Code	0	0	0	0	0	0	0
	Bus Voltage/V	0	0	0	0	0	0	0
W	Fault Code	0	0	0	0	0	0	0
	Bus Voltage/V	0	0	0	0	0	0	0

Fault Code		
0: Normal	5: IGBT Driver Fault	12: Ultra Over Voltage
1: Power Cell Bypass	6: Input Phase Loss	13: DC 24V Power Fault
2: Reserved	7: Downstream Optical Link Fault	14: Capacitor Fault
3: Under Voltage	8: Over Voltage	14-30: Reserved
4: Over Temperature	9-11: Reserved	31: Upstream Optical Link Fault

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Negative Sequence Compensation
Introduction

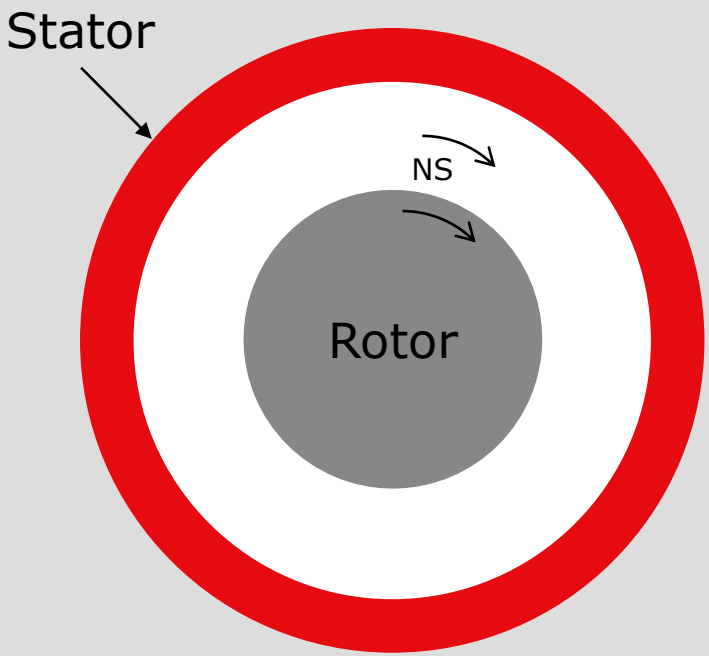


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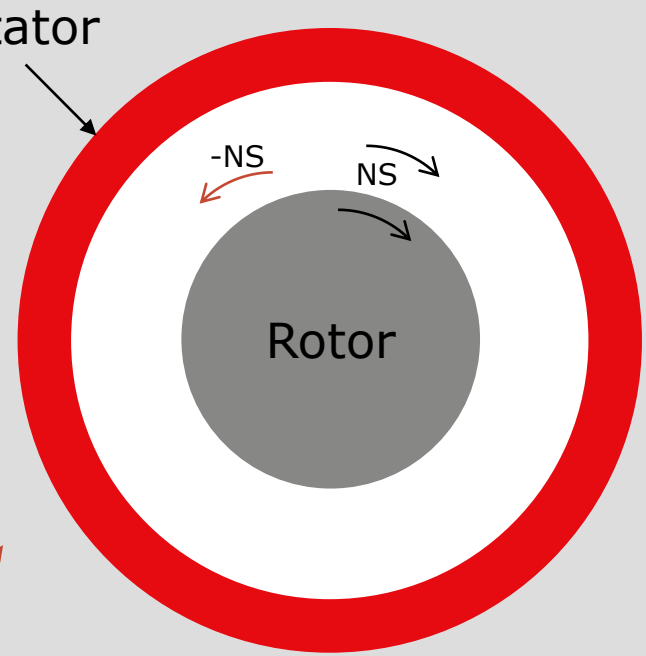
Unbalanced supply

- Balanced supply voltage
- Unbalanced supply voltage

AC motor cross-sectional view



NS = Synchronous speed



$I = I_1 + I_2 + I_0$

Where:

I_1 = positive sequence

I_2 = negative sequence

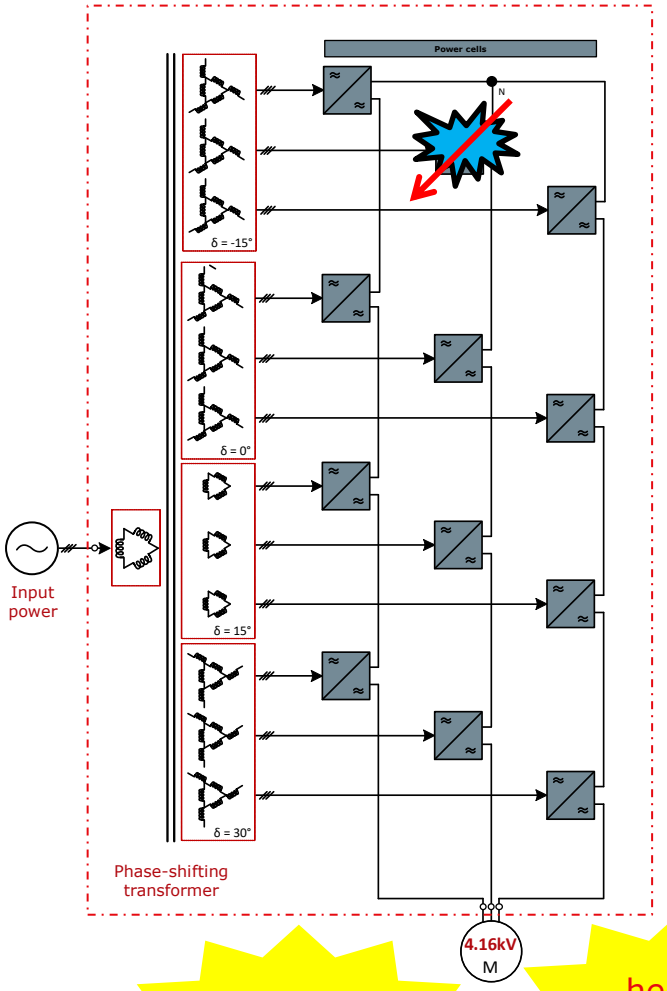
I_0 = zero sequence

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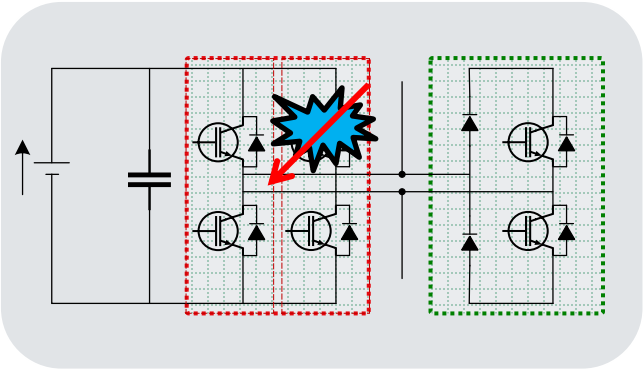
Negative Sequence Compensation
Description

- The output will be unbalanced when one or more power cells fails and are bypassed. The VACON 1000 controller will detect negative sequence components and adjust each phase's modulation individually by a close-loop controller to optimize all the power cells' output to compensate these negative sequence components. Consequently, the output will be controlled to be balanced again, and VACON 1000 continues to run.
- When power cell bypass mode is set to negative sequence compensation, other power cells keep normal operation once a failed power cell is bypassed. The negative sequence compensation control is performed to restrain output negative sequence voltage.



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Negative Sequence Compensation
Description



Inactive

Active

- When the modulation ratio is above the maximum modulation ratio parameter, the drive output speed is decreased automatically after power cell bypass occurs, namely bypass derating. Therefore, the actual motor speed becomes lower than the specified speed.
- When the modulation ratio is lower than the maximum modulation ratio, bypass derating is finished.
- The operating thresholds of negative sequence compensation are:
  - Minimum operating power factor for negative sequence compensation
  - Minimum operating speed for negative sequence compensation
- When the power factor or output speed is below the thresholds, the drive works in symmetrical bypass mode.

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Negative Sequence Compensation
Limitations

Motor output voltage	Motor voltage with one power cell bypassed [%]	Motor voltage with two power cells bypassed in different phase [%]	Max qty of power cell bypassed [qty]	Lowest output voltage when max qty is bypassed [%]	How many power cells from the same phase can be bypassed
2300 V (9 cells)	84.4	72.6	3	64.1	1
2400 V (9 cells)	80.5	69.2	3	61.2	1
3000 V (9 cells)	91.4	78.6	3	69.4	1
3300 V (9 cells)	82.8	71.2	3	62.9	1
4000 V (12 cells)	87.5	79.1	3	72.1	1
4160 V (12 cells)	84.3	76.2	3	69.4	1
6000 V (15 cells)	86	79.7	6	55.6	2
6300 V (18 cells)	93.2	87.6	6	66	2
6600 V (18 cells)	88.8	83.5	6	62.9	2
6900 V (18 cells)	90.5	85.1	6	64.1	2
10000 V (24 cells)	84.7	80.9	9	55.3	3
11000 V (27 cells)	87.4	84	9	60.6	3

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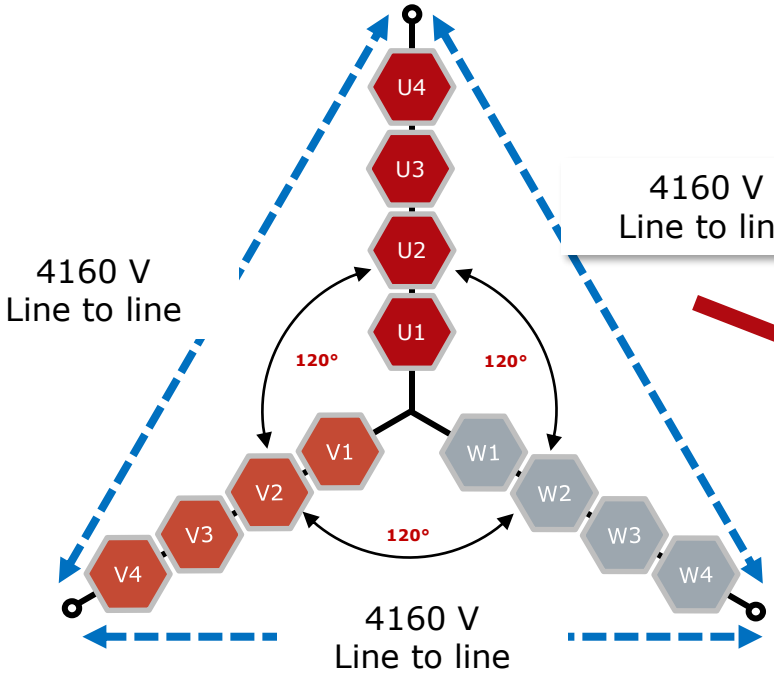
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Limitations

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4000 V (12 cells)	87.5	79.1	3	72.1	1
4160 V (12 cells)	**84.3 (3507 V)**	**76.2 (3170V)**	**3**	**69.4 (2887 V)**	**1**
6000 V (15 cells)	86	79.7	6	55.6	2
6300 V (18 cells)	93.2	87.6	6	66	2
6600 V (18 cells)	88.8	83.5	6	62.9	2
6900 V (18 cells)	90.5	85.1	6	64.1	2
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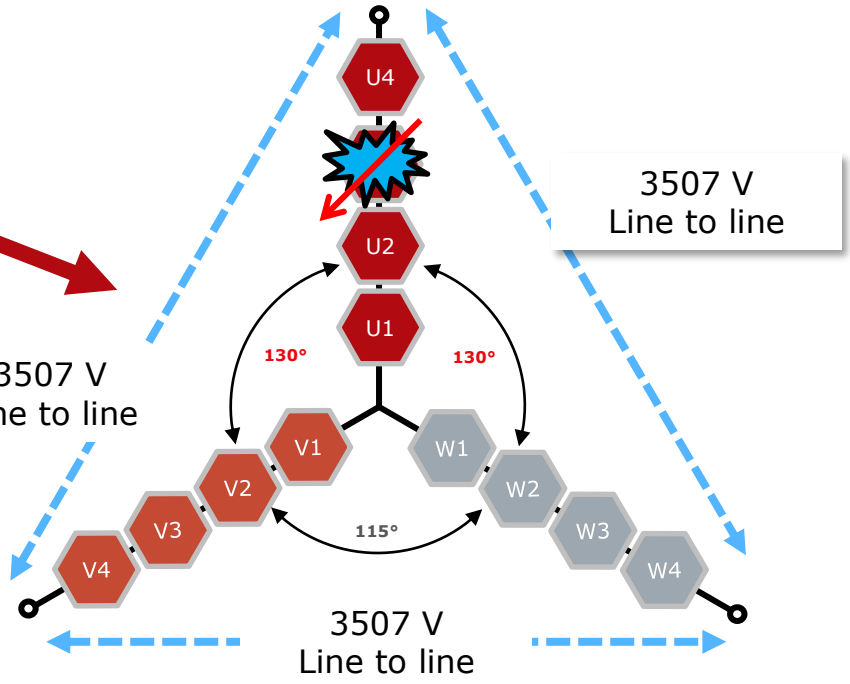
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Negative Sequence Compensation

Power cell bypass (+PPCB)



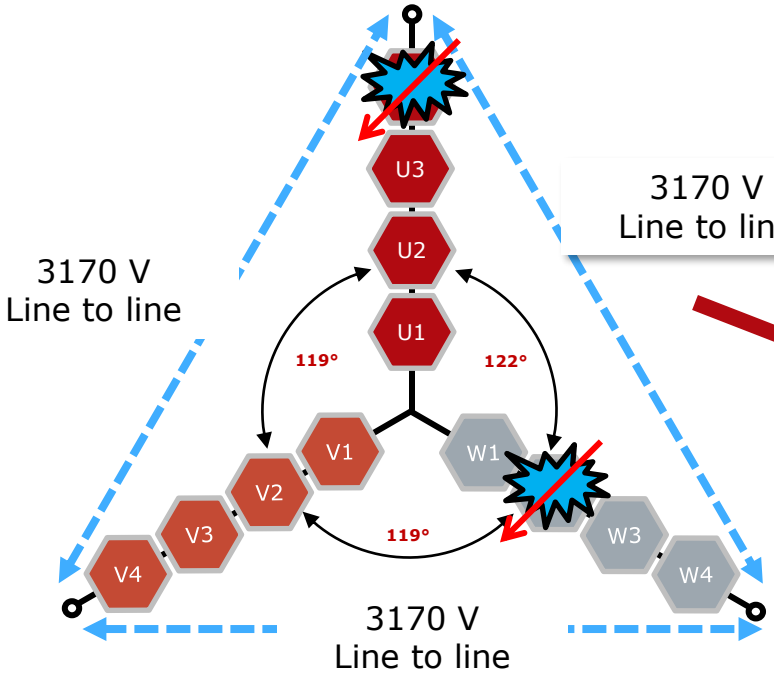
4.16 kV, normal operation



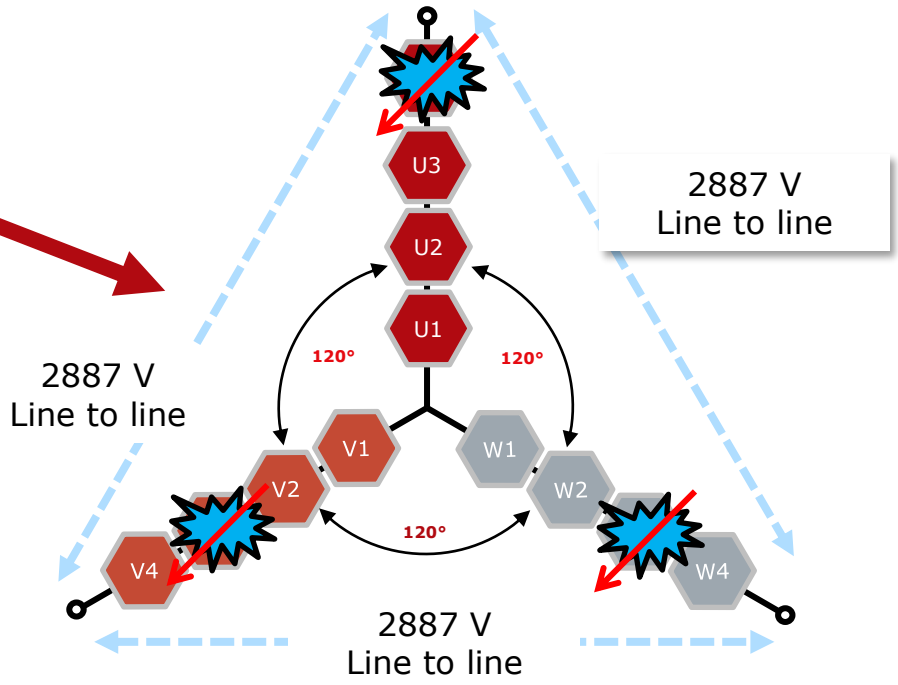
4.16 kV, with one power cell faulty and bypassed

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Negative Sequence Compensation
Power cell bypass (+PPCB)



4.16 kV, with two power cell faulty and bypassed

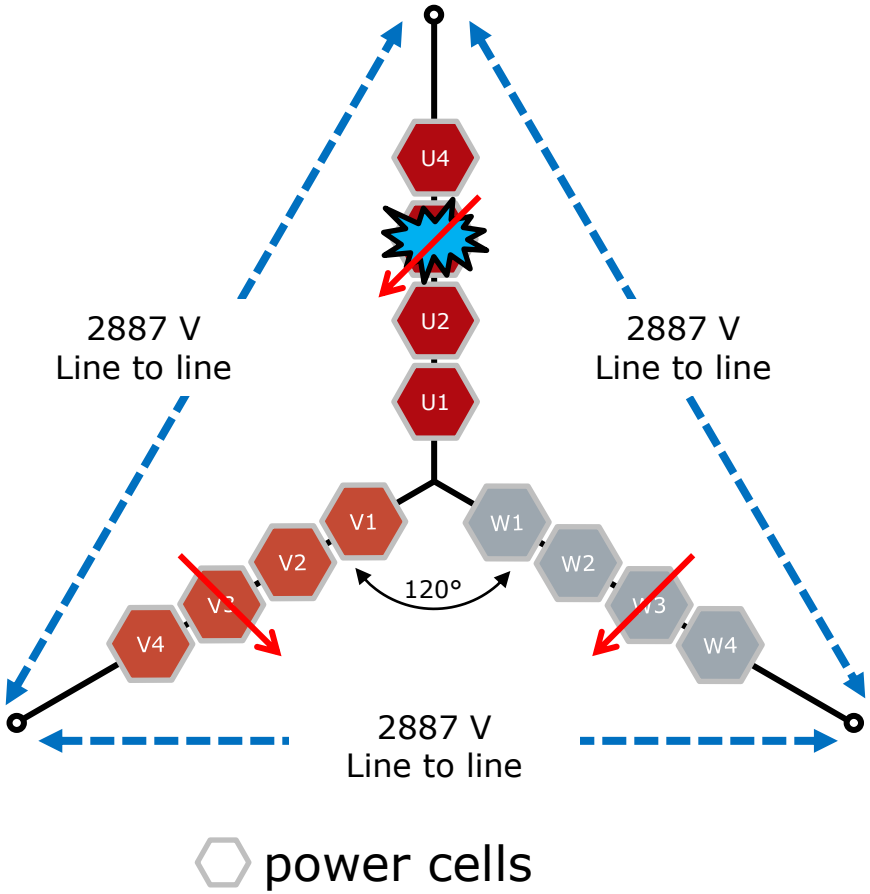


4.16 kV, with three power cell faulty and bypassed

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Symmetrical bypass mode

Power cell bypass (+PPCB)



- When the power factor or output speed is below the thresholds, the drive operatess in symmetrical bypass mode

Maximum output power

Output Power 100%

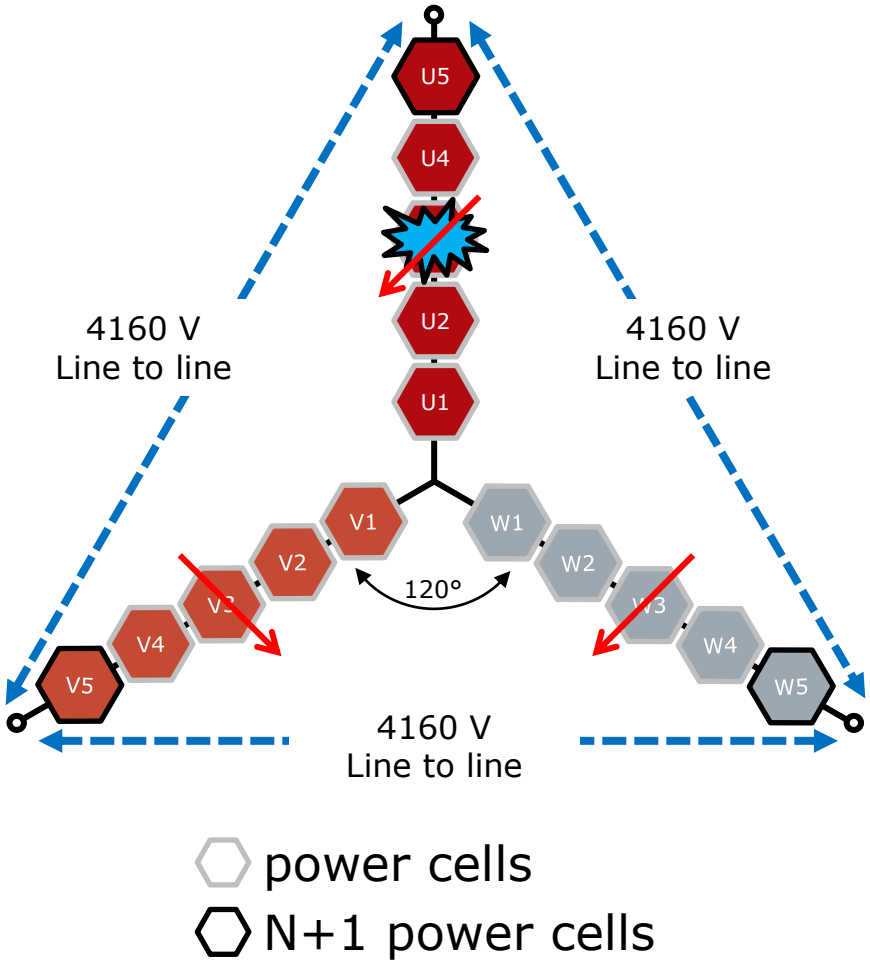
Reduce 25%

Output Power 75%

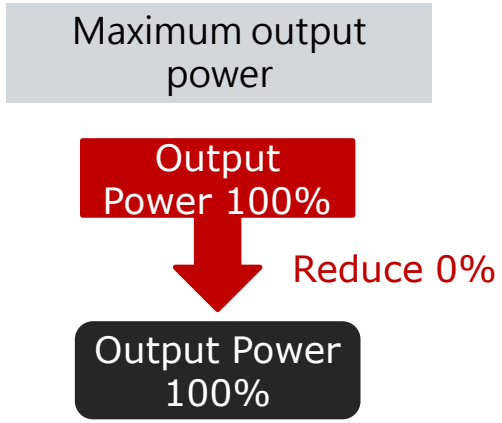
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Power cell redundancy (+PPCR)



- Implement one more power cell in each phase
- When power cell bypass function is on, the MVD can still output 100% power without power de-rating
- The output voltage is equally distributed to each power cell before and after power cell bypass



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Conclusion
Wrap–up



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Unbalanced supply consequences

- Induction motors
  - 5% unbalance can cause the reduction in the motor power by 25%
    - even if the induction motor continues to get the rated current before unbalancing.
    - This reduced electrical power of the induction motor attributes to heating in the rotor.
  - The unbalance present in the VFD output by 3% can increase the rotor heating by approximately 20%.
- The VFD will balance the output voltage to reduce losses in the motor
- The VFD will provide proper protection against the unbalanced currents in induction motors

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