

# Overcurrent and Overvoltage Protection devices in Pad-Mounted Transformers

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**Abstract.** Pad-mounted transformers are oil-immersed transformers, which comprise under the same housing all the elements of a conventional transformer substation, including medium voltage protections. Although these transformers perform the same functions as the traditional ones, there are important differences between both types of distribution transformers, where protections are concerned. This paper analyzes the performance of primary protections in pad-mounted transformers.

## Keywords

Pad mounted transformers, overcurrent protection, overvoltage protection, fuse, self protected transformers

## 1. Introduction

Although due to historical reasons, design practices of distribution transformers have been different in North America and Europe, pad-mounted type transformers have been recently introduced in the European distribution systems.

The main differences between traditional oil-immersed transformers and the pad-mounted ones can be summarized in two important points:

- The protection system in pad-mounted transformers is immersed in the dielectric liquid used by the transformer, under the same tank.
- Generally, the overload protection in pad-mounted transformers is located in the high-voltage side, in contrast with the traditional distribution transformers, where this protection is usually in the low-voltage side.

For those reasons, it is very important to know and control the most common possibilities in three-phase pad-mounted transformer protection, because malfunctions in operation or coordination of these protections could cause dangerous situations in which security and reliability would not be assured.

This paper analyzes the state-of-the-art and the performance of the most common overcurrent and overvoltage primary protections in pad-mounted transformers.

## 2. Overload and secondary fault protection

### A. Bay-O-Net Fuse

These are oil-immersed expulsion fuses but externally replaceable. The fuse assembly, mounted on the faceplate (some manufacturers offer a cover-mount model), extends into the tank under the oil and combines the ease of hotstick load breaking possibility with the safety of deadfront construction (Figure 1).

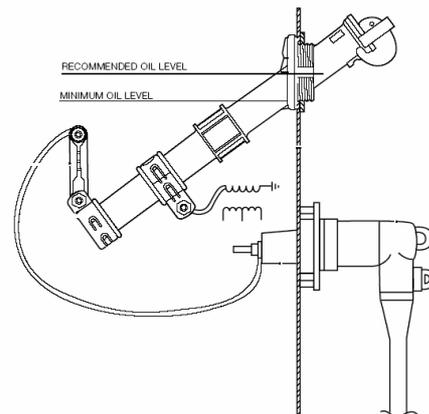


Fig. 1. Bay-O-Net fuse situation (COOPER)

Two types of fuse elements can be mentioned:

- Those used to protect only against damaging currents: Current Sensing Fuse Link
- Those used to protect against damaging currents and dangerous transformer fluid temperature: Dual Sensing and Dual Element Fuse Link.

Apart from the previous ones, there are also “High Ampere Overload Fuse Links”, which are able to withstand large overloads, minimizing heat dissipation. The aim of these fuse links is to make possible its use with larger transformers.

In case this fuse opens, two important things should be taken into account:

- Venting the transformer tank, releasing the excess air pressure to avoid dangerous situations, such as fuse holder expulsion or spraying fluid out of the holder.

- Replacing a blown fuse, manufacturers recommend remote opening and closing of the circuit, due to the possibility of refusing a failed transformer. The fuse could close in on the systems maximum fault current.

When a fuse is replaced, it is often used a kind of drip tray (Figure 2) to protect the other elements of the transformer (surge arresters, terminators, cables, etc.) to avoid dielectric liquid dripping.



Fig. 2. Drip tray (ABB)

These fuses are ideal for coordinating with partial-range current limiting fuses or with the element called Isolation Link.

### B. Internal Cartridge Fuse

These kind of fuses (Weak Link, Protective Link or Cartridge), are oil immersed expulsion fuses located inside the transformer tank, vertically orientated and without the possibility of accessing them from outside, which is one of their main problems (Figures 3 and 4).

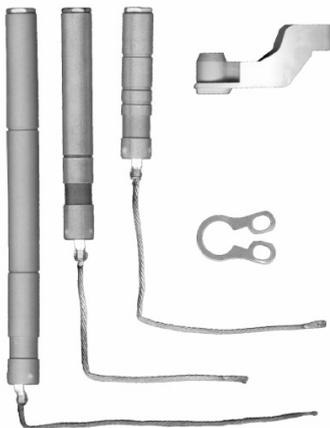


Fig. 3. Internal expulsion fuses (ABB)

In distribution systems, where short circuit power is not very high, this fuse can be used as the only primary overcurrent protection. Nevertheless, in case of high short circuit currents it should be used in coordination with partial-range current limiting fuses.

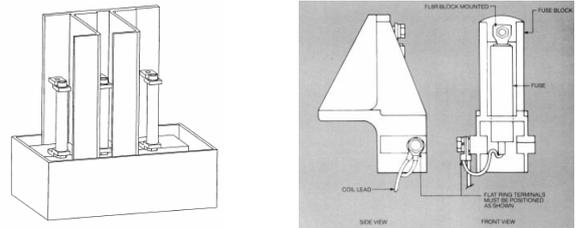


Fig. 4. Location of internal cartridge fuses (COOPER)

As previously in the case of Bay-O-Net fuses, they can be found with either current sensing or dual sensing elements.

### C. Magnex® Interrupter

The Magnex® Interrupter (Figure 5) is a protection device that, besides its protection function, can be used as a loadbreak switch. Consequently, it can reduce costs (i.e. core losses in transformers not in service) and space in the whole pad-mounted transformer. They are available in single phase, two phase or three phase models.

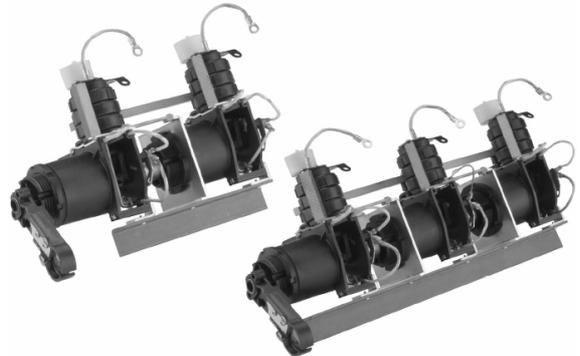


Fig. 5. Magnex® interrupter (COOPER)

Similar to some of the expulsion fuse links, its sensor react not only under overcurrent conditions, but also when temperatures in the transformer exceed dangerous limits for insulating materials. Furthermore, it may be said that, under fault conditions, its TCC (time current curves) characteristics are similar to the ones used for fuses.

Externally accessible, the three phase Magnex® Interrupter can operate in two different ways (Figure 6):

- Single-phase sense, single-phase trip. Containing a sensor per phase, it will react only in the phase affected by the fault, tripping that phase. It is used in transformers with primary wye connection, and can be used in coordination with either back-up current limiting fusing or an isolation link.
- Single-phase sense, three-phase trip. Containing a sensor in two of the three phases, it will react only in the phase affected by the fault, tripping three phases. It is used in transformers with primary delta connection, and should always be used in coordination with back-up current limiting fusing.

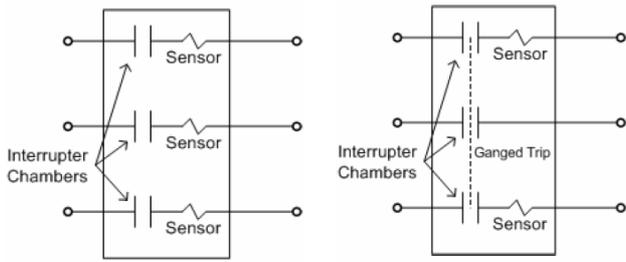


Fig. 6. Operation systems (COOPER)

In both cases, it is possible to close and open all three phases simultaneously just using a single operating handle.

In case of using the Magnex® interrupter coordinated with an isolation link or a current-limiting fuse, HV line should be firstly connected to them and then to the Magnex®.

### 3. Internal Fault Protection

#### A. Isolation Link

This element (shown in Figure 7) is used in series with Bay-O-Net fuses and Magnex® interrupter, in situations where there is no current-limiting fuse connected in series, to guarantee extra protection in case of an internal transformer failure and also in refusing and switching operations.



Fig. 7. Isolation Link (COOPER)

It is designed to melt under the high currents produced due to an internal failure in the pad-mounted transformer, avoiding dangerous re-energizings of failed transformers. This element has no interrupting rating but melting characteristics.

#### B. Submersible Partial-Range Current-Limiting Fuse

This kind of back-up fuse (Figure 8) is used coordinated with low current primary protection, such as Bay-O-Net type fuses or Magnex® interrupter, because below certain level of overcurrent it can not operate properly due to its TCC (time-current curves) characteristics.

Due to their location (inside the tank) and their function (internal failure detection), in case one of the fuses opens, it is advisable not only to change the fuse, but also to take the transformer to manufacturer to repair it.

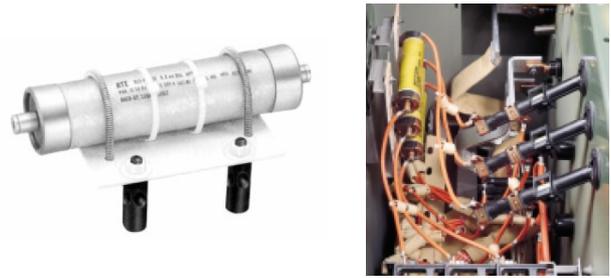


Fig. 8. Submersible current-limiting fuse (COOPER)

When current requirements are too high, it is possible to install two parallel fuses per phase, increasing performance rating but with higher cost of space.

Apart from the usual submersible current-limiting fuses, some manufacturers offer some fuses with shorter dimensions (“Shorty”, Figure 9), especially designed to be more compact in design and make the installation easier in shorter distribution transformers.



Fig. 9. OS Shorty back-up current-limiting fuse (HIGH-TECH FUSES)

### 4. General Protection

#### A. Dry-Well Canister Fuses

These are general purpose current-limiting fuses (Figure 10), accessible from high-voltage compartment, air-insulated whose canister extends into the tank beneath the oil. External replaceable, there are straight and slant type designs (the last ones more appropriate for pad-mounted transformer shorter dimensions).

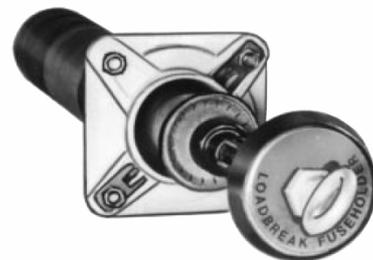


Fig. 10. Canister type fuses (SIEMENS)

The fuseholders are hot stick operable and two types can be distinguished:

- Nonloadbreaking designs. Due to the absence of arc stretching and quenching capabilities in this type of fuses, a load-breaking switch becomes essential. They present the possibility of optional interlock with this switch, using a safety baffle (Figure 11). This way is possible to assure that, unless the switch is off, there is no possible access to fuse disconnection.
- Loadbreaking designs. They are similar, but just with the addition of a loadbreak switching device, using an arc quenching component.

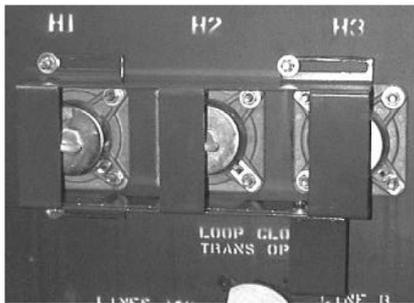


Fig. 11. Canister fuse safety baffle (GE)

**B. Clip Mounted Fuses – Arc Switchblade**

These are full-range current-limiting fuses (Figure 12), usually used for live front construction, so the hotstick operation becomes essential. Like in the case of submersible current-limiting fuses, if higher current requirements are needed it is possible to use parallel mountings.

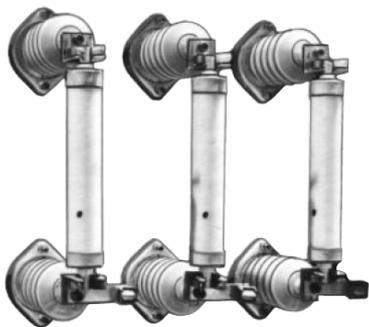


Fig. 12. Clip Mounted Fuses (SIEMENS)

An arc switchblade (Figure 13) can occasionally be mounted in tandem with these fuses, or they can sometimes be mounted alone connected to current-limiting fuses with different ranges.

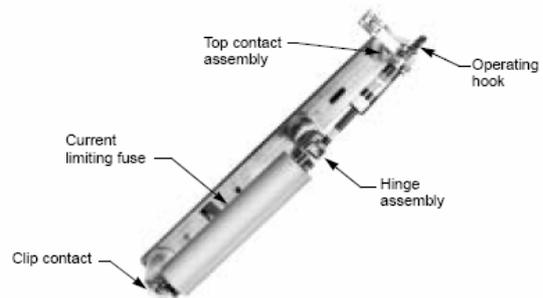


Fig. 13. Arc-Strangler with Clip Fuse (SQUARE D)

In those cases, incoming lines connect to the top clips, so when the switch is open the line is de-energized.

**5. Most commonly offered overcurrent devices**

Analyzing the most common overcurrent protection devices offered by different pad-mounted transformer manufacturers in [1], we can conclude with table I.

As it is shown, dead front practices are more offered than the live front ones, especially where fuses are concerned. Among them, the coordination between an expulsion fuse and a partial-range current limiting fuse results to be the most offered one. As it can be seen in [6], this protection system has some advantages comparing with the use of a single general purpose current-limiting one: cost, operation and maintenance ease and safety. Besides, due to their external replaceability, Bay-o-Net fuses seem to have an important advantage over the internal cartridge fuses.

Table I. Most common overcurrent protection devices

	ABB	COOPER	ERMCO	GE	HOWARD INDUSTRIES	MAGNETRON	MGM	SIEMENS	SQUARE D
Bay-o-Net Fuses	X	X	X	X	X	X	X	X	X
Internal Cartridge Fuse	X	X	X	X	X			X	X
Internal Partial-Range CL Fuse	X	X	X	X	X	X	X	X	X
Dry-Well Cannister Type Fuses	X		X	X	X		X	X	X
Clip-Mounted Live Front Fuses – Arc Strangler		X						X	X
Magnex® Interrupter		X							
Isolation Link		X				X		X	

## 6. Overvoltage Protection

Usually, in pad-mounted transformers, MOV type surge arresters are used for overvoltage protection. It is possible to distinguish three different types:

- External Elbow arresters (Figure 14). They are dead front surge arresters, which are connected to dead front bushings. It is generally used with a Rotatable Feed-Thru Insert to allow its use in the same bushing of the elbow connector.



Fig. 14. Elbow surge arresters (COOPER)

When space problems are important or in certain applications, other type of elbow surge arresters, called parking stand arresters, can be used.

- External Live Front arresters (Figure 15). They are used for live front configuration and are made with polymer or porcelain housings.



Fig. 15. External live front arresters (SQUARE D)

- Under-Oil arresters (Figure 16). They are designed to be mounted inside the transformer tank and operate submerged in oil. These arresters are used to prevent shortened life due to several factors: surface contamination, wildlife damage, vandalism or moisture ingress. When transformer testing is done some kind of disconnecter becomes essential.

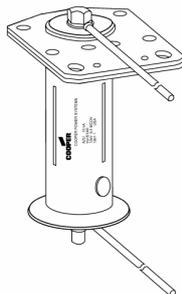


Fig. 16. Under Oil arresters (COOPER)

## 7. Conclusions

This paper analyzes the different devices used for pad-mounted transformer primary overcurrent and overvoltage protection, describing their main characteristics. This knowledge is especially important for proper protection selection and also for coordination, when two devices are connected in series [7].

The advantages or disadvantages of each possibility should be considered from different points of view:

- Live or dead front construction
- Replaceability ease
- Space and price cost
- Maximum/minimum interrupting ratings and system short circuit power
- Coordination with other devices

## Acknowledgements

The work presented in this paper has been performed by the research team of Project 1/UPV 00142.345-E-15277/2003, with funding from the University of the Basque Country (UPV/EHU), Spain.

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