Over-Voltage Protection of Insulated Joints in Pipelines
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Introduction
Insulated joints in pipelines may be subject to over-voltage failure due to lightning and, in some applications, AC voltage. When a pipeline is near an electric transmission line, it can be subject to significant AC voltage if a phase-to-ground fault occurs. Over-voltage protection against both lightning and AC fault conditions is possible using appropriately rated products, and is required for protection of equipment and personnel.

Various types of insulated joints appear in pipeline facilities, including fittings in measurement tubing, threaded unions, flanged insulators, and monolithic insulators. All types can fail if not addressed, and should have over-voltage protection.

Solid-State Over-Voltage Protection
A solid-state protection device connected across the insulated joint will limit the voltage to safe levels, and provide a conduction path around the joint, protecting the insulation system. Devices switch into this protective mode during an event, and then automatically switch back into the OFF state to isolate the cathodic protection system.

Dairyland offers a large selection of products specifically designed to provide over-voltage protection for insulated joints in cathodically protected systems. Solid-state products offer numerous benefits over alternatives including: Fail-safe construction for assured safety grounding, maintenance-free operation, high ratings for AC fault current and lightning, safe turn-on voltage level, and Dairyland is known for outstanding technical support. In addition, products commonly used for this application have extensive third party certifications, discussed below.

Safety Regulations Affecting Insulated Pipeline Joints
U.S. Pipeline Safety Regulations: When the voltage across an insulated joint exceeds the voltage withstand level, arcing will occur either through or around the joint insulation and current will flow. Arcing can damage and short out the joint, or in the event of a leak at the joint, a combustible atmosphere may be present and may be ignited by the arc (assuming the pipeline is carrying a flammable material). To protect personnel and public against this possibility, Section § 192.467 (e) and (f) of the U.S. Pipeline Safety Regulations requires protective measures to prevent arcing across insulated joints, both for lightning and AC fault current. These protective measures require the installation of a suitable over-voltage protective device across the insulated joint. This regulation also incorporates “by reference” the US National Electrical Code, further requiring compliance to electrical product safety standards. Dairyland products meet these requirements (likewise in Canada per the Canadian Electrical Code and hazardous location standards).

Similar International Regulations: Due to the universal risk of unmitigated over-voltage affecting safety at insulated joints, many world-wide governing and technical authorities mandate actions to prevent these hazards. Either under the health and safety regulations, or regarding product use in hazardous locations, authorities require protection product use at insulated joints. Dairyland products are third-party certified to numerous international standards to assure users and regulators that the highest level of care has been applied to product design and use. Examples of such certifications include UL, ATEX, IECEx, EAC, among other standards and certification systems.

Why Not Use an Arrester?
Some companies consider using spark gap arresters to address over-voltage concerns on insulated joints. However, these products have some serious shortcomings compared to solid-state over-voltage protection devices and are not recommended.

Fail-Safe Construction
Dairyland devices are considered “fail-safe.” If exposed to fault current values beyond their already high ratings, Dairyland devices will always fail safely and un-eventfully in the shorted mode (fail as a dead-short), bonding the two points together for safety. This assures that over-voltage conditions will be addressed – whether the product is working or failed. (Failures are exceedingly rare due to the high energy capability of the products.) A gapped arrester has an open gap, which will always remain an open gap. If the arrester were to fail, it would be as an open circuit. After failure, an arrester provides no over-voltage protection and a potential safety hazard is created, as voltage can rise to unsafe levels.

AC Fault Current
By design, Dairyland devices have the ability and ratings to handle AC fault current, with published and tested rating data to assure long-lasting performance. Devices such as gapped arresters do not have published AC fault ratings (or have minimal ratings) as they are not intended for such faults, yet AC conditions on pipelines are common.
Low Threshold Voltage
Dairyland devices have a low threshold voltage, typically 2 or 3V, and begin voltage clamping just above the blocking threshold voltage of the device. This assures that over-voltages will be clamped to the lowest levels, providing a significant advantage for personnel safety and for applications such as insulated joint protection. Arresters typically conduct at hundreds to low thousands of volts.

Lightning Capabilities
Dairyland devices will handle 75,000A or 100,000A (depending on model selected) of lightning surge current. The device goes into conduction at a much lower voltage than a gapped arrester, keeping the voltage across the insulated flange to a low value. For lightning surge conditions, after initial conduction at the several volt threshold, the voltage across the device is approximately 100V. The voltage allowed across a gapped arrester, in comparison, will reach unsafe levels prior to conduction, exposing personnel and equipment to this voltage until the device fires.

Dairyland Product Selection
Guidelines for selecting a protective product for insulated joints are as follows:

Site conditions
Induced AC
Where no induced AC voltage is present, such as insulated joints on airport fueling systems or within a facility, the products of choice are the OVP (Div 1 or Zone 1 hazardous locations) or OVP2 (Div 2 or Zone 2 hazardous locations). Avoid use of OVP/OVP2 where induced AC is present, or expected, otherwise full conduction will affect cathodic protection levels. Often, users assume that a low value of induced AC voltage is present and apply the OVP or OVP2, when they should instead default to a decoupler, such as the SSD, PCR, or PCRH, which can mitigate AC while blocking DC.

With induced AC voltage present across the joint, the products of choice are the PCR or SSD, assuming the joint is classified as an ordinary, Div 2, or Zone 2 hazardous location. If the joint is in a confined space it is likely a Div 1 or Zone 1 hazardous location, thereby requiring a PCRH. When in doubt about the level of induced AC voltage present, or for any cross-country pipelines that may have nearby paralleled power lines in the future, the best approach is to apply a decoupler (SSD, PCR, PCRH) instead of an OVP or OVP2.

Electrical ratings
AC Fault Current
Select a product AC-rms current rating that is above the expected site value. Where induced AC voltage on a pipeline has been modeled, use the modeled value for insulated joint protection as well. For cases where the fault current is not known, apply a 3.7kA AC-rms rated product by default, unless other site conditions indicate that this value should be altered. Don't forget to select a conductor or attachment method that is also rated for this AC fault current. The Dairyland website contains guidance on relating conductor size to ampacity.

Threshold Voltage
This voltage, measured between the product terminals, determines when the product changes from blocking DC to full conduction (switches ON) to provide over-voltage protection. Typical choices are -3V to +1V (asymmetrical), which would be used for connections between cathodically protected and grounded/unprotected systems, or -2V to +2V (symmetrical) for connection between systems with a similar DC voltage, such as between two different CP systems. Some choose the -2/+2V models for simplicity, since the symmetrical nature prevents an installation with reversed polarity.

Steady-State AC Current
For those models that have a steady-state AC current rating (SSD, PCR, PCRH), this value reflects the level of induced current from overhead power lines that must be handled. The typical value of 45A AC-rms 50/60Hz is usually adequate. Note: OVP and OVP2 products do not have a steady-state AC current rating and should not be used for such application. To determine the steady-state AC current rating needed for the site, measure the current in a temporary bond across the insulated joint or from pipe to ground, as appropriate, and select a decoupler rating that exceeds this value.

Lightning Current
Product families have a default value for lightning current capability, which is typically 75kA to 100kA peak.

Environmental ratings
Hazardous Location Classification
All Dairyland products for insulated joint application are certified for use in hazardous locations. To address world-wide use, products are certified to various international standards and have a Div 1/Zone 1 rating, or a Div 2/Zone 2 rating, which should be selected to match the classification of the specific installation point. If the location is "ordinary" (non-hazardous), then select a Div 2/Zone 2 product by default.

Environmental and Water Ingress
Above-grade product installation typically utilizes Dairyland products rated NEMA 4X or IP66, while submersed locations require NEMA 6P or IP68 ratings. Ideally, the product placement should be very near the insulated joint, in order to minimize conductor length (see discussion below), however this can be difficult for buried insulated joints. Products should not be direct buried in the soil, but may be installed in a vault or other enclosure. Sealing terminals and wire terminations is important in damp settings. Contact Dairyland to discuss below grade applications.

For additional information on product selection and for assistance in selecting a model number, please use our online product selection tool.

Installation Guidelines
Connection Across Joint
Joint insulation can only be confidently protected from over-voltage conditions by connection of a protective product directly across the joint. Often, clients propose to connect a device from one side of an insulated joint to a grounding system, assuming that this will prevent flashover of the insulation, however for reasons related to conduction path length (see discussion below) protection is not guaranteed. All types of joints should be protected in this manner – by connection directly across the joint - whether small tubing insulators, unions, flange-type, or monolithic, to assure...
over-voltage protection.

Connections in Parallel
Where multiple insulation joints are in parallel, all joints should be protected. For closely spaced measurement tubing insulators, a single Dairyland device can protect all, if best practices are used. For large pipelines with insulators in parallel at a manifold, it is generally best to individually protect each.

Pipe to ground connections: While insulators should be protected by device connection directly across them, this does not automatically reference either side to ground. One side of the joint will have cathodic protection, while the other side may be unprotected and grounded, unprotected and not grounded, or also cathodically protected. If this second side also has CP, and the insulator is sited at a facility, then an additional Dairyland device is needed to reference the pipeline to the facility grounding system. Most typically, the resulting two Dairyland devices are decouplers vs OVP-type products, to provide AC continuity with DC isolation. The decoupler connected from pipe to ground can be attached to either side of the insulated joint, as long as a second decoupler connects across the joint, thus referencing each side to the other and to ground.

If at a facility, with CP on one side of a joint and other side bonded to the facility grounding system, then a second decoupler is not needed – the piping is already safely grounded. For the situation where the station piping is not referenced to ground, this is an unsafe arrangement that should be addressed by installing a bonding conductor or Dairyland protective device to ground, as appropriate.

Again at a facility, there may be a series of two insulated joints between the main pipeline and the site grounding system. This requires protection using Dairyland devices across both insulated joints to reference each pipe segment to each other and to ground. If the main pipeline has induced AC, it is via this series of two decouplers that voltage mitigation is achieved, reaching the station grounding grid as the low impedance connection to earth.

As you can see from this discussion, there are many ways that insulated joints can be arranged on pipelines and in facilities, and the protection scheme employed must address both the joint of interest, plus consider the neighboring sections of pipe and whether those are at risk as well.

Lead length: A primary concern for lightning protection
One very important installation guideline, independent of which product is selected to provide over-voltage protection, is as follows: when the primary concern is over-voltage protection from lightning, it is extremely important that the device be connected across the insulated joint with the shortest possible conductors for optimum protection. When lightning current flows in a conductor, the inherent inductance of the conductor develops a large voltage, which appears between the two connection points. If this voltage is in excess of the insulation or coating strength, arcing will occur. This voltage can be up to 3kV per foot (10kV per meter), depending on the lightning waveform, and it adds directly to the voltage drop that is developed across the terminals of the protective device selected. Dairyland devices have very low and safe threshold voltage settings, so under lightning conditions the resulting voltage across an insulated joint is almost exclusively the inductive voltage drop due to the fast-rising lightning waveform.

Dairyland recommendations: To address these potential hazards due to lightning, all Dairyland devices can, and should, be installed with no more than about 6” to 8” (150 to 200 mm) of conductor length for optimum protection. All products are offered with custom mounting options to aid in minimizing conductor length, including bus bar arrangements that have low inductance compared to conductors. Refer to the Dairyland website or call for assistance. Conductor length is not of concern if only providing over-voltage protection for AC voltage because the rate of rise of current under AC fault conditions does not produce a significant voltage drop in the leads.

Summary
Appropriately rated over-voltage protection products can protect pipelines against both lightning and AC fault current, while at the same time maintaining cathodic protection of insulated pipeline joints. Proper device selection and installation location are key, and adjacent pipelines and facilities should be examined to establish a thorough protection scheme. If you need assistance selecting the proper product for your pipeline application, please contact Dairyland technical support at techsupport@dairyland.com or (608) 877-9900.

www.dairyland.com