PAD-MOUNTED TRANSFORMER INSTRUCTION MANUAL

Meta-Power Solutions ®

Contents

Introduction

Meta-Power Solutions' three-phase pad-mounted transformers are powerful, dependable, and designed with the environment in mind. With the ability to function indoor and outdoor, this transformer offers enhanced reliability and protection against critical equipment failure. The lower operating costs and heat emissions of this transformer make it an ideal choice for a wide range of applications.

MPS' pad mount transformers are protected against tampering and the weather, so they can be safely placed where people are present. All enclosures are made from heavy gauge sheet steel and powder painted with a baked-on coating to make them tamper-resistant. Our pad mount transformers come in live-front and dead-front designs along with radial or loop feed.

Our transformers are made of premium materials and typically support residential, commercial, and industrial loads in cities and rural areas. They are filled with sustainable and biodegradable dielectric fluid, which offers excellent fire protection and a longer lifespan.

Applications

MPS primarily serves utilities (step-down transformer), bitcoin miners (step-down transformer with 415 V (Y) on the load-side), and solar power facilities (step-up transformer) across North America. For almost two decades, MPS, a transformer manufacturer in the United States, has been designing and manufacturing three-phase, liquid-filled, pad-mounted distribution transformers. Our transformer designs are suitable for a wide range of applications, including those involving hazardous environments. Our pad-mounted transformers come in live-front and dead-front designs along with radial or loop-feed applications.

Industry Standards

All of our transformers are built according to NEMA, ANSI, and UL standards and tested numerous times during the manufacturing process to ensure conformity with relevant standards and any particular requirements of our customers. Our liquid-filled Three-Phase Pad-Mounted distribution transformers comply with the following ANSI/IEEE standards:
IEEE C57.12.00, IEEE C57.12.28, IEEE C57.12.34, IEEE C57.12.70, IEEE C57.12.90, IEEE C57.91, IEEE C57.12.80, NEMA

Ratings

Base KVA Rating:	45 kVA through 10,000 KVA1
Primary Voltages:	600-35,000 V
Secondary Voltages:	208/120Y - 34,500V
HV Taps:	2 x ±2.5%
Third-Party Recognition:	UL / C-UL Listed / Classified
Standard Basic Insulation Level (BIL)	

Rated Line – Line kV	BIL (KV)
1.2	30
2.5	45
5.0	60
8.7	75
15	95
25 Grounded-Y	125
25	150
34.5 Grounded-Y	150
34.5	150

1 *Transformers come in standard ratings and can be customized for specific requirements.*

Design Percentage Impedances

The transformer's percentage impedance usually ranges between 2-6 % for distribution transformers. The impedance ranges for each size are given below:

Transformer Rating (KVA)	Percentage Impedance (%Z)
45	2.70–5.75
75	2.70–5.75
112.5	3.1–5.75
150	3.1–5.75
225	3.1–5.75
300	3.1–5.75
500	4.35–5.75
750	5.75
1000	5.75
1500	5.75
2000	5.75
2500	5.75
3000	5.75
3750	5.75
5000-10,000	6 – 6.5

Application Limitations

Meta-Power Solutions solar transformers are designed for installations in all environmental conditions and can be used for indoor and outdoor applications. Get in touch with MPS for unusual operating conditions like:

- Abnormal transient voltages on the source voltage
- Scheduled overloading in compliance with the IEEE loading guide
- Motors with a horsepower rating greater than half the transformer's kVA rating
- Abnormal impact loading when feeding welding equipment, electric furnaces or motors with cyclical loads
- Loads with abnormal harmonics that can occur when solid-state or similar power-electronics devices control the load currents

Temperature Guidelines

Temperature is one of the main factors affecting the transformer's life. In reality, a higher temperature is the main factor contributing to a shorter transformer life.

The term "transformer's temperature rise" refers to the average increase in winding temperature above the ambient temperature when the transformer is fully loaded. The maximum values are determined by applied standards.

There are two standard rises for liquid-filled transformers, 55oC and 65oC. These figures are based on a maximum ambient temperature of 40 °C.

Types of Insulating Fluids

A liquid-immersed transformer is generally used outdoors due to concerns over oil spills or fires if the oil reaches its flash point level. Recently, new insulating liquids (e.g., silicone fluid, FR3) have been developed with a higher flashpoint temperature than mineral oil, and transformers with such liquids can be used indoors. However, it is important to note that these less-flammable liquid-immersed transformers have higher initial costs relative to their dry-type counterparts, preventing their widespread market adoption.

For transformer applications, silicone is ideal because of its heat stability, material compatibility, low flammability, and low toxicity. Silicone's high fire point of 340 oC makes it a less flammable fluid that is UL Listed and factory mutual approved for indoor and outdoor applications. It is ideal in locations where fire hazards are present and special fire-suppression systems are in place.

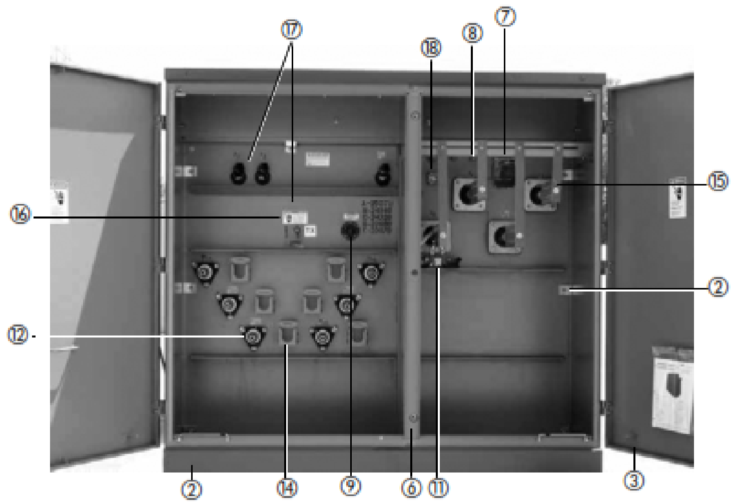
The FR3 dielectric fluid is fully biodegradable and environmentally friendly. It is appropriate for indoor use and for areas with high environmental sensitivity where any spilled insulating fluid could require extensive cleanup.

Minimum and Specific Dimensions

There are two configurations for deadfront design: minimum dimensions and specific dimensions. The minimum dimensions cover minimum bushing spacing, bushing height, and compartment depth. In contrast, the specific dimensions cover dimensions other than the minimum ones while considering the installations, maintenance, and ease of connections.

Standard Features of a Pad-Mounted Transformer

1.	Lifting Hooks
2.	Terminal compartment with removable front sill
3.	Hinged, lift-off cabinet doors
4.	Interlocked Penta-head bolt padlock handle
5.	Ground pads (not shown)
6.	Compartment barriers
7.	Nameplate
8.	Pressure relief device
9.	Tap changer
10.	Drain valve
11.	Removable ground strap
12.	Bushing wells (for deadfront design)
13.	Spade bushings (for livefront design)
14.	Parking stands
15.	Spade terminals
16.	Load-break switch
17.	Bay-O-Net fuse
18.	Liquid level gauge



Transformer Cooling Classes

Transformer fluid has a direct impact on the operation of the components as well as the cooling efficiency of the transformer. Three types of transformer fluid are used in pad-mount distribution transformers: mineral oil, silicone liquid and Envirotemp FR3 insulating oil. These three classes of oil are compared from the environmental protection, reliability, fire safety, and maintenance standpoint. It offers a solid basis for choosing the transformer fluid.

Mineral Oil

Advantages	Disadvantages
Low purchase and maintenance costs	Low moisture tolerance
Readily available	Quick oil darkening under the overloaded condition
Low pour point	Higher risk of catching fire
extended dielectric properties	Low flash point (~155oC)

Silicon Fluid

Advantages	Disadvantages
Good dielectric properties	Higher transformer cost
Highly stable	Difficult troubleshooting
Self-extinguishing	Higher moisture absorption
highest thermal stability	Non-biodegradable
High flash point and fire point	
Not petroleum-based, non-bio accumulating	

FR3 Fluid

Advantages	Disadvantages
Improved fire safety	Excellent switching medium
Biodegradable	High transformer cost
High flash point – 330 oC	Works well under cold weather conditions
Low moisture absorption	Higher pour point
High fire point 360 oC	

Fluid Properties Comparison

Properties	Mineral Oil	Silicone Oil	FR3 Oil
Dielectric Breakdown	30	43	49
Relative permittivity at 25oC	2.2	2.7	3.1
Viscosity (cSt.), 0oC	76	90	300
Viscosity (cSt.), 40oC	12	38	<50
Viscosity (cSt.), 100oC	3	16	<15
Pour point, °C	-40	-55	<-10
Flash point, °C	145	300	343
Fire point, °C	160	330	360
Dissipation factor (%) 25 °C	0.05	0.01	<0.20
Resistivity	1013	1014	1013
Biodegradability	<30%	0%	>99%

NEC Guidelines for Less-Flammable Liquid-Filled Transformers Installation

NEC (NFPA) Recognition

These guidelines cover the requirements of NEC® Article 450.23 for installing less-flammable liquid-insulated transformers. Transformers that require an additional level of fire safety employ less-flammable liquids. Typical applications involve indoor installations near buildings, forest fire-prone areas, and pedestrian areas.

Less-flammable liquids, or high-fire point liquids, are transformer dielectric coolants with a minimum fire point of 300 oC. Dimethysiloxane and ester-based fluids are two widely used less-flammable fluids. Currently, less-flammable liquids and liquid-filled transformers are listed by two Nationally Recognized Testing Laboratories (NRTLs); Underwriters Laboratories (UL) and FM Global (FM).

In 1978, the NEC officially recognized less-flammable liquid-filled transformers for indoor deployment. In 1990, the NEC included particular less-flammable transformer criteria for outdoor applications in Article 450.23. Less-flammable transformers, long recognized as an additional safety measure for indoor installations, are now being considered for outdoor installations as well.

NEC Requirements

The NEC 450.27 sets out requirements for mineral oil insulated transformers deployed outdoors. Depending on the degree of a fire hazard the transformer installation poses, one or more of the following safety measures will be implemented:

- Space constraints.
- Fire-resistant barriers.
- Systems for automatic fire suppression.
- Containers that keep the oil from a damaged transformer tank.

According to NEC Article 450.28, “Modification of Transformers,” when transformers are modified in existing installations that change the type of transformer, the transformers must be marked to indicate the kind of insulating liquid installed, and the installations must also adhere to the most current NEC requirements. Examples of modifications include replacing a transformer entirely (retrofitting) or just the liquid (retrofilling).

Transformers filled with mineral oil or Askarel (PCB) are frequently retrofitted or refilled with less flammable fluids. NEC 110.34 specifies the minimum dimensions of a clear workspace around transformers.

Table. NEC Article 450.23 Less-Flammable Liquid Insulated Transformer Requirements

Outdoor Installation	NEC Requirements
Non-combustible building 1 and materials stored in the area.	If it meets either of the following listing requirements, it may be installed alongside the building. • FM approvals • Underwriters Laboratories
Combustible building or materials stored in the area.	According to NEC Article 450.27, oil-insulated transformers installed outdoors must be protected by fire barriers or water spray systems.

1 *For a definition of non-combustible Type I and II building construction, consult NFPA 220-1999.*

UL Classification Marking for FR3 Fluid

The Envirotemp FR-3 fluid is a biodegradable ester naturally derived from renewable vegetable oils. It has good heat absorption qualities that make it a suitable replacement for mineral oil as transformer oil. The FR-3 fluid is typically used in Pad-mounted transformers due to its High Fire Point tolerance and excellent Dielectric characteristics. Transformers that use the FR-3 fluid are often labelled with the FR3™ decal on their air compartment doors to distinguish them from other transformers that do not. This decal is shown in the figure below, and a transformer with this decal must only ever be filled with more FR-3 when needed. Filling these transformers with mineral oils would hamper the device's capabilities. The FR-3 fluid is also a more environmentally friendly choice for transformer oils compared to mineral oils due to its biodegradability.

The National Electrical Code also classifies the FR-3 fluid as a "less-flammable liquid" when used in three-phase transformers of various ratings, specifically from 45 to 10,000 kVA transformers. In such cases, the operation of the fluid is dependent on the following restrictions:

1. The fluid can be used in three-phase transformers only if they have suitable tanks, i.e., they must be capable of supporting an internal pressure of 12 pounds per square inch without rupturing.

2. The transformer tank must be equipped with a pressure relief device, which must be capable of limiting the internal pressure buildup as per the following table, so it can prevent any tank damage, or even a rupture, due to gas accumulation which may be caused due to low current arcing faults.

3. Current-limiting Fuses, having I2t characteristics not violating the values in the following table, must be used on the transformer's primary windings. For additional security, under-fluid expulsion fuses may also be used in series with the current-limiting fuses.

4. Overcurrent protection, having I2t characteristics not violating the values in the following table, must be used on the transformer's primary windings. The fuse must be attached from outside the transformer tank, so there is enough clearing from the main body in case the fuse is designed to vent when operated, e.g., the expulsion fuse.

Table. UL Classification Marking for Envirotemp FR3 Fluid

Three-Phase Transformer KVA Rating	Required Protection			Required PRC
	Required Current Limiting Fusing Maximum I^2t (A^2s)	OR	Required Overcurrent protection Maximum I^2t (A^2s)	Minimum Required Pressure Relief Capacity, SCFRM @ 15 psi
45	500,000		**700,000**	35
75	500,000		**800,000**	35
112.5	550,000		**900,000**	35
150	600,000		**1,00,000**	50
225	650,000		**1,200,000**	100
300	750,000		**1,400,000**	100
500	900,000		**1,900,000**	350
750	1,100,000		**2,200,000**	350
1,000	1,250,000		**3,400,000**	350
1,500	1,500,000		**4,500,000**	700
2,000	1,750,000		**6,000,000**	700
2,500	2,000,000		**7,500,000**	5,000
3,000	2,250,000		**9,000,000**	5,000
3,750	2,500,000		**11,000,000**	5,000
5,000	3,000,000		**14,000,000**	5,000
7,50	3,000,000		**14,000,000**	5,000
10,0000	3,000,000		**14,000,000**	5,000

Important!

Fuses have particular conditions and ratings and should always be operated within them. When a fuse is to be replaced, the replacement fuse must have similar characteristics. E.g., their voltage and time-current characteristics must be the same. There are generally two considerations to selecting the fuse ampere rating.

The **first consideration** in determining the fuse's ampere rating is to test the fuse's ability to withstand inrush currents without taking damage. For example, the fuse must be able to withstand the large transient current that momentarily passes through a transformer when it is initially energized. This current flows through the transformer due to the connected load, which draws current through the transformer, the transformer's magnetic circuit, or even due to the system configuration. Therefore, this current is also called the magnetizing inrush current or the cold load pickup current, and it is important in observing a fuse's withstand capability.

The **second consideration** in determining the fuse's ampere rating is verifying whether it can successfully carry the maximum normal load current without operating or damaging it. The fuse manufacturer normally provides a fusing table for their product, and these tables can help determine the range of tolerable overload currents. The exact value of permitted overload can be found by comparing the longtime minimum melt current of a particular fuse to the transformer's rated current. The application table of the fuse is usually obtained from tests conducted under the ambient temperature of 25°C to 40°C. The permitted overload is inversely proportional to temperature, and when fuses are used in high-temperature applications, the operators should apply extra care to how the fuse is used. General-purpose CL fuses can be accommodated for the overload and derating factors by following the ratio:

$$\frac{\text{The fuse' s nameplate current rating}}{\text{The transformer' s nameplate current rating)}} = 1.25$$

Note:

All fuses are designed with specific criteria in mind. They must, therefore, be operated within specific ratings. They should have time-current characteristics and equivalent voltage, per the Manufacturer's provided tabulations.

High temperatures have minimum effects on the operation of expulsion and backup CL fuses and thus do not suffer the derating factors.

Finally, it is vital to verify the fuse's capability to isolate the transformer when a current beyond its current rating flows through it, without the transformer suffering any thermal damage. To do so, an observer must take the observed total clearing characteristics of the fuse and compare them with the standard provisions found in the IEEE damage line (I2t).

WARNING:

A fuse should never be removed with pressure on the tank. The dielectric fluid has high temperatures and may cause severe burns and injuries.

The damage line indicates the tolerance of a device when faced with possible faults. When the total clearing characteristics of the fuse lie to the left of the damage line for all expected values of fault current, it indicates that no damage is done to the device. However, most fuse characteristics do cross the damage line, and thus, it is crucial to isolate the device at the lowest possible value of the fault current.

All protective devices **have an Interrupting Rating,** which is a measure of the device's maximum symmetrical fault current tolerance. This rating indicates the highest value fault condition, e.g., the maximum value of current, that the protection device can clear without excessive damage to itself, its characteristics, or the device under its protection. It is crucial for the interrupting rating of a protective device to be greater than the maximum available symmetrical fault current that it might have to clear during its life. This maximum fault current results from the electrical system configuration, for example, the voltage and current flow it usually operates with. Hence, the interrupting rating must be greater than the maximum fault current that a particular system can feed in case of faults.

Bay-O-Net Fuse

The Bay-O-Net fuse is a single-phase disconnecting device with a dead-front design that adds to the security requirements needed to operate the fuse manually with a hot stick (a live-line tool). The Bay-O-Net fuse is found in the transformer's high voltage compartment, which is above the transformer's primary bushings. The Bay-O-Net fuse is specifically rated to make and break the connections to a transformer supplying load-level currents and is, therefore, used to turn on or turn off the transformer under safe operating conditions. Because of its nature as a manually operated fuse, the operator's skills are essential in ensuring reliable operation; who must verify the latching of the fuse before re-energizing. The Bay-O-Net fuse typically comes in two distinct packages; The fuse can be either a partial range current-limiting type or an expulsion type.

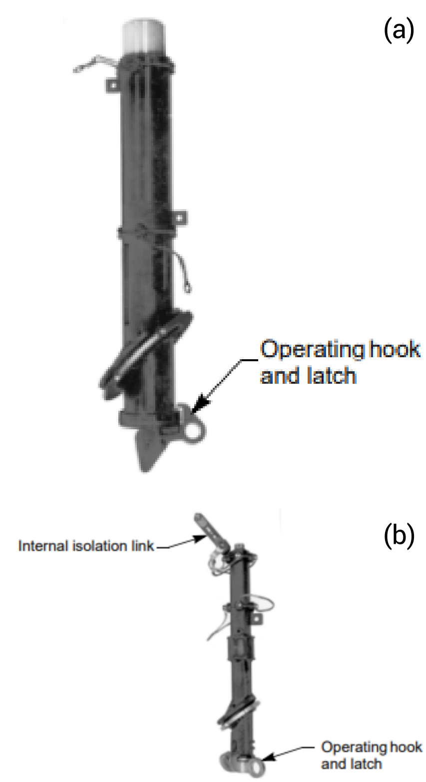


Figure. The two types of Bay-O-Net Fuses: (a) A Current Limiting Partial-Range Type Model and Holder. (b) The Expulsion Type Model and Holder image, with the external Isolation Link.

Bay-O-Net Fuse Electrical Ratings

KV Rating	Specifications
23	150 KV BIL and Full-Wave Crest 50 KV, 60 Hz, AC, 1-min withstand
38	200 KV BIL and Full-Wave Crest 70 KV, 60 Hz, AC, 1-min withstand

Partial Range Current Limiting (PRCL) Fuses

The Partial Range Current Limiting Type Bay-O-Net fuse is designed to clear high current (low impedance) faults. Under proper operations, this fuse must only operate for internal faults - faults within the transformer. A PRCL fuse has several key characteristics:

- It is an Oil immersed fuse and has an internally block-mounted design.
- Its principal function is to provide protection against tank rupture – an undesirable consequence of high current faults.
- A PRCL fuse is used in a series configuration with the Expulsion type fuse, which itself is a low-current primary protection device.

The PRCL fuse is used in transformers to protect and isolate faulty equipment, and the current limiting section of the fuse is highly efficient in protecting the distribution system from high fault current stresses. The minimum interrupting rating of the fuse is set in such a way to avoid any undesirable low current operations for which sufficient protection must be provided through additional low current interrupters while still executing the isolation of the transformer in case of the higher fault currents because of its maximum interrupting rating. The continuous current ratings of the protective setup can even be increased, if needed, by combining two fuses in parallel to one another.

The PRCL fuse is seldom used alone, however, as it is usually connected to a low current interrupting device like the replaceable expulsion type fuse to increase the range of protection, i.e., it gives protection from high fault currents and low fault currents. And while this may not be as economical as many assemblies, such a two-part protection scheme is usually very reliable and secured. As an additional benefit, the two-part assembly can easily be coordinated with any upstream or downstream protection devices, whether they offer low current or high current protection.

Expulsion Type (ET) Fuse

The Expulsion Type Bay-O-Net fuse is designed to clear any low current (high impedance) faults and overload conditions. An ET fuse has the following key characteristics:

- It is an Oil immersed fuse, and it has a load-break design.
- A Hookstick is needed to operate the ET fuse
- The fuse can be replaced by drawing out the defective fuse.
- The ET fuse is available with fault sensing or a load-sensing dual element to facilitate its operation.

The Bay-O-Net fuses are primarily used for transformer protection and distribution system protection. Their design is well suited to protect pad-mounted transformers and fluid-filled, sub-surface distribution transformers. The two key features of the Bay-O-Net fuse design are its ease of use because its hot-stick operation is facilitated throughout its design and the added security from its dead-front design, which means that its outer shell never becomes energized due to the properties of the material used for its construction.

The electrical isolation of an apparatus can be presumed after removing the fuse holder from the assembly. At this moment, the fuse element can easily be inspected, and, if needed, it can just as easily be replaced.

A typical sidewall-mounted Bay-O-Net assembly called the Flapper™ fuse houses a flapper valve to help prevent oil leakage by closing automatically whenever the fuse holder is removed.

Figure: The assembly of a Bay-O-Net Fuse

Current-Limiting Back-Up Fuse Interrupting Ratings

Continuous Current Rating (A)	8.3 KV			9.9 KV			15.5 KV		
	Minimum Interrupting Capacity (A)	Minimum Melt I²t (A²s)	Maximum Clear I²t (A²s)	Minimum Interrupting Capacity (A)	Minimum Melt I²t (A²s)	Maximum Clear I²t (A²s)	Minimum Interrupting Capacity (A)	Minimum Melt I²t (A²s)	Maximum Clear I²t (A²s)
30	200	1800	9400	200	1800	9500	200	1800	10,000
40	250	2900	14,000	250	2900	14,000	250	2900	19,000
50	330	6300	30,000	330	6300	30,000	330	6300	33,000
65	400	9300	33,000	400	9300	34,000	400	9300	40,000
80	300	11,600	56,000	300	11,600	56,000	350	11,600	62,000
100	450	20,600	76,000	450	20,600	76,000	450	20,600	116,000
125	470	32,100	120,000	-	-	-	500	32,100	150,000
150	700	58,500	290,000	-	-	-	700	58,500	260,000
165	800	82,200	395,000	-	-	-	800	82,200	365,000
180	900	103,100	485,000	-	-	-	900	103,100	445,000
250	1000	148,500	690,000	-	-	-	-	-	-
250	-	-	-	-	-	-	1100	128,500	500,000
300	1300	234,200	1,280,000	-	-	-	1230	234,200	1,300,000
330	1500	328,900	1,700,000	-	-	-	-	-	-
360	1800	412,500	2,100,000	-	-	-	-	-	-
500	2000	594,000	2,500,000	-	-	-	-	-	-

Continuous Current Rating (A)	17.2 KV			23.0 KV			38.0 KV		
	Minimum Interrupting Capacity (A)	Minimum Melt I²t (A²s)	Maximum Clear I²t (A²s)	Minimum Interrupting Capacity (A)	Minimum Melt I²t (A²s)	Maximum Clear I²t (A²s)	Minimum Interrupting Capacity (A)	Minimum Melt I²t (A²s)	Maximum Clear I²t (A²s)
30	200	1800	10,000	200	1800	12,000	-	-	-
40	250	2900	19,500	250	2900	20,000	-	-	-
50	330	6300	34,000	330	6300	39,000	450	3870	30,600
65	400	9300	42,000	400	9300	44,000	490	7160	39,300
80	350	11,600	62,000	300	11,600	70,000	625	11,450	60,700
100	450	20,600	116,000	450	20,600	120,000	635	16,100	80,500
120	-	-	-	-	-	-	700	21,200	118,000
125	500	32,100	150,000	465	32,100	180,000	-	-	-
140	-	82,200	-	-	-	-	800	36,240	163,000
150	-	103,100	-	700	58,500	320,000	-	-	-
165	-	148,500	-	900	82,200	430,000	-	-	-
250	-	-	-	900	128,500	650,000	-	-	-
300	-	234,200	-	1200	234,200	1,300,000	-	-	-
330	-	328,900	-	1500	328,900	1,700,000	-	-	-

Pad-Mounted VFI Transformer

When a conventional distribution transformer is combined with a Vacuum Fault Interrupter (VFI), such an assembly is called the “Pad-Mounted VFI transformer”. Such a combination adds the benefits of both technologies, i.e., the voltage transformation of the transformer and the over-current protection of the VFI in one integrated, space-saving, and cost-effective package. As a result, the transformer is sufficiently protected from fault currents, and the transformer can be properly coordinated with upstream protective devices.

Figure. Pad-Mounted VFI Transformer Front View

The VFI breaker can initiate its operation based on the parameters of any one of the three phases under its protection, but its operation itself is a mechanical gang trip of all three phases. This means that whenever a trip condition of either a fault or an overload condition is sensed from any of the three phases, the breaker isolates the transformer from all three phases. This feature is useful because it protects three-phase loads from single phasing. Therefore, The VFI breaker can be used as a three-phase load break-off switch by purposefully providing it with a trip signal.

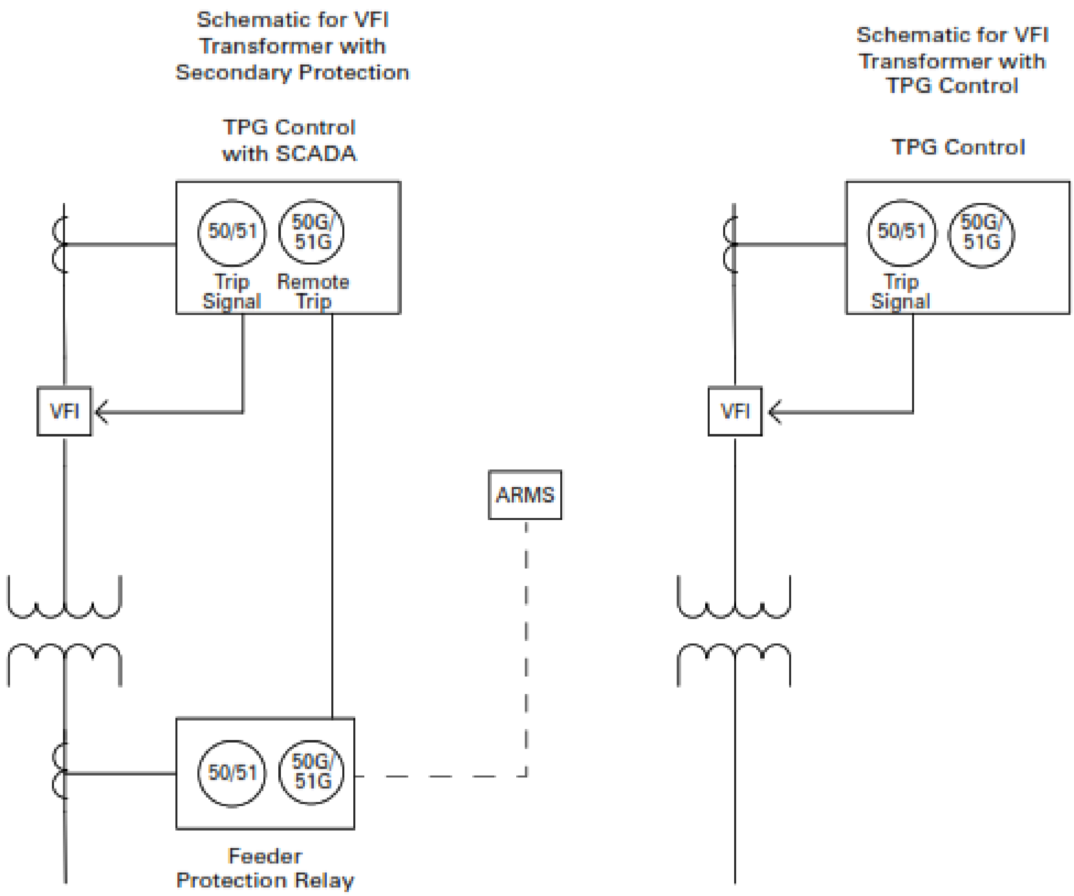


Figure. VFI Schematic with protective and control components

Table. Ratings for VFI Switchgear and Load-Break Switch

Maximum design Voltage, KV		15.5	27.0	38.0
BIL, KV		95	125	150
1-minute withstand voltage (60 Hz), kV		35	60	70
Momentary current, 10 cycles (sym.), kA		16	12.5	12.5
Vacuum Fault Interrupter	Continuous current, (max.), A	600	600	600
	Interrupting current (sym./asym.), kA	16/25.8	12.5/20.0	12.5/20.0
	Making current (sym.), kA	16	12.5	12.5
	Cable charging interrupting current, A	10	25	40
Load-Break Switch	Continuous current, (max.),A	600	600	600
	Load switching, A	600	600	600
	Fault making (sym./asym.), kA	16/25.8	12.5/20.0	12.5/20.0

Additionally, three-phase services can be restored quicker and more easily because the VFI breaker characteristics can be reset using the tri-phase control technique. This control method can be used to set up more than a hundred minimum trip settings, each with its time-current curves. The tri-phase control scheme can easily satisfy different protection and coordination requirements, as it incorporates all three general power system safety needs, i.e., the minimum response characteristics, optional ground tripping, and standardized instantaneous tripping, with all three factors controllable for the operator. The tri-phase control technique also provides a wide array of minimum trip settings and TCCs, which means that the scheme itself is also adaptable to distribution systems. The SCADA accessory is optional but can provide restraint during inrush, local phase and ground trip targets, remote tripping, etc.

The tri-phase control scheme can be replaced with an optional relay when more flexibility is required and when it is desirable to have more control over the VFI's primary overcurrent protection. Secondary CTs may be used to transmit any overcurrent or overload conditions to the VFI, in addition to the primary protection. This setup allows the VFI to protect against any downstream arc flashes and the subsequent current response from the secondary winding side.

A visual cue is sometimes provided through a sealed visible break window and switch. This window and switch combination allows for an easy way to look into the position of the load-break switch contacts. An operator can peek through this window to assess whether they are clear to pursue their tasks like maintenance.

Primary Switching Options

The internal load-break switch is used to de-energize the transformer by causing load interruptions, as no current will pass through the transformer when its secondary winding delivers no power to a load. The switch is connected between the transformer fuses, windings, and primary bushings.

Load break switches can be of three types based on the number of positions they can take. Therefore, these switches are called the **two**, **three**, and **four** position load break switches. A manually charged spring with an over-toggle mechanism is used for these switches to make the operation of the switch independent of the operator's speed. Due to this spring-loaded mechanism, the load break and make functions can be implemented in a short period. Minimum input torque is needed from the operator to switch the state of the two-position switch. The switch is hot-stick operable and has low cable capacitance because of how close it is to the core and coil assembly. The chances for Ferro resonance are also greatly reduced due to the simultaneous three-phase switching.

Note: **The Direction of the switch should not be reversed before the switch has changed its position.**

Applications of the two-position switch:

Loop-feed and radial systems may employ the two-position (state) switches - the states being on and off. While some applications use a single two-position switch to turn a portion of the circuit on or off, Multiple two-position switches can be combined to meet different requirements. For example, an application may require a combination of two switches for limited sectionalizing, while three switch combinations may be used for comprehensive sectionalizing.

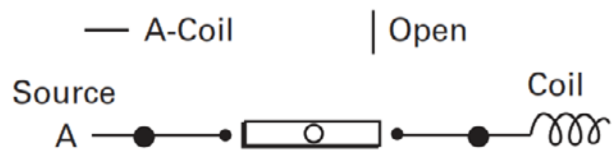


Figure. 2-Position Switch

Applications of the three-position switch:

These switches are primarily used in applications where two sources exist, and the transformer feed can be toggled to come from either one of these two sources. These switches ensure that no interlocking is required, as the two sources can never be connected to the transformer simultaneously.

Applications of the four-position switch:

These switches are sectionalizing switches that can be used instead of the three switch combinations of the two-position switches. Thus, one switch can be used instead of three, reducing the need for coordinating multiple switches. Four-position switches are of two types based on their configuration, i.e., they are either a T-blade or a V-blade configuration four-position switch.

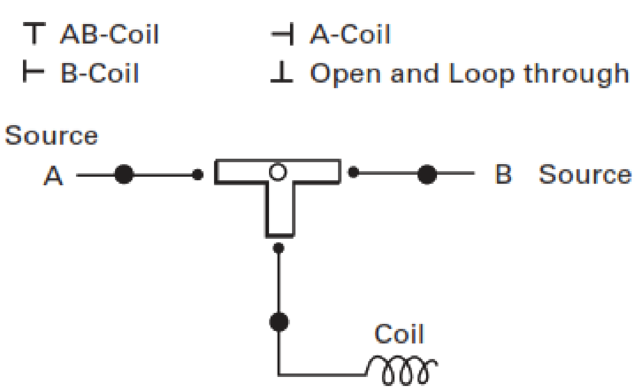


Figure. Four-Position Switch (Loop Feed) "T Blade"

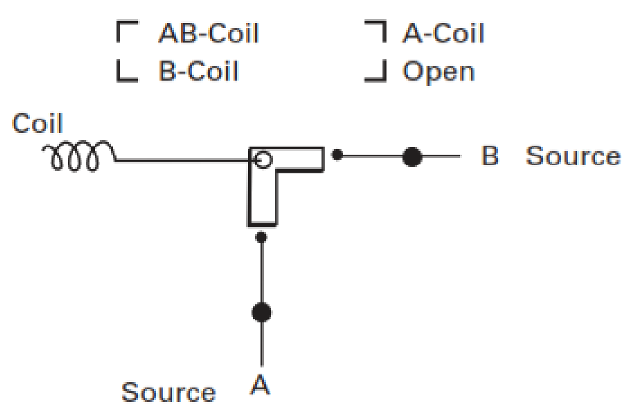


Figure. Four-Position Switch (Loop Feed) "V Blade"

Table. Two-Positon Load-Break Switches Ratings

Rated Voltage					
Phase to Phase	KV	15.5	27.6	38	46
Phase to Ground	KV	8.9	15.6	21.9	26.5
Impulse withstand voltage (1.2/50 μs)	KV	200	200	200	200
Power frequency withstand (1 minute)	KV	70	70	70	70
Continuous current	A	550	400	300	65
Switching current	A	550	400	300	65
Fault withstand current (momentary)—10 cycle sym.	KA	12	12	12	12
1-second sym. Rms	KA	8	8	8	8
Fault close and latch—10 cycle sym.	KA	-	12	12	12
Fault close and latch—15 cycle sym.	KA	12	-	-	-

Table. Three- and Four-Positon Load-Break Switches Ratings

Rated Voltage				
Phase to Phase	KV	15.5	27.8	38
Phase to Ground	KV	9	17.2	21.9
Impulse withstand voltage (1.2/50 μs)	KV	95	125	150
Power frequency withstand (1 minute)	KV	35	60	70
Continuous current	A	630	300	200
Switching current	A	630	300	200
Fault withstand current (momentary)—10 cycle sym.	KA	12.5	12.5	12.5
1-second sym. Rms	KA	12.5	12.5	12.5
Fault close and latch—10 cycle sym.	KA	12.5	12.5	12.5

Note: **When the Load-break switch is operated, it only interrupts the load current. A switch is not capable of interrupting fault currents and should, therefore, not be used for such purposes. The switch ratings should be respected and should never be exceeded.**

Externally Operable Visible Load-Break Switch and Gauges

Before working on the Transformer's maintenance, operators need to verify the state of a transformer, whether it is energized or de-energized. A sudden break to the Transformer's load terminals through the transformer termination compartment can lead to Arc Flashes which are dangerous to human life. As Load breaking is an everyday task, operators are always at risk of these Arc Flashes. Typically, there is no easy way of verifying the Transformer's state, but MPS offers an external load-break visibility option that attaches an external viewing window to the Transformer for easy and safe verification of an electrical disconnection.

The external visible load-break option is implemented through a switch box mounted on the side of a transformer. The switch box is away from all possible live parts of the Transformer, and the disconnected load-break switch is visible from the safety of the external viewing window. Therefore, operators can safely ascertain the Transformer's state or condition without accessing the termination compartment.

Additional protective equipment also becomes redundant due to the safety afforded by not having to enter the transformer termination compartment to verify the transformer state. A qualified individual can simply verify the de-energized state of the low voltage bushings of the transformers by using the externally operable load-break switch and the external viewing window. The switch box also has an optional on/off/ground feature that can be used to internally ground the transformer windings through the grounded tank of the Transformer.

To summarize, the visible load-break assembly consists of:

- A Large viewing window to verify the state of the Transformer.
- A Rotary handle to operate the moveable isolating contacts.
- Different Gauges for monitoring various transformer parameters like internal pressure, liquid level, liquid temperature, etc.
- A pad-lockable cover to protect the gauges and switches.

Some additional options are offered by MPS, like the Pressure Relief Device, Sampler, Locating Gauges and Drain Valves, etc. These are all external to the low voltage termination compartment and help maintain the Transformer.

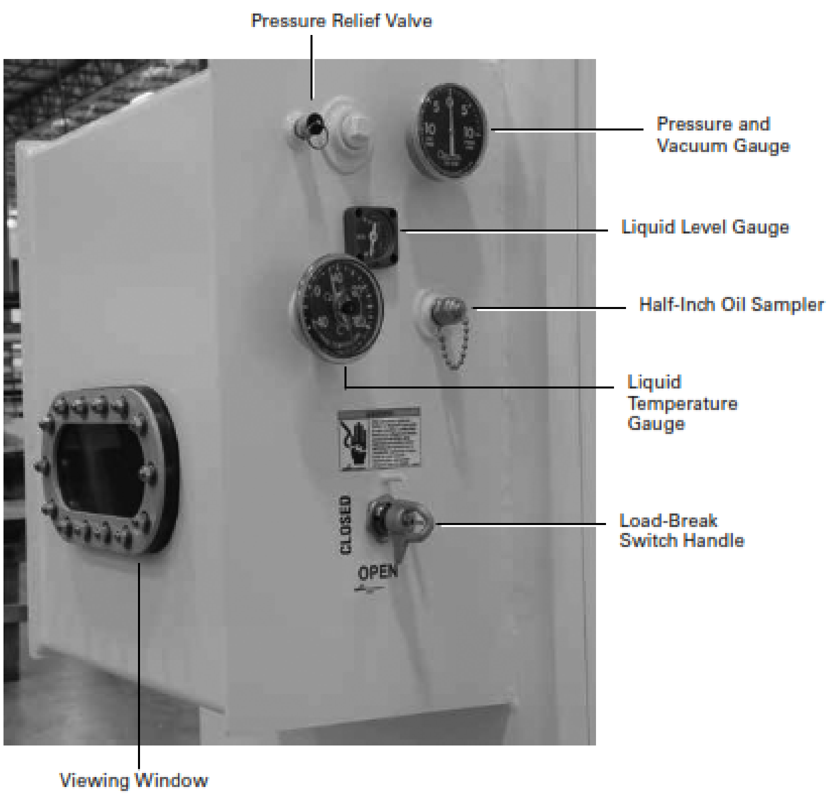


Figure. The External Load-Break Switch Box attached to a Three-Phase Pad Mounted Transformer.

Peak-Demand Transformers

Transformers are often subjected to temporary overloads, which can accelerate the loss of insulation; the insulation's quality, efficiency, and life are all drastically reduced. The uniquely designed Peak-Demand Transformers by MPS are specifically built to manage these overloads, thus protecting the quality of insulation better than traditional mineral-oil-filled transformers. The MPS Peak-Demand transformer's unique design consists of:

- Optimized coil and core design.
- Biodegradable FR3 Insulating fluid.
- Advanced high-temperature insulation system, which consists of thermally improved kraft paper.

Important! **The capacity of a Peak-Demand transformer to take up varying loads, continuously, at a higher temperature without suffering any damage is vital to improve the reliability of the overall system and the lifespan of the equipment.**

Applications of MPS Peak-Demand Transformers

The MPS Peak-Demand Transformers come with different Average Winding Rise (AWR) ratings; Transformers with specific ratings are better suited for certain applications: **75 °C AWR** Peak-Demand Transformer is preferred for applications that require a smaller footprint, a lighter transformer, and a capability similar to that of the traditional **65 °C AWR** Transformer, which is a physically larger unit; while the **65/75 °C AWR** and **55/75 °C AWR** Peak-Demand Transformers are better when used for applications that require additional overload capacity to manage peak demand and load increase.

Features and Functions

The MPS Peak-Demand Transformer improves upon the standard Transformer variants in several ways:

1. Improved Overload Capacity

- The 65/75 °C AWR slash-rating allows the customers to operate the Peak-Demand three-phase transformers at a 12% overload – beyond its full rated base load. Similarly, a 55/75 °C AWR slash-rating allows operations at a 22% overload. The availability of these two options allows customers to pick the best-sized Transformer for their application based on their peak demand considerations.
- Peak-Demand transformers have a higher kVA rating than the traditional mineral oil-filled transformers because of better retention of the quality and efficiency of their insulating liquid.
- It is easier to replace ageing equipment, which adds to the reliability of the existing system and allows the customer to undertake long-term distribution planning.

2. Improved Reliability

The life of a transformer's insulation system is significantly reduced when exposed to thermal stresses and moisture. The MPS Peak-Demand transformer has superior thermal stress and moisture managing capability. Therefore, the insulation system life is extended, and its quality is maintained longer, which contributes to the improvement in the overall system reliability through the reduction in the number of outages caused by transformer failures. Generally:

- When the Transformer is operated at its base kVA rating, a 75 °C AWR Transformer design offers the insulation system a life extension of about four times that of the IEEE 20.55-year life requirement. Similarly, the 65/75 °C AWR Transformer design offers a life extension of up to 8 times that of the IEEE standard.
- The insulation life is also extended through the use of Soybean oil-based fluid, as it creates a hydrophobic barrier at the insulation surface. This helps protect the kraft paper in the windings from degrading due to heat and thus helps extend the insulation's service life.
- The MPS Peak-Demand Transformers use a UL and FM Global recognized biodegradable soybean oil-based dielectric fluid, which is a less flammable liquid than mineral oil. Therefore, these transformers have significantly improved fire safety when compared to traditional transformers that continue to use mineral oil. The FR3-filled Transformers have had more than 15 years of field experience, and no fire breakouts have ever been reported.

3. Reduced Transformer Size and Weight

The 75 °C AWR Peak-Demand transformer units are lighter in weight and smaller in size compared to traditional 65°C AWR transformer units having the same kVA rating. The 75°C AWR Peak-Demand Transformers have a better value than traditional transformers because they use less construction material and require less dielectric fluid for their operations. The benefits of the Peak-Demand Transformer over the traditional Transformer of the same rating are as follows:

- Less Operation Costs for the Peak-Demand Transformer.
- Installation and Handling are easier due to the smaller size.
- Crane and Hoisting costs are significantly lower due to their smaller size and weight.
- Retrofitting additional equipment is easier.
- Utility pole upgradation is not necessary for the Peak-Demand Transformer.
- Elevators and Doorways can be easily accessed to move the Transformer.
- Smaller concrete pads can be used to support the Transformer.

Product Scope

MPS Peak-Demand Transformers come with different ratings; these are differentiable based on the number of phases and the applications they are designed for, namely:

- The Three-Phase only, 55/75 °C AWR Transformer unit.
- The Single-Phase Pole-Mount and the Single-phase Pad-Mount Transformers are available, rated between 5 to 167 kVA.
- The Three-Phase Pad-Mount Transformers with a rating between 45 to 12,000 kVA.
- The Single-Phase Substation Transformers rated between 500 to 6667 kVA.
- The Three-Phase Substation Transformers rated between 300 to 12,000 kVA.

Transformer Standard

These Peak-Demand Transformers are designed, tested, and their application at elevated temperatures is verified through the procedures and conditions tabulated within the IEEE Std C57.154-2012, published on the 30th of October 2012.

The example below illustrates the potential footprint change in three-phase pad-mounted transformers.

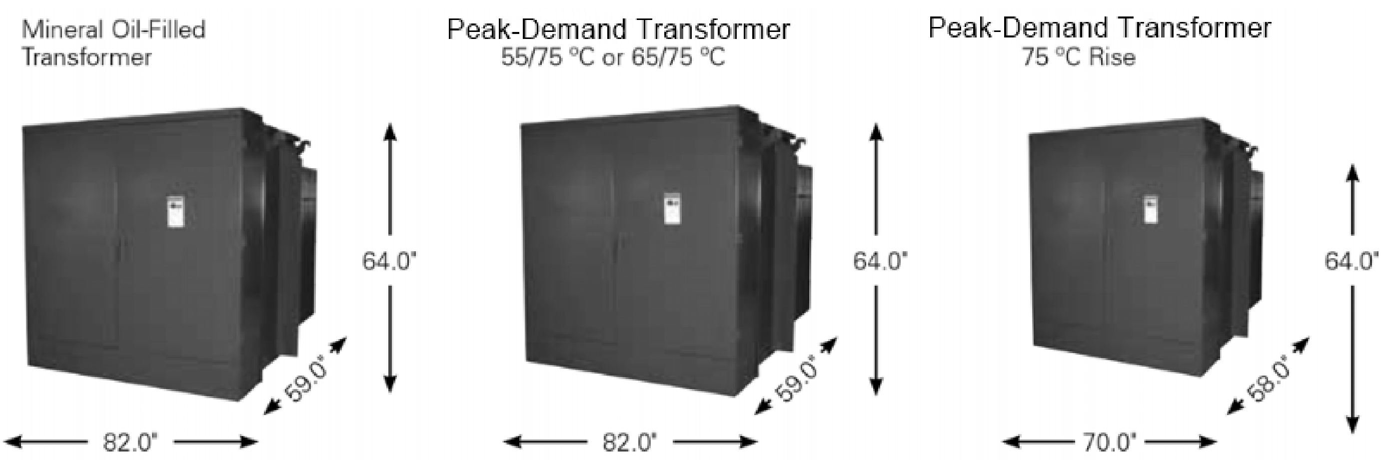


Table. Three- and Four-Positon Load-Break Switches Ratings

Description	Mineral Oil	Peak-Demand 75°C	Peak-Demand 65/75°C	Peak-Demand 55/75°C
Three-phase load capacity	IEEE Std C57.91-2011 standard	IEEE Std C57.91-2011 standard	+12% continuous (above base kVA rating)	+22% continuous (above base kVA rating)
Life expectancy	1x	3-4x	8 x (when operated at base kVA)	8 x (when operated at base kVA)
Enhanced fire safety	-			
Environmentally preferred	-			
First Price	Low	High	High	High

Surge Arresters

Overhead Lightning Storms and Loss of Line conditions can cause overvoltage transients to flow in transmission lines, distribution systems, and expensive outdoor equipment (e.g., Transformers). Thus, Special devices called Surge Arrestors are used to protect these devices as they intercept the overvoltage transients and divert them to the ground.

Customers can choose to connect surge arresters to their transformers for protection against overvoltage transients. The Arrestors can be attached in the low-voltage, high-voltage compartments, or even internally under the oil. Hi-pot and Induced Voltage tests cannot be performed on a Transformer without first disconnecting the arrestors because the high voltage tests would otherwise be grounded through the arrestor due to the low impedance path provided by the arrestor.

The design of the electrical distribution system, the one connected to the Transformer that needs to be protected, plays a vital role in determining the size and installation of the surge arresters. The rating of the surge arrester also depends on the electrical system's maximum operating voltage and grounding conditions.

Under steady-state conditions, there is a potential difference between the two terminals of the surge arrestor, which is equal to the line-to-ground voltage of the electrical system. In this case, the surge arrestor acts like an open circuit. However, when an overvoltage surge occurs, the arrester immediately grounds the surge by acting like a short-circuit and offering the lowest impedance path to the surge. Once the surge passes, however, the arrester returns to its open circuit state and only allows a minimal leakage current to flow through it.

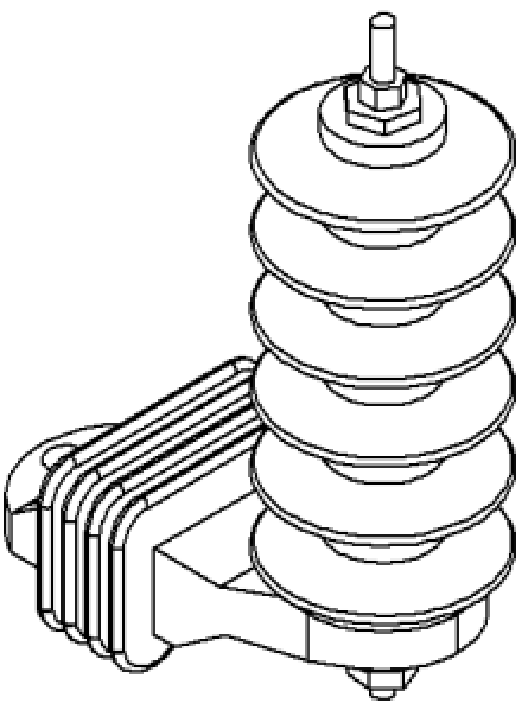
Note: **Surge arrestors are less efficient in gh-frequency overvoltage surges.**

Under Oil Arresters

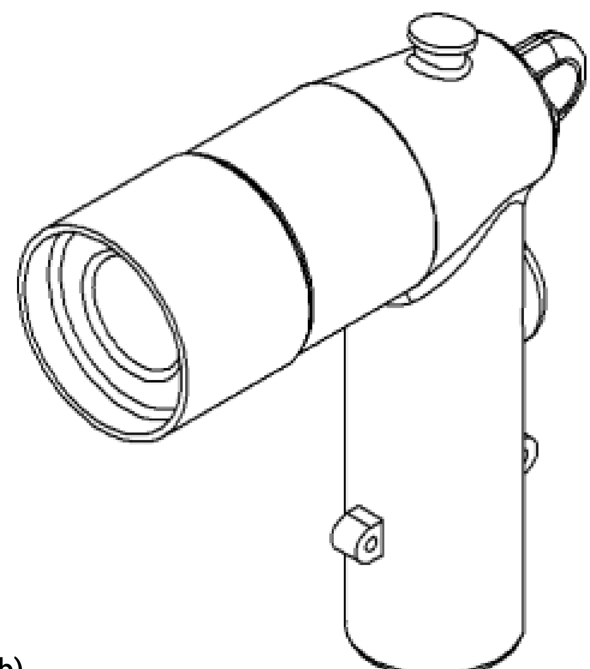
Internal Under Oil Arrestors like the Metal-Oxide-Varistor (MOV) Surge Arresters are attached to transformers to protect them from overvoltage surges. These arrestors come with a switch and a switch plunger that can be used to disconnect and reconnect the Surge Arrestor.

Live Front Arresters

Live-Front Type Surge Arrestors are typically used with transformers that have epoxy or porcelain bushings and live-front eyebolt, stud, or spade type terminals. Manufacturers attach these arrestors to the transformers' tanks through a proper wire size and a fault current withstand rating based on expected fault levels for the system.



(a)



(b)

Figure. A picture of (a) Live-Front Surge Arrester and (b) Dead-front Elbow Arrester.

Dead-Front Arrester

Dead-Front Arrestors are used with transformers that have dead-front type bushings. The Metal Oxide Varistor Arrester falls into this category. These Arrestors are compact and can be implemented in all applications that allow for the use of a load-break elbow. The varistor elements have highly nonlinear characteristics and thus provide for more precision and predictability during arrestor operations.

These arrestors are submersible rated and can be mounted at any angle due to their dead-front and fully shielded design, while their durable rubber construction prevents the need to chip or crack any fragile porcelain skirts. Metal Oxide Varistor Arresters come in different ratings from 3kV to 36kV. The multiple rating allows for sizing options for different applications.

Unlike the Live-Front Type Arrestors, Dead-Front Type Arresters are not attached to equipment by the manufacturers at the factory; instead, they are shipped separately on the pallet and are installed on-site. The separate installation is necessary because the Insulated body of the Dead-Front equipment has to be maintained, even if by replacement. To replace a faulty Dead-Front Arrestor, the arrestor rating and bushing interface type are two critical parameters to consider.

Important! **The Maximum Continuous Operating Voltage to Ground (MCOV) of the arrestor must be greater than the MCOV of the system to prevent any unnecessary operation of the arrestor.**

Load-Break Elbow-Connector

The Load-Break Elbow Connector (LEC) is an insulated and fully shielded plug-in termination used to connect underground cables to different station equipment like switching cabinets, transformers, and load-break bushings on junctions. All load-break connections consist of bushing inserts and elbow connectors. The LEC is a switching device with a 200A full rating designed according to the IEEE Std 386™ standard. Available connectors are rated 15, 25, or 35 kV and are now also available through the 200 kV BIL.

The molding process for the load-break elbows uses high-quality EPDM Rubber Semiconductor and Peroxide-Cured Insulation. A Standard load-break elbow is composed of a Pulling-Eye with stainless steel reinforcement; a Copper Load-Break Probe, which is tin-plated and has an ablative arc-follower tip; and a Coppertop Connector. Additionally, purchasers can choose to incorporate Capacitive Test Points for fault indications. These capacitive indicators are made from Corrosion-Resistant Plastics and thus have a long service life.