# Line Traps





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Fig. 1 Post mounted Line Traps

### Introduction

With over 40 years of successful field experience Trench is the recognized world leader in the design and manufacture of aircore dry-type inductors for electric utility applications. The unique custom design approach, along with fully integrated engineering and manufacturing facilities in both North America and Europe have enabled Trench to become the technical leader for high voltage inductors world wide.

Line Traps for Power Line Carrier (PLC) communication systems represent a significant application segment for high voltage inductors.

#### **Basic Function of Line Traps**

Power Line Carrier (PLC) is a common method of Power System Communication, such as teleprotection, voice and data communication, etc. It has developed the reputation of being one of the most economical and reliable forms of communication and versatile in its application. Fig.2 shows a basic PLC system consisting of three distinct components:

- signal carrying medium (HV transmission line)
- communication apparatus (transmitters, receivers and associated components)
- coupling/blocking equipment such as coupling capacitors, line tuners (coupling devices) and Line Traps.

Line Traps are connected in series with HV transmission lines. The main function of the Line Trap is to present a high impedance at the carrier frequency band while introducing negligible impedance at the power frequency. The high impedance limits the attenuation of the carrier signal within the power system by preventing the carrier signal from being:

- dissipated in the substation
- grounded in the event of a fault outside the carrier transmission path
- dissipated in a tap line or a branch of the main transmission path.

# Design and Construction

Line Traps are designed to meet ANSI standard C93.3, IEC standard 353 or other international standards.

The major components of a Line Trap are the main coil, tuning device and protective device (see Fig. 3). Since Line Traps are series connected with the HV transmission line, they must be designed to withstand the high mechanical forces generated by the short circuit (s/c) current associated with the HV transmission system.





Fig. 4 Suspension mounted Line Traps





## Main Coil

The main coil of a Line Trap is an air-core dry-type power inductor.

Trench offers Line Traps with either of two well established winding technologies:

- Encapsulated design (E-design)
- Open style design (O-design).

Both technologies fully comply with power system and PLC requirements and are therefore applied over the full range of commonly specified main coil ratings. However, in the upper limits of inductance and current ratings the encapsulated design is the preferred concept (see Fig. 5).

The winding of the encapsulated design utilizes aluminum wire or cable, whereas the open style winding employs aluminum flatbar conductor. All power current carrying components utilize welded connections.

High mechanical strength of the winding is either achieved by resin impregnated, fiberglass reinforced encapsulation (E-design) or by fiberglass spacers which are resin bonded between turns (O-design).

The winding is terminated at both ends on a system of aluminum bars, denoted as the spiders which are tensioned together by fiberglass ties (E-design) or fiberglass rods (O-design). These spiders are additionally used for

- the electrical connection to the Line Trap by terminal pads or studs
- providing the hardware for lifting (lugs), mounting (pedestals) and corona protection (bells, rings)
- connecting the tuning and protective device across the main coil.

Trench can provide the complete range of standard ratings (inductance, continuous and s/c current ratings, system voltage) in accordance with IEC 353 or ANSI C93.3 standards (see Fig. 5). Customized units are also available to meet specific customer requirements, such as specific inductance, current (s/c or continuous), low loss requirements, etc.



Rated Currents IEC 353		Rated Inductance IEC 353							
Continuous A	Short-time Series 1 kA/1sec	mH at 100 kHz							
100 200 400 630 800 1000 1250 1600 2000 2500 3150 4000	2,5 5 10 16 20 25 31,5 40 40 40 40 40 63	0,2 0,2 0,2 0,2 0,2 0,2 0,2 0,2 0,2 0,2	0,25 0,25 0,25 0,25 0,25 0,25 0,25 0,25	0,315 0,315 0,315 0,315 0,315 0,315 0,315 0,315 0,315 0,315 0,315 0,315	0,4 0,4 0,4 0,4 0,4 0,4 0,4 0,4 0,4 0,4	0,5 0,5 0,5 0,5 0,5 0,5 0,5 0,5 0,5 0,5	1,0 1,0 1,0 1,0 1,0 1,0 1,0 1,0 1,0 1,0	2,0 2,0 2,0 2,0 2,0 2,0 2,0 2,0 2,0 2,0	
Continuous A	Short-time Series 2 kA/1sec			mH at	100 kHz				
100 200 400 630 800 1000 1250 1600 2000 2500 3150 4000	5 10 16 20 25 31,5 40 50 50 50 50 50 80	0,2 0,2 0,2 0,2 0,2 0,2 0,2 0,2 0,2 0,2	0,25 0,25 0,25 0,25 0,25 0,25 0,25 0,25	0,315 0,315 0,315 0,315 0,315 0,315 0,315 0,315 0,315 0,315 0,315 0,315	0,4 0,4 0,4 0,4 0,4 0,4 0,4 0,4 0,4 0,4	0,5 0,5 0,5 0,5 0,5 0,5 0,5 0,5 0,5 0,5	1,0 1,0 1,0 1,0 1,0 1,0 1,0 1,0 1,0 1,0	2,0 2,0 2,0 2,0 2,0 2,0 2,0 2,0 2,0 2,0	

Rated Currents ANSI C93.3		Rated Inductance ANSI C93.3							Note: All ratings available with E-design
Continuous A	Short-time kA/2sec			r	nH at 100 k	кНz			Shaded ratings not
400	15		0,265	0,53	1,06	1,59	2,12	2,65	available with O-design
800	20		0,265	0,53	1,06	1,59	2,12	2,65	
1200	36		0,265	0,53	1,06	1,59	2,12	2,65	
1600	44		0,265	0,53	1,06	1,59	2,12	2,65	
2000	63		0,265	0,53	1,06	1,59	2,12	2,65	
3000	63		0,265	0,53	1,06	1,59	2,12	2,65	
4000	80		0,265	0,53	1,06	1,59	2,12	2,65	

*Fig. 5 Values of continuous current, short time current and inductance* 



Fig.6 Single frequency tuning

# Z, R (0hm)





Fig.8 Wideband tuning

- Z Blocking impedance
- R Resistive component f Carrier frequency
- f<sub>m</sub> Resonant frequency (Geometric Mean Frequency GMF)
- f'<sub>1</sub> f'<sub>2</sub> Frequency limits of blocking impedance
- f<sub>1</sub> f<sub>2</sub> Frequency limits of resistive blocking impedance

Different types of tuning may be supplied.

• Single Frequency Tuning

If narrow blocking bands are required single frequency tuning is the simplest and most economical type of tuning available. Fig.6 shows a typical schematic and blocking characteristic. Within this narrow band, however, high blocking impedance can be provided, resulting in excellent PLC signal isolation.

• Double Frequency Tuning

The double frequency tuning arrangement blocks two relatively narrow bands of frequencies. Otherwise, the blocking characteristic is similar to single frequency tuning.

For proper operation and isolation of the tuned bands a minimum frequency separation must be maintained between the peak tuning frequencies. This is 25 kHz or 25 % of the upper tuning frequency peak, whichever is greater. Fig.7 shows a typical double frequency schematic and blocking characteristic.

# Tuning Device

The tuning device, connected across the main coil, forms a blocking circuit which provides high impedance over a specified PLC-frequency range. Depending on the type of tuning (see below) the tuning device consists of capacitors, inductors and resistors, all having relatively low power ratings, compared to the main coil. For environmental protection these components are mounted in one or more fiberglass housings. The tuning device is installed inside the main coil. To meet changing PLC frequency requirements the tuning device is easily accessible for replacement or field adjustment (if applicable).

The bandwidth of a Line Trap is that frequency range over which the Line Trap provides a certain specified minimum blocking impedance or resistance. Minimum blocking resistance should be specified if the potential exists for the reactive component of the Line Trap impedance to resonate with the substation impedance. The achievable bandwidth can be expanded by increasing the main coil inductance.

Different types of tuning may be expanded by increasing the main coil inductance.



• Wideband Tuning

Wideband tuning is the most common type of tuning as it efficiently utilizes the main coil inductance. Wideband tuned Line Traps are suitable for multi-channel applications, since relatively constant impedance is obtained over a broad frequency range. This type of tuning provides high bandwidth flexibility for future changes or expansion of PLC frequencies. PLC channels can be placed anywhere within the blocked bandwidth.

Fig.8 shows a typical wideband frequency Line Trap schematic and blocking characteristic.

• Selftuned Line Traps

Selftuned Line Traps do not require the use of tuning devices. The blocking characteristic as shown in Fig.10 is achieved by simply utilizing the self-capacitance of the main coil winding. The inductance of a selftuned Line Trap is higher than that of a tuned Line Trap.



Fig. 9 Suspension mounted 380 kV, 1.0 mH, 2100 A Line Trap



Fig.10 Selftuned Line Trap blocking characteristics

# C

# Protective Device

The protective device is a surge arrester connected in parallel with the main coil and the tuning device. It protects the main coil and the tuning device by reducing the transient overvoltages to levels corresponding to distribution voltage class insulation.

The insulation level of the main coil and tuning device is coordinated with the surge arrester protective characteristics.

Trench Line Traps are equipped with advanced metal-oxide type surge arresters having a discharge current rating of 10kA. Surge arresters with higher discharge current or high energy dissipation arrangements are also available on specific request.

## Mounting and Connection

Trench Line Traps can be mounted in several configurations. Suspension mounted Line Traps are available with either single point or multi-point suspension brackets. Line Traps can also be pedestal mounted directly onto coupling capacitors (CCs), capacitive voltage transformers (CVTs) or station post insulators. Trench offers several types of mounting pedestals:

- single insulator support pedestal
- multi-insulator support pedestal
- insulated pedestal

Other than the insulated pedestal, all pedestals are electrically connected to the lower terminal of the Line Trap, and as such can be used as both the electrical and mechanical connection to the CC or CVT (see Fig.11a). Should it be necessary to utilize the upper Line Trap terminal as the connection to the CC or CVT, a pedestal insulated from the bottom end (bottom spider) of the Line Trap must be used in conjunction with a special insulated connection rod supplied by Trench (see Fig.11b). All pedestals can be custom made to suit customer requirements.

Terminals supplied on the Line Traps can be either pad or stud type. Each type is manufactured to meet the applicable IEC or NEMA standards.

In addition, terminals can be located on virtually any spider arm, ensuring total flexibility to meet individual requirements. Terminal details and terminal orientation are shown in Fig. 12 and Fig. 13.



Line Trap connection







Top view





Fig. 13 Standard terminal types plated or bare aluminum

#### Note:

Unless otherwise specified, flat terminal pads will be vertically oriented to reduce eddy current heating. (ie. terminals oriented so that the coil's axis is in the plane of the terminal.)



Fig.13

## Definiton of Blocking Terms

The blocking requirement of a Line Trap is dependent on the characteristic impedance of the transmission line where Power Line Carrier is to be applied. The Line Trap blocking requirements can be specified in terms of:

• Blocking Impedance (Z<sub>b</sub>):

 $Z_b$  is the complex impedance of the complete Line Trap within a specified PLC frequency range.

• Blocking Resistance (R<sub>b</sub>):

R<sub>b</sub> is the value of the resistive component of the blocking impedance, within a specified PLC frequency range.

• Tapping Loss (A<sub>t</sub>)

 $A_t,$  also known as "Insertion Loss", is a measure of the loss of power sustained by a carrier frequency signal due to the finite blocking ability of the Line Trap. The tapping loss of an ideal Line Trap should be very low and approach zero.

Blocking Attenuation (A<sub>b</sub>)

A<sub>b</sub> is a measure of the relative transmitted carrier frequency signal which enters the trapped circuit section of network. The blocking attenuation of an ideal Line Trap should be infinitely high. Calculation of tapping loss (A<sub>t</sub>) and blocking attenuation (A<sub>b</sub>)

 $Z_1$  = Characteristic impedance of the line

The impedance of substation  $\rm Z_{\rm s}$  is assumed to be 0 Ohms.

Equ. I A<sub>t</sub> (dB) = 20 log<sub>10</sub> 
$$\left(1 + \frac{Z_1}{2Z_b}\right)$$
  
Equ. II A<sub>b</sub> (dB) = 20 log<sub>10</sub>  $\left(1 + \frac{Z_b}{Z_1}\right)$ 

• Center Frequency ( $f_c$ )

 $f_c$  is the mean frequency of the blocked bandwidth limit frequencies ( $f_1$ ,  $f_2$ ).

$$f_c = \sqrt{f_1 x f_2}$$







1,0 mH Line Trap



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