Transforming standards

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IEEE style pad-mounted transformers have been used in the Americas and other parts of the world for a long time. However, it can still be somewhat of an unknown transformer style in some markets. With the increased demand from the USA, mostly for pad-mounted transformers for onshore wind farm and solar applications, transformer manufacturers from IEC markets may not be all that familiar.

According to IEEE Standard C57.12.80 (IEEE Standard Terminology for Power and Distribution Transformers), the definition for a pad-mounted transformer is 'an outdoor transformer utilized as part of an underground distribution system, with enclosed compartment(s) for high-voltage and low-voltage cables entering from below, and mounted on a foundation pad.'

Yet, one of the most obvious unique characteristics of the IEEE pad-mounted transformer is its self-protection. The transformer is fully protected by means of two fuses: an oil immersed backup current-limiting fuse and an oil immersed expulsion fuse. Both fuses must be properly coordinated for a full range protection inside the transformer, without the need for external fused switchgear.

Currently, the ability to fully protect pad-mounted transformers using the full range protection concept goes up to 35KV class and 8 MVA size.

So, what is full range protection? Let's just say it is a protection coordination concept made with devices to cover the three overcurrent areas of the transformer: overloads, external, or secondary, short circuits, and internal failures.

All transformers should be protected against these three possible over currents in a power system. Each one of these overcurrents conform a range of current magnitude in a per unit basis; range number 1 applies to overloads with a '1 to 3' per unit range, range number 2 applies to external short circuits with a '3 to maximum short circuit current' per unit range, and finally range number 3 applies to internal failures with a 'bigger than maximum short circuit current' per unit range.

It should be noted that the maximum short circuit current is 100/Z%.

The combination of the two fuses, if properly coordinated, allows for the protection of the transformer in all of these three ranges. The Expulsion Fuse protects overcurrents from range 1 and 2 while the Backup Current Limiting Fuse protects the larger current faults resulting from transformer failure. In reality, this Current Limiting Fuse does not protect the transformer but rather it isolates the failed transformer, from the system, to avoid the failure from extending into other areas within the system.

The coordination is done as follows. Firstly, the fuse arrangement must protect the transformer in any of the three overcurrent zones (Fig. 1). The Minimum Melting Time (MMT) curve of the expulsion fuse must always stay to the right of the transformer inrush characteristic (Figs. 2 and 3).

The Expulsion Fuse and Backup Current Limiting Fuse curves must intersect at a current point, or cross point, that meets following two conditions. The amps value at the intersection point must be higher than the Current Limiting Fuse minimum interrupting rating (IR) and lower than the Expulsion Fuse maximum IR. We do not want the Current

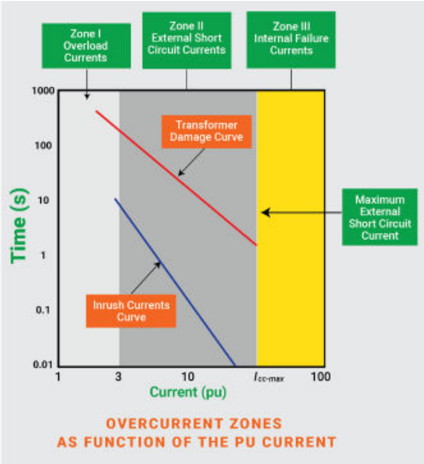


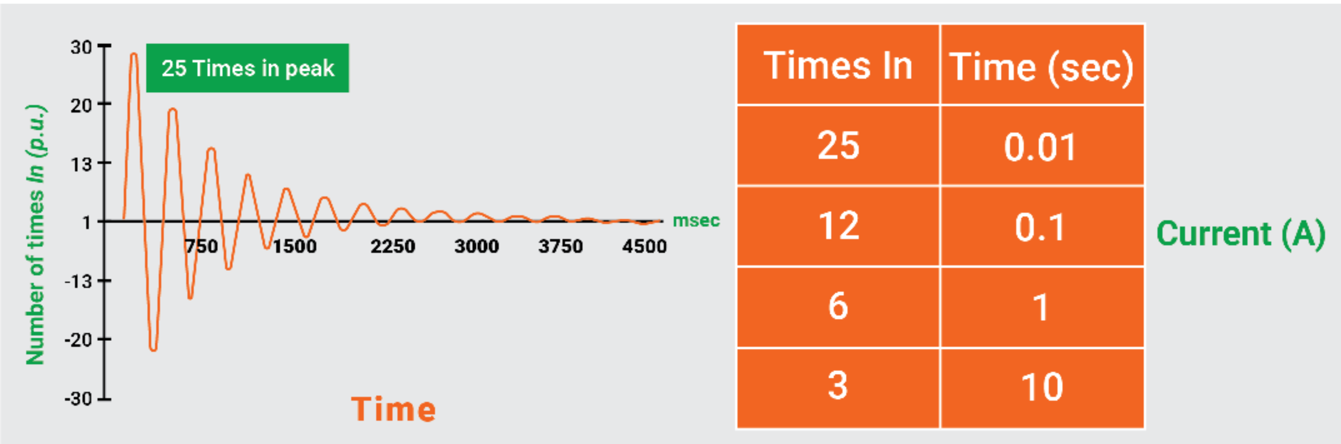
Fig. 1. Main transformer overcurrent zones

Limiting Fuse operating due to short circuits external to the transformer, thus the amps value of intersection must be higher than the maximum short circuit current allowed by the minimum impedance of the transformer. This is accomplished by locating the cross point in the yellow zone 3 of Fig. 1.

Lastly, curves of selected fuses must be separated enough to have for t = 1000 seconds a ratio of currents less than 0.90, thus avoiding damages to the Current Limiting Fuse Elements.

We already know that both fuse types are oil immersed. While the Current Limiting Fuse is installed by means of a fuse holder that is clamped anywhere inside the transformer, the Expulsion Fuse is installed by means of an externally removable bayonet fuse holder, which easily provides a way to change the fuse should it operate without the need to open the transformer.

In those cases where the transformer size is larger than 3.2 MVA at 34.5KV or 2.2 MVA at 23KV, the Expulsion Fuse must be installed inside the transformer without a bayonet fuse holder.



Times In	Time (sec)
25	0.01
12	0.1
6	1
3	10

Fig. 2. Inrush current typical accepted characteristic

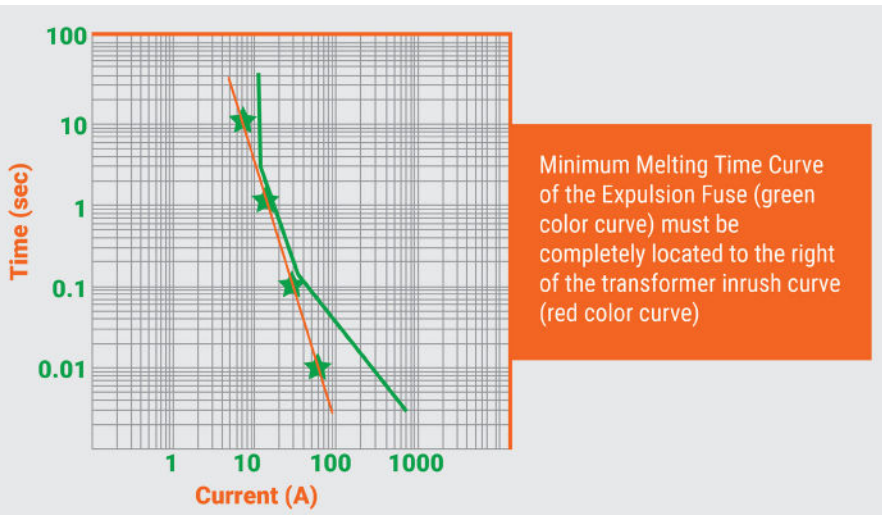


Fig. 3. Transformer inrush characteristic and MMT fuse curve location

A look into the future

This fuse arrangement is adequate for currently available solar farms and onshore wind farms where the transformer size required is not more than 8 MVA. However, as the need arises for larger distribution transformers, especially coming from offshore wind turbines, demand will increase for transformer components for higher current and voltage ratings: HV bushings, LV bushings, fuses, etc.

It is expected that turbines will reach 20MW by 2030 at voltage levels of 72.5kV. These changes will be accompanied by an increase in the IEEE pad-mounted step-up transformer kVA size up to about 20MVA as well.

One of the biggest challenges in the industry is the upgrading of the oil immersed Backup

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Current Limiting fuses and Expulsion Fuses to fully protect these larger sized transformers.

Currently, Backup Current Limiting Fuses are available with a maximum voltage of 38KV while Expulsion Fuses have a range of up to 34.5KV. Both types of fuses will have to be upgraded to 42KV class for 72.5KV Ground Y systems or 42KV Delta connected systems. 72.5KV Delta connection is not considered at this time due to technical limitations.

The H-J Engineering team is working to accomplish it.

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Biographies

Xavier Pinol is Sales Manager for EMEA and Asia at The H-J Family of Companies. Based in Barcelona, Spain and with over 20 years of experience in the transformer industry, Xavier holds a dual BA degree in international business and Marketing and an MBA, both from Saint Louis University in St. Louis, Mo. USA.

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About The H-J Family of Companies

The H-J Family of Companies provides high quality, cost-effective products and services for transformers and switchgear apparatus. Founded in 1969 in High Ridge, Mo. USA, today H-J has manufacturing plants in the USA, Mexico and China while at the same time developing strong partnerships with world-renowned manufacturers and making available to customers complete solutions with a breadth of offering which is unprecedented in the market.

Expulsion style fuses

Bayonet style fuses

Bayonet fuse holder

Oil immersed back up current limiting fuses