Protection of Distribution Transformers

Raycap

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Contents

Executive Summary

Distribution transformers are the most critical equipment installed on the electric grid. Transformers are exposed to severe weather conditions, and failure rates dramatically affect network reliability as well as increasing maintenance costs for the Distribution System Operators (DSO).

In the past, distribution transformers have been protected solely by medium voltage arresters. Today, appropriate surge protection is also required on the low voltage side of the transformer.

Conventional Surge Protective Devices (SPD) cannot withstand the high levels of over-voltage and impulse currents anticipated in the event of a lightning strike; indeed, their internal configuration gives rise to safety concerns.

Raycap has developed an innovative protection solution based on our patented Strikesorb SPD technology. Our unique devices solve distribution transformer overvoltage problems once and for all, providing immediate benefits to DSO in terms of cost reduction, grid reliability and safety.

This report will analyze transformers failure rates in order to present the huge cost these failures represent to DSO. In addition, it will use scientific studies and pilot projects to demonstrate both the necessity of installing Raycap's surge protection technology on the low voltage side of transformers, and the millions of Euros Distribution System Operators (DSO) could save every year as a result.

Transformer Failure Due to Power Surges

More than 75% of transformer failures are due to power surges, the majority of which are caused by lightning and switching surges. However, it is standard practice to limit distribution transformer lightning protection to the installation of medium voltage surge arresters. It should be borne in mind that transformer failure can also stem from lightning surges arising on the low voltage side of the transformer. The latter may occur when lightning strikes the low voltage power lines directly or indirectly, or when the resultant surge is transferred throughout the medium voltage side of the transformer.

The transfer of overvoltages to the low voltage side are mainly associated with a rise in potential at the transformer grounding caused by the current flowing through the medium voltage surge arresters and creating an electromagnetic coupling between the medium-voltage and low-voltage transformer terminals.

Installing SPDs significantly reduces the overvoltages to safe (low) peak values which remain practically unaffected by transformer and/or load grounding resistances. The installation of SPDs can minimize the effects of a high grounding resistance under surge current conditions.

Financial Consequences of Transformer Failure

Power distribution grids are particularly susceptible to lightning surges. The latter may cause system outages which, by affecting the reliability of the power supply, can result in enormous financial costs. The distribution transformer is the backbone of the grid, and its performance directly affects the reliability of the power distribution provided to the end customer. The failure of distribution transformers can mean power outages for many customers with serious financial consequences for the DSO.

The direct costs to the Distribution System Operator (DSO) include:

- Cost of purchasing new transformers
- Labor costs
- Logistical costs
- Lost revenues due to power outages

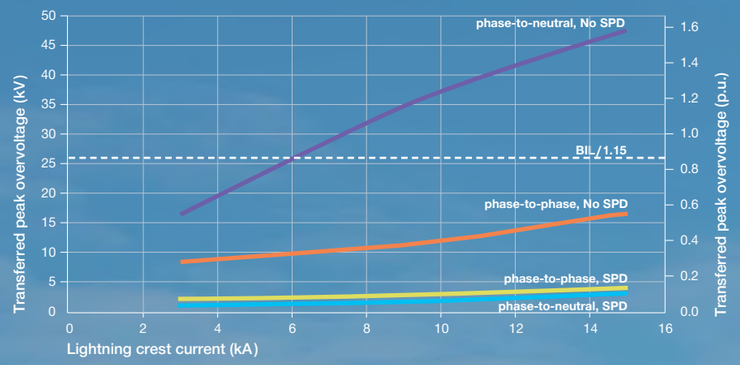
Although these costs may vary considerably from country to country, it has been calculated that a single transformer failure can mean an average direct cost to the power provider of over €5,000. Even a low transformers failure rate of 2.5% due to lighting surges would mean an annual direct cost to the DSO in excess of millions.

The Need for Protection on the Low Voltage Side of the Transformer

Scientific modelling analysis performed using ATP-EMTP simulations has concluded that:

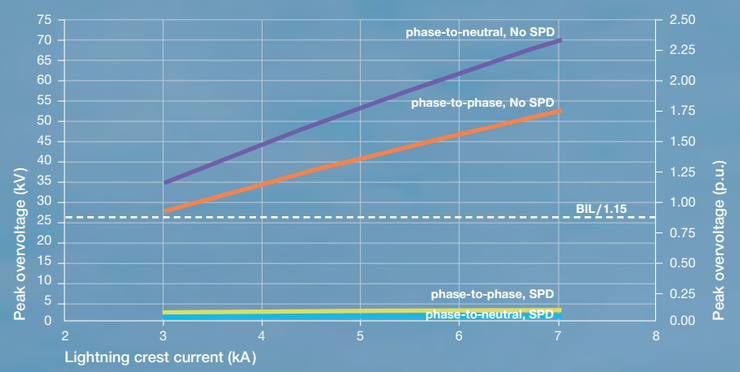
In the case of lightning strikes to the MV overhead distribution lines, the overvoltages transferred to the transformer's LV terminals may exceed their insulation level, even when surge arresters are in operation close to the transformer's MV terminals. These transferred overvoltages are greatly reduced when surge protective devices are installed (see Fig. 1).

FIGURE 1. Peak overvoltages transferred to the LV terminals of the transformer as a function of lightning crest current; $RE_T = RE_L = 10\ \Omega$



For lighting strikes to the LV overhead service line, the overvoltages arising at the transformer's LV terminals may exceed their insulation level, even in the case of less intense strikes (see fig. 2); these overvoltages are greatly reduced when surge protective devices are installed. The overvoltages transferred to the MV terminals of the transformer are also reduced when surge protective devices are installed at the LV side.

FIGURE 2. Peak overvoltages arising at the LV terminals of the distribution transformer as a function of lightning peak current; $RE_T = RE_L = 10\ \Omega$



Drawbacks of Conventional SPD Technologies

Transient overvoltages can be classified into two categories according to their origin:

- **Externally-generated overvoltage** events caused by lightning
- **Internally-generated overvoltages** caused by generators switching on or off or by the operation of fuses and circuit-breakers

Surge Protective Devices (SPDs) can be installed to prevent damage to low-voltage equipment caused by transient overvoltages. The SPDs should have the following characteristics:

- **High energy-handling capability.** The SPD should be capable of withstanding high-energy transient surge currents
- **Protection level.** The SPD should provide an effective voltage protection level which is lower than the withstand capability of the equipment being protected
- **Safety.** The product should not be prone to catastrophic failure under any circumstances
- **Continuous protection.** The SPD should provide uninterrupted protection
- **Maintenance-free.** The lifespan of the SPD should be greater than that of the infrastructure it protects.

The conventional SPD technologies available on the market employ either Spark Gaps or Metal Oxide Varistors (MOVs). Unfortunately, both of these technologies come with specific drawbacks and safety issues:

Spark Gaps, which consist of two electrodes separated by an air gap, have high energy-handling capabilities. However, because they are slow to react, the protection they provide is extremely limited. They are typically certified as IEC Class I SPDs, which means they are tested for direct lightning currents with the long duration 10/350µs waveform.

MOVs, although offering more effective protection than Spark Gaps, have very low energy-handling capabilities, while their initial performance degrades very quickly due to inefficient thermal energy management. They are typically certified as IEC Class II SPDs, and are tested for induced lightning currents with the shorter duration and high rise-time 8/20µs waveform.

A combination of these two technologies is sometimes advocated—the objective being to overcome the inner limitations of each technology. However, this leads to complex coordination problems which make such devices cumbersome and expensive to integrate. Furthermore, surge protection systems of this type remain prone to failure.

Field experience has shown that none of these SPD configurations can guarantee effective, safe, continuous protection.

Raycap's Next Generation Overvoltage Protection Technology

With the aim of overcoming the limitations of conventional SPDs, Raycap introduced Strikesorb,® an innovative surge protection technology that is capable of handling large amounts of energy safely. Strikesorb has an extremely high surge current capability, meaning it can withstand thousands of voltage transients without performance degradation or failure. Furthermore, it ensures maintenance-free and safe operation without relying on internal disconnects.

Strikesorb SPDs are available in four different form-factors: Strikesorb 80, Strikesorb 40, Strikesorb 30 and Strikesorb 30-DRM. All four come in a variety of operating voltages, making them suitable for integration across applications with extremely diverse electrical, mechanical and environmental requirements.

All Strikesorb modules accord fully with UL 1449 3rd edition (2013), and comply with IEC 61643-11 (2011 edition). Our Strikesorb 40 and Strikesorb 80 units are certified as Class I SPDs and also meet the requirements of Class II SPDs. Raycap offers a 10-year global replacement warranty on all Strikesorb modules.

Rayvoss® solutions rely on Strikesorb technology and are suitable for installation in most industrial applications. They come in the form of enclosures which are easy to install at existing or newly-built facilities, ensuring the highest standards of electrical protection for these systems and guaranteeing minimum operation downtime. For power providers, installing Rayvoss represents both maintenance-free protection from all overvoltage events and the added benefit of increased safety for people and property. Given the significant operational costs caused by overvoltage events, investments in Rayvoss are typically recovered within a few months of installation.

Raycap's Transformer Protection Solution

Strikesorb technology offers superior performance and safety to conventional SPDs. However, Raycap's system is also easy to install very close to the transformer's LV terminals and, perhaps most importantly of all, offers maintenance-free service with a guaranteed lifetime of more than 10 years.

Raycap's transformer protection solution consists of three (3) Strikesorb 80 modules with the neutral earthed locally in the transformer.

Raycap's systems have been protecting distribution transformers since 2006. Operating in severe environments where transformers typically failed as often as 10 times a year, our system's unique performance has led to a significant drop of up to 80% in transformer failure rates, saving our customers hundreds of thousands of Euros in operational expenses.

About Raycap

Founded in 1987, Raycap has decades of experience creating products that protect the world's most valuable industrial assets. The company strives to keep its customers' sophisticated, mission-critical equipment running through any overvoltage event. Raycap never stops striving to make advances in the design and manufacture of its surge protection technology.

The company is the market leader in the field of surge protection technology because it collaborates with its customers and transforms their needs into unique, innovative solutions such as Strikesorb, which represents the state-of-the-art in surge protection technology today.

Manufacturing Capabilities
Raycap has created a global manufacturing organization that is capable of meeting the most demanding requirements of the most discerning customers

The company's advanced global quality system and disaster recovery strategies focus on ensuring uninterrupted global supply. In addition, while Raycap can handle large customer volumes and roll-outs, it also specializes in custom manufacturing.

In order to optimize the service it can provide its global customers, the company maintains automated manufacturing plants in Europe (Drama, Greece and Munich, Germany) as well as in the United States (Post Falls, Idaho and Dallas, Texas). All facilities adhere to the industry's most stringent quality and inspection standards.

Raycap's products are certified by global standards bodies and the company's testing facilities include a UL-certified test lab in the United States and IEC & VDE certified R&D labs in Europe.

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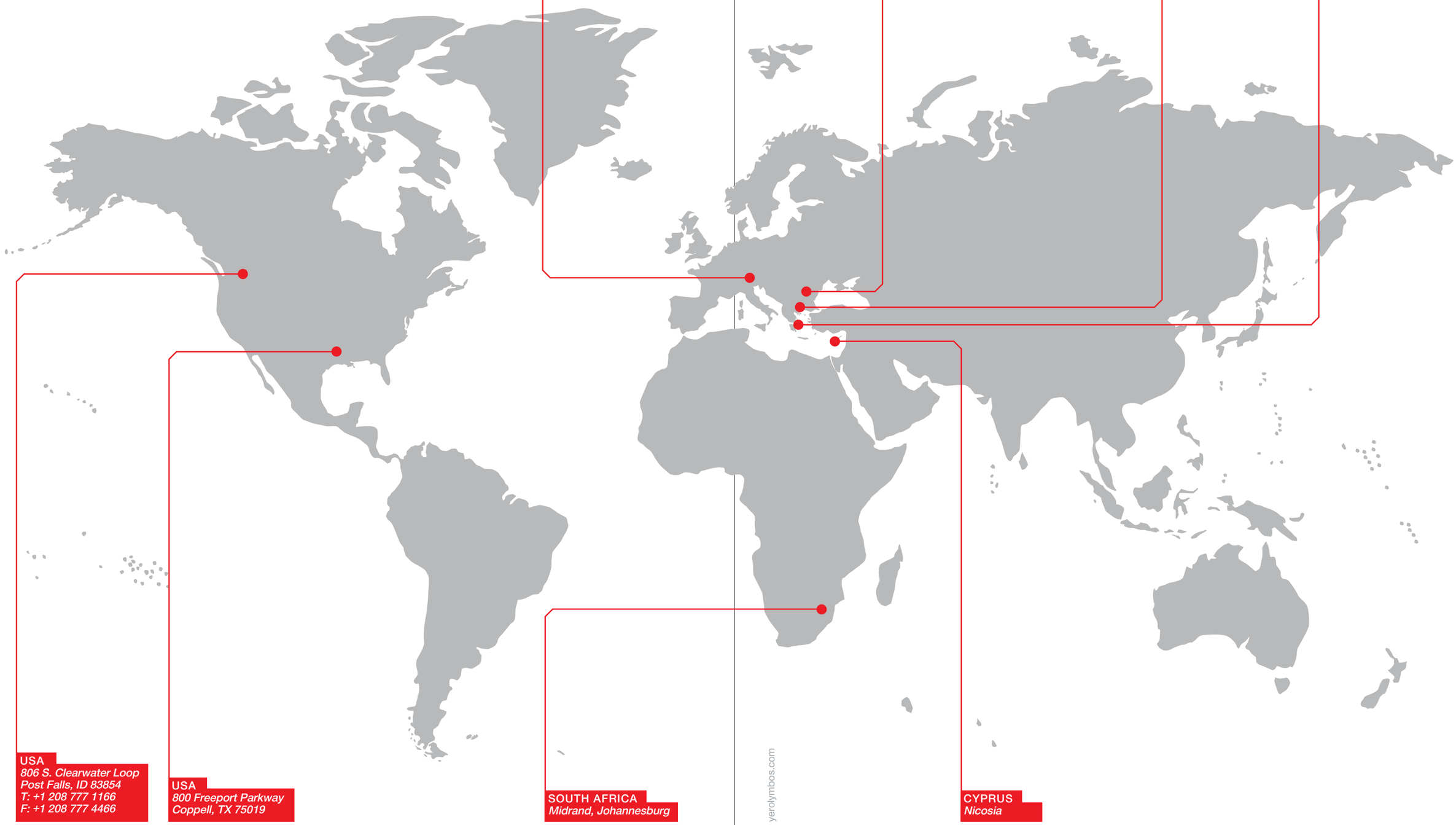

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