Case Study: The Effectiveness of Line-to-Line Discrete Protection Modes in Electrical Systems with a Neutral Connection

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Abstract--This document examines the use of line-to-line discrete protection modes in electrical systems with a neutral connection. The document investigates what existing IEEE (Institute of Electrical and Electronics Engineers) standards have to say regarding the use of discrete protection elements in the line-to-line mode when protecting electrical systems that have a neutral connection. Further, three case studies are cited to show the effectiveness of discrete protection in the line-to-line mode through the analysis of surge protective devices that have sacrificed themselves while protecting electrical systems with a neutral connection.

Keywords – protection modes, surge protective device, transient voltage surge suppressors, power quality

I. INTRODUCTION

Transient Voltage Surge Suppressors (TVSS) also referred to as surge protective devices (SPDs), have been applied to electrical systems for several decades. As power and control systems become more sensitive and complex, SPDs will continue to be utilized as an essential component of power quality.

SPDs of many sizes, types and circuit topologies are available in today’s market place. This paper will discuss the effectiveness of SPDs with discrete protection in the line-to-line modes (that is, protection elements exist in the line-to-line mode that are not dependent on the other modes being protected) when protecting electrical systems with a neutral connection by examining products that have sacrificed themselves while protecting electrical systems.

II. ELECTRICAL SYSTEM MODES

An electrical system mode, or mode, is a unique or distinct pair of circuit conductors within an electrical system. For example, a typical wye connected electrical system has ten available modes to be protected. The modes are each of the three line-to-neutral modes, the three line-to-ground modes, the three line-to-line modes, and the neutral to ground mode. A ten mode wye distribution circuit may be protected with commercially available three mode, four mode, seven mode or ten mode SPDs. The ten mode SPD is known as a “true all mode protection” device and provides discrete protection in all three line-to-line modes, all three line-to-neutral modes, all three line-to-ground modes and the neutral-to-ground mode. The three mode (typically, the three line-to-ground modes), four mode (typically, the three line-to-neutral modes and the neutral-to-ground mode) and seven mode (typically, the three line-to-neutral modes, the three line-to-ground modes and the neutral-to-ground mode) SPDs are known as “reduced mode” or “partial protection” SPD designs. The ten mode, true all mode SPD designs address each protection mode and the transients that appear on each mode independently.

III. IEEE STANDARDS

As cited in the references below, the IEEE (Institute of Electrical and Electronics Engineers) supports and recommends the use of discrete line-to-line protection in devices used to protect electrical systems with a neutral connection.

The Emerald Book, IEEE Recommended Practice for Powering and Grounding Electronic Equipment (ANSI/IEEE Standard 1100-1999). In section 8.6.1 of this standard, it states: “Surge protective devices used for three-phase, four-wire [Wye] circuits are generally recommended to be connected in all combinations of line-to-line, line-to-neutral, line-to-ground, and neutral-to-ground. Surge protective devices for three-phase, three-wire circuits are recommended to be attached in both line-to-line and line-to-ground modes.”

The IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000V and less) AC Power Circuits (ANSI/IEEE Standard C62.41.2-2002). A review of Tables 2, 3, and 5 from C62.41.2-2002 shows that all modes are affected by transient activity and the standard describes the voltage and current surges for the various “Location Categories”. Ring Waves (100 kHz) are shown in Table 2. Combination Waves (the 8x20 µs current impulse) are shown in Table 3. Note that Table 3 specifically calls out the line-to-line, line-to-neutral, line-to-ground modes for polyphase (electrical system with more than one phase) systems, with a reference to Table 5 for the neutral-to-ground mode discussion. In this standard, the IEEE clearly acknowledges the necessity of protecting against transient activity in all modes (line-to-neutral, line-to-line, line-to-ground and neutral-to-ground).

The above standards point out that discrete protection in the line-to-line mode is not only supported but it is recommended and necessary for a complete protection scheme.
IV. CASE STUDIES

To show the effectiveness of discrete protection in the line-to-line mode through the examination of surge protective devices that have sacrificed themselves in the electrical systems with a neutral connection, three case studies are discussed. In all of these cases the devices were installed on the electrical system for several months and did not fail as a result of a manufacturing defect or improper installation. All devices were replaced, free of charge, according to the Surge Suppression Incorporated® 25 year warranty.

Case 1: Surge Suppression Incorporated® model number SDL3D1. This device is a three-phase, high-leg delta (120/240V) SPD (3 phases, neutral and ground) with all ten modes discretely protected. This device was exposed to a direct lightning strike at the service entrance of a facility and was sacrificed. No equipment within the facility was lost.

In the analysis of the failed device, the findings were consistent with the report of the customer. All modes were inspected and it was found that the line-to-neutral, line-to-ground and neutral-to-ground modes were intact and functioning properly. The only sacrificed mode was from line A to line B.

In this case, it is obvious that the line-to-line mode took the majority of the surge energy rather than the energy being distributed through protection elements from line-to-neutral-to-line or from line-to-ground-to-line.

Case 2: Surge Suppression Incorporated® model number SHL3Y2-F. This device is a three-phase, wye (277/480V) SPD (3 phases, neutral and ground) with all ten modes discretely protected. This device was exposed to a sustained overvoltage in the line-to-line mode due to a utility fault and was sacrificed. No equipment within the facility was lost.

In the analysis of the failed device, the findings were consistent with the report of the customer. All modes were inspected and it was found that the line-to-neutral, line-to-ground and neutral-to-ground modes were intact and functioning properly. The only sacrificed mode was from line A to line C.

In this case, it is obvious that the line-to-line mode took the majority of the energy from the event that caused the failure rather than the energy being distributed through protection elements from line-to-neutral-to-line or from line-to-ground-to-line.

Case 3: Surge Suppression Incorporated® model number SHDL3Y1. This device is a three-phase, wye (120/208V) SPD (3 phases, neutral and ground) with all 10 modes discretely protected. With this device, no obvious event was reported at the time of failure, but the device was sacrificed. No equipment within the facility was lost and the unit prevented any disruption of service within the facility.

In the analysis of the failed device, all modes were inspected and it was found that the line-to-neutral, line-to-ground and neutral-to-ground modes were intact and functioning properly. The only sacrificed mode was from line B to line C.

In this case, the line-to-line mode took the majority of the energy from the event that caused the failure rather than the energy being distributed through protection elements from line-to-neutral-to-line or from line-to-ground-to-line.

V. CONCLUSIONS

Based on the recommendations by the IEEE and the case studies above, the inclusion of discrete line-to-line protection elements in surge protective devices are necessary, recommended and effective in electrical systems with a neutral connection.

In the examples cited above, the discrete line-to-line protection modes were the only modes damaged by any of the disturbances—in fact, the other modes were still fully functional. After having provided protection for the customer’s electrical system and connected equipment, Surge Suppression Incorporated® replaced the ten mode devices (with nine modes of protection still fully functional) under warranty and without cost. The damaged ten mode devices provided more protection modes than what many other manufacturers sell as new products—that is, a three, four or seven mode product without discrete line-to-line protection modes.

In the three cases cited above, the inclusion of the discrete line-to-line protection modes to provide true all mode protection, proved effective and protected the respective electrical systems and connected equipment from transient damage.

VI. REFERENCES


Ronald W. Hotchkiss is the Vice President of Product Engineering for Surge Suppression Incorporated® and has been involved in the design, development and certification testing of one-port and two-port surge protection devices for since 1990. Ron also manages engineering, safety agency, and compliance and quality operations. He is a member of IEEE’s Power Engineering Society and is an active participant and contributor to several IEEE SPD working groups for the development of standards and the Underwriters Laboratories Standard Technical Panel for Transient Voltage Surge Suppressors. He is a member of the IEEE Standards Association balloting group for the approval of IEEE standards. Ron received his Electrical Engineering degree with Honors from the University of South Florida in Tampa.

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