APPLICATION GUIDE

PIPE-TYPE CABLES

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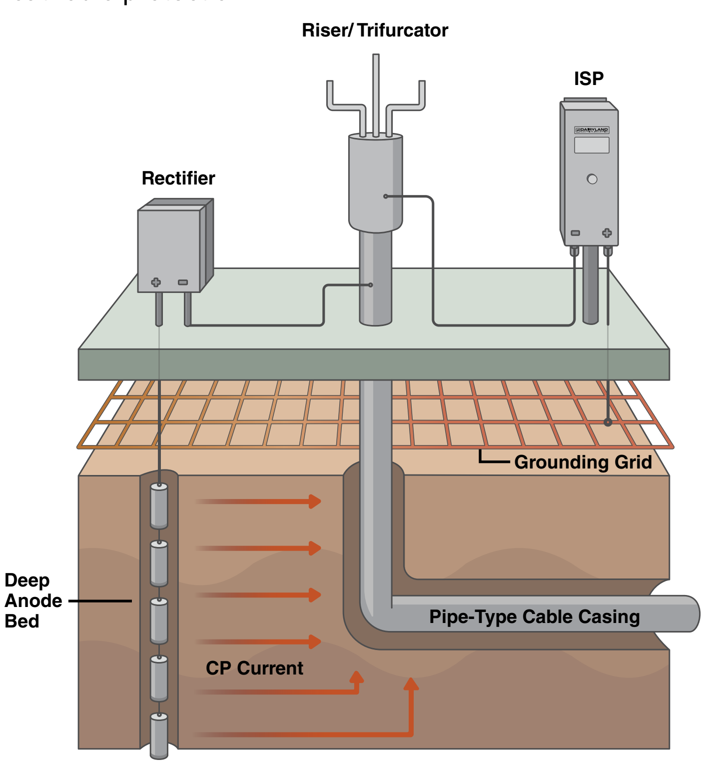
INTRODUCTION

Underground pipe-type transmission cable casings (and unjacketed lead sheath cables) are normally cathodically protected to prevent corrosion. Typically located in dense urban settings, pipe-cable casings are not easily accessed, and casing wall protection is key to extending the life of the asset, as repairs in these settings are highly undesirable and expensive. As pipe cable installations are often many decades old, cathodic protection serves the electric utility industry by minimizing corrosion at defects in the pipe coating.

Cathodic protection supplies DC current to the pipe, shifting the potential slightly negative in order to overcome the natural corrosion potential of the metal, usually steel. The current source is usually a rectifier, connected between the pipe cable casing and an anode arrangement. Many different anode arrangements are possible, but for urban settings with limited space the anode bed is most commonly a vertical deep well with multiple anodes to distribute current via a small surface footprint. Often the deep well is drilled within the substation. The coated steel casing will have current demand that depends upon the coating quality and condition.

TYPICAL ARRANGEMENTS

Effective cathodic protection is achieved by coating and electrically isolating the casing from the soil and from other metallic structures. This minimizes the current requirements, as well as corrosion risks. Coatings provide isolation from the soil, while other means are needed to electrically isolate the above-grade riser from contact with substation structures and the grounding grid. A solid-state Dairyland Isolator/Surge Protector (ISP) is the key to achieving isolation of the riser from other metallic structures, and address the key safety issues. Connected between the riser or trifurcator and the grounding grid, the ISP blocks DC from the CP system while simultaneously acting as a fault-rated solid-state switch to assure safety grounding of the casing during high energy transient events. The ISP takes the place of solid casing bonds to ground, accomplishing both the DC isolation and AC safety grounding needs. The following schematic illustrates the major elements of a typical pipe cable system with cathodic protection.



Elements of a typical pipe cable system with cathodic protection

The typical arrangement will locate one ISP at each end of a three-phase cable run, as the AC grounding means. This replicates the fault-rated bonds that would otherwise be present on a transmission system at each end of the circuit. Another common use occurs at riser poles, where overhead transmission lines transition to underground. In that case, stand-off insulators separate the cathodically protected riser pipe from contacting the grounded pole, and the ISP bonds the riser to the pole and its grounding system.

Where transition joints separate a cathodically protected underground cable construction from an unprotected type, an ISP is also typically used to connect between the protected sheath (typically lead) and the unprotected sheath (typically copper). Often this occurs in a below-grade vault.

Older Technologies Used By Industry

The arrangement shown above involving the Dairyland ISP is the most typical protection method used on transmission systems. While most sites have been converted to the above design, one old arrangement for pipe-cable cathodic protection was referred to as a "resistor-rectifier" system. This involved major elements including a rectifier with substantial current output and a heavy resistor capable of handling fault current. The paralleled resistor and rectifier were both connected between the pipe and the substation grounding grid. The concept was that the resistor value was high enough to allow a DC voltage drop to appear on the pipe for cathodic protection, yet low enough to limit the voltage during fault conditions. In reality, this "split the difference" method was poor at accomplishing either goal, resulting in high rectifier output current, high voltage under fault conditions, and accelerated corrosion of the substation grounding grid, which was being used as an anode. A conventional CP arrangement instead uses a smaller rectifier, a dedicated anode bed, and a fully-fault-rated ISP connected between the pipe and grounding grid to keep voltage limited to low levels during fault conditions.

One other older technology that may still be present on some systems is the liquid-filled polarization cell, which has the characteristic of blocking DC and conducting AC. However, the polarization cell has major drawbacks of containing hazardous liquids, requires maintenance, and fails as an open-circuit. In contrast, the ISP is a fault and lightning rated switching device that assures safety grounding of the transmission pipe under all conditions—whether functional or failed—due to its fail-safe design.

ISP TECHNOLOGY

The ISP is a solid-state device that, under normal operating conditions, blocks the flow of DC current while simultaneously allowing the flow of any steady-state AC current. This characteristic applies up to a predetermined voltage threshold or up to a predetermined AC current threshold. Any time either threshold condition is exceeded, the ISP considers this an abnormal condition and instantly transitions to a virtual short-circuit to solidly ground the cable pipe casing. After the transient event, the ISP automatically reverts to its normal mode of blocking the flow of DC current while allowing any steady-state AC to flow to ground.

The ISP utilizes custom capacitors to provide a low impedance path for AC current while blocking DC current under normal operating conditions. Since capacitors cannot withstand the magnitudes of AC fault current associated with pipe-type cable faults, a current bypass path must be provided around the capacitors to protect them from failure. This bypass path is provided using inverse-parallel silicon controlled rectifiers (SCRs) that are triggered into conduction whenever either of the previously mentioned threshold conditions is exceeded. The SCRs are selected to be capable of carrying the fault current until the circuit breaker clears the fault. The ISP is offered in several standard fault current ratings that cover most applications.

Product Ratings

ISP ratings are selected to exceed the site steady-state and fault conditions to assure long life. The standard steady-state current rating is 90A AC-rms for this application, which exceeds typical imbalance, circulating, or stray current. Final installation should verify that this value is adequate by measurement using a clamp-on ammeter. AC fault ratings are selected to exceed the modeled current magnitude and time duration until cleared, including back-up clearing. Dairyland publishes multiple current-time combinations for the several ISP fault-rated models, to allow for interpolation of system fault current values and comparison to product ratings.

The voltage blocking threshold is set at a value above typical site conditions, yet low enough to be safe, with selection at either 12.5V or 20V peak. There is a relationship between the allowable DC voltage being blocked and the simultaneous AC steady-state current flow (contributing a peak AC voltage), the sum of which must remain below the ISP threshold limits. Typically, the combination remains below the ISP thresholds for steady-state conditions. The standard lightning (impulse) current rating is 75kA (8x20 microsecond waveform).

See full technical literature on the ISP at www.dairyland.com for additional product information.

Unit Operation and Self-Protection

Certain features must be built into any DC isolation/AC grounding device based on the use of SCRs for it to work as described under all field operating conditions. When SCRs are turned ON, they remain ON until the current through the SCR drops below a minimum “holding current” current value that is typically a small fraction of one ampere. In this application, whenever the SCRs are triggered into conduction, they also carry any DC current available in addition to any AC fault current. The DC cathodic protection voltage or stray DC voltage sources, such as from rapid transit systems, can readily provide sufficient current that may prevent the SCRs from turning OFF after the circuit breaker has cleared the fault. To assure that the device will revert to its normal operating mode after a triggering event, it is necessary to incorporate an automatic reset circuit; otherwise, the device could remain stuck in its conductive mode indefinitely. The standard ISP furnished by Dairyland will assure automatic reset with up to 40 amperes of DC current available. A unit that assures reset with at least 100 amperes of DC current is available upon request and is used only where significant stray DC current is available. One cannot assume that if the steady-state AC current is of a sufficient magnitude to cause the current to go through a zero value each one-half cycle, that permanent reset of the SCRs will result. This is explained in the next section.

For this application, the automatic reset circuit requires a complementary circuit to assure that the device will remain reset. During the time that the SCRs are ON, and DC current is also flowing, energy is being stored in the inductance of the system that exists between the DC voltage source and the decoupling/grounding device. Immediately after fault current ceases to flow, and the automatic reset circuit turns the SCRs OFF, the DC voltage will instantly increase in value to keep the current flowing. Depending on the system inductance, this voltage can increase to values well in excess of the 12.5 or 20 volt trigger level. Unless provision is made to address this issue, the device would immediately be triggered into conduction, starting an endless cycle of resetting and retriggering. Dairyland incorporates a voltage clamping/energy dissipation circuit that comes into play immediately after automatic reset occurs. This circuit limits the voltage increase, due to stored inductive energy, to a value below the trigger level (unless another over-riding triggering event occurred) while simultaneously dissipating the stored inductive energy, a process typically accomplished in less than a second. Once this inductive energy is dissipated, the unit will remain reset until the next triggering event.

Another highly desirable design feature built into the ISP is self-protection against failure if either the steady-state AC current or DC blocking voltage is above rating for the product model selected for extended periods of time. Should this situation occur, a red LED indicator will flash, indicating that this condition is occurring. During such event, the ISP will not be blocking DC but it will be protected from failure. (The LED is not incorporated in submersible models, but the self-protection feature is in all models.)

Dairyland ISP

Testing Options

An ISP option, specified by most power utilities, is a Test Point to allow advanced field testing. When the ISP incorporates a Test Point it can then be tested while in service with an ISP Tester available for purchase or rent from Dairyland. The ISP Tester measures all steady-state parameters associated with a given installation and it completely checks all functions of the ISP, including tolerances of critical parameters. It also determines if the ISP will transition to its shorted mode in the event of an AC fault or lightning surge and automatically reset.

The ISP can still be tested for basic functionality without the Test Point option, with details included in the product instruction manual. This includes use of typical clamp-on ammeters and multimeters.

PRODUCT APPLICATION DETAILS

As shown above, the most typical arrangement is to apply a correctly rated ISP at the end of each circuit, bonding the casing or riser to the grounding grid. Multiple circuits that have a common cathodic protection system ideally still utilize one ISP at each end of each circuit, to assure local bonding and grounding at each circuit. This limits over-voltage conditions local to each circuit by minimizing the conductor length, and therefore inductance, involved in connecting an ISP between the riser and ground grid.

The ISP is typically mounted on an existing substation steel structure adjacent to the riser to keep conductor lengths limited. A user-supplied custom support can be utilized when existing structures are not adjacent to the riser. For riser pole applications, the ISP is mounted to the pole at a height inaccessible to the public and adjacent to the connection points.

Polarity of the ISP should be noted, with the negative terminal (left hand terminal when facing the upright product) connected to the cathodically protected riser or casing, and the positive to the grounding system or grounded structure. Reversing polarity in some ISP models can short the cathodically protected structure to the grounding system, affecting CP effectiveness. NEMA two-hole terminals allow attachment of an insulated cable to the connection points, rated to match the ISP fault ampacity.

Mounting should generally occur in above-grade locations, in keeping with the NEMA 4X environmental rating of the product for the typical arrangement that includes the LED light and Test Point on the cover. Inclusion of these two items necessitates above-grade location. For vault application or other locations subject to immersion, the LED and Test Point options must be omitted.

The complete high-pressure fluid filled cable system will include a pump station and piping to pressurize and circulate the fluid in the cable system, providing cooling and dielectric to support the system voltage. The fluid supply system is often forgotten in the over-voltage protection scheme, resulting in a lack of protection being applied to the isolation joints in the fluid supply line. This can result in flashover, pipe damage, fluid loss, and fire during AC fault events. The solution is to apply an additional ISP connected closely across the isolation joint via short conductors to limit the over-voltage conditions to within the insulation limits. Connection to each side of the isolation joint, which may require brackets or other acceptable fault-rated attachment methods, results in better protection than connecting the ISP between the cathodically protected side of the joint and a nearby grounded structure. Finally, for complete protection, assure that the pump station and any piping on the non-cathodically-protected side of the isolation joint is all solidly bonded and grounded to the substation grounding grid.

Occasional system upgrades may result in increased system fault current or coupled steady-state imbalance or circulating current. Ratings of existing ISPs should be reexamined prior to planned system upgrades to assure that the device ratings exceed the expected exposures. As ISPs do not have a specific lifetime limitation when applied to conditions within their ratings, existing ISPs may be relocated to other system locations with acceptable fault exposure if a target site requires new, higher-rated ISPs as a part of an upgrade.