# ENHANCED OVERVOLTAGE PROTECTION FOR RELIABILITY BEYOND THE FIRST DECADE

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## ABSTRACT

*Adequate overvoltage protection is essential for long solid dielectric insulation service life. Within the first few years of operation, the AC breakdown (ACBD) voltage of new cable insulation is quite high, but typically drops within the first decade to a fraction of the original value. Overvoltage protection margin has traditionally been calculated on the basis of new cable basic impulse levels (BIL). Thus, there is a significant opportunity to improve overvoltage protection by calculating margin using the typical BIL insulation will ultimately retain. A utility case study involving thousands of kilometers of cable systems study will be presented to show how a combination of improved overvoltage protection and the removal of discrete defects can significantly improve cable reliability and therefore extending its useful life for decades*

## KEYWORDS

Arrester, surge, lightning, overvoltage, transient, cable, fault, asset management, life extension, reliability, partial discharge

## INTRODUCTION

Medium voltage solid dielectric cable systems have provided good performance over the last few decades. However, some significantly aged populations are experiencing undesirable increasing failure rates. Many cable owners are looking for ways to reverse this trend in order to maintain a high level of reliability. While some cables are failing, research [1] shows other cables of the same vintage removed from service can perform as good as new cables in laboratory tests, provided they are not exposed to extreme conditions. So why are cables failing? They could have stress enhancements which are producing high localized stresses, but studies like the one described later in this paper show, that even after removing PD producing defects in cables, a few cables failed. In such cases the authors noticed the single most common risk factor associated with an unexpected failure on an aged cable with no substandard PD was a missing arrester. This realization lead to further study and the conclusion of this paper indicating the critical need to have adequate overvoltage protection.

## TRANSIENTS AND IMPACT ON CABLE SYSTEMS

Transients can be grouped into two categories operational switching, and lightning. While lightning can cause the highest stresses, switching is the most frequent. The sources of switching transients include circuit switching, restoration activities (breaker operations and fuse reclosures), impulse fault location, momentary flashovers and grounds (momentary contacts with air insulated components), complete faults elsewhere in the system, sectionalizers, capacitor banks switching, and transformer tap changes.

In general, transients reflect and resonate within the power system and if proper overvoltage protection is not implemented, can increase in magnitude exponentially [2]. Voltage transients typically occur in the microsecond to millisecond time-frame. This short duration is more than enough time to damage the cable insulation.

One commonly misunderstood aspect of voltage transients is how the duration of the pulse is represented in circuit length. A pulse typically travels down a shielded power cable system at a velocity in the range of 160 m/µs (~500 ft/µs). Thus a 10 µs pulse is on the order of 1,6km (1 mile) long and a 100 µs pulse is on the order of 16 km (10 miles) long. Thus, transients impact all insulation systems over a large area and if arresters are not properly designed and installed at points of large impedance changes (including branches, cable ends, transitions from overhead to underground, shield breaks, and long shield connections), doubling and triple reflected waves can cause extreme stress on cable systems.

All insulation systems are adversely affected by extreme electric stress. In general, solid dielectric cable system insulation fails due to an erosion process associated with phenomena called partial discharge (PD). PD can arise from an extreme focus of electric stress, a lack of the appropriate insulation, or a combination of both.[3] A focus of electric stress, or stress enhancement, can be caused by an accessory interface contamination, a foreign object, a protrusion of a semiconducting layer, or a water tree. A lack of appropriate insulation, or a void, can be caused by a damaged semiconducting layer, overheating of the cable or accessory insulation, an insulation cut, a lack of accessory void filler or an incorrect accessory/cable interface dimension. PD, and its associated erosion process at a defect site, is rarely active at steady state operating voltage. PD is initiated, when localized electric stress overcomes the local dielectric strength. The voltage at which PD initiates is called the partial discharge inception voltage (PDIV). PD activity extinguishes when the localized voltage stress is sufficiently lowered. The voltage at which the PD extinguishes is called the partial discharge extinction voltage (PDEV). Voltage transients; fast, short duration electrical transients, are the primary driver of PDIV and insulation failure. However, extreme transients in the range of 4 Uo to 5 Uo not only can advance defects, they can create new defects in aged cable by overcoming the local dielectric strength of portion of otherwise serviceable insulation. In some cases of aged cable 4 Uo to 5 Uo is sufficient to fail the cable insulation immediately. Successive transients can cause intermittent growth of an electrical tree (fault channel) [2,4]. As the