DC Decoupling/ AC Grounding of Cathodically Protected Pipe-Type Electric Transmission Cables

Application Note 4A

Introduction

Underground pipe-type transmission cables (and other unjacketed metal covered cables) are normally cathodically protected to prevent corrosion which, if not prevented, would lead to premature cable failure. To cathodically protect metal encased cables, the standard procedure is to insulate the metal casing, decouple it from ground, and apply a negative DC potential using either an active or passive cathodic protection system. For safety reasons, the metal casing must also be solidly AC grounded to prevent an unsafe voltage rise in the event of a cable failure. In the past, this dual DC decoupling/AC grounding requirement for the metal casing was accomplished by various means; the most common being (1) liquid-filled polarization cells, (2) a stainless steel resistor/rectifier combination, or (3) spark-gap type devices. Each of these approaches had undesirable limitations that users will readily recognize without elaboration. Recognizing these limitations, DEI worked jointly with several large U.S. power utilities in the late 1980's to develop a solid-state device that would not have the limitations of the devices mentioned. The result was a solid-state product called an Isolator/Surge Protector (ISP) that was commercially introduced in 1990. Several other DC decoupling/AC grounding devices have since been introduced by DEI for other applications, but the primary product used for pipe-type cable applications is the ISP. Since introduction, the ISP has become the only approved product at most U.S. power utilities because it is the only product that incorporates all of the functions required for this application.

Product Description

The DEI catalog contains a section titled "Technical Information on the ISP." This section is recommended reading for anyone new to this application. Following is a synopsis of this section.

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 back to its normal mode of blocking the flow of DC current while allowing any steady-state AC to flow to ground.

The ISP utilizes one to three custom made capacitors (depending on the steady-state AC current rating specified) 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 by-pass path must be provided around the capacitors so as to protect them from failure. This by-pass 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 so that they are capable of carrying the fault current until the circuit breaker clears the fault. The ISP is offered in four standard fault current ratings that cover most applications, with higher ratings available upon request.

Key Design Considerations

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 are also carrying 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 so as to 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 DEI 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 in an attempt 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. DEI 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 in to 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.)

An ISP option, specified by most power utilities, is a Test Point. When the ISP incorporates a Test Point it can then be tested in situ (i.e., while in service) with a tester available for purchase or rent from DEI. This 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.

Where the AC fault current is limited, and a DC voltage blocking level of about 4 volts is acceptable, another product called a PCR (Polarization Cell Replacement) can be used. Since this product is not based on SCRs, it does not require many of the above features that are unique to a SCR based design.

Product Application

For most pipe-type cable applications, an ISP (or PCR, if selected) is connected at each end of a pipe-type cable to electrical system ground. For long pipe-type cable runs, it may be necessary to connect a unit to ground at intermediate points. Contact DEI if additional information is required.

Experience has shown that the steady-state conditions imposed on pipe-type cable can vary with time, system loading, system reconfiguration, etc., therefore, it is recommended that the steady-state AC current rating and the voltage blocking rating selected be well above the values that might be obtained by taking spot measurements.