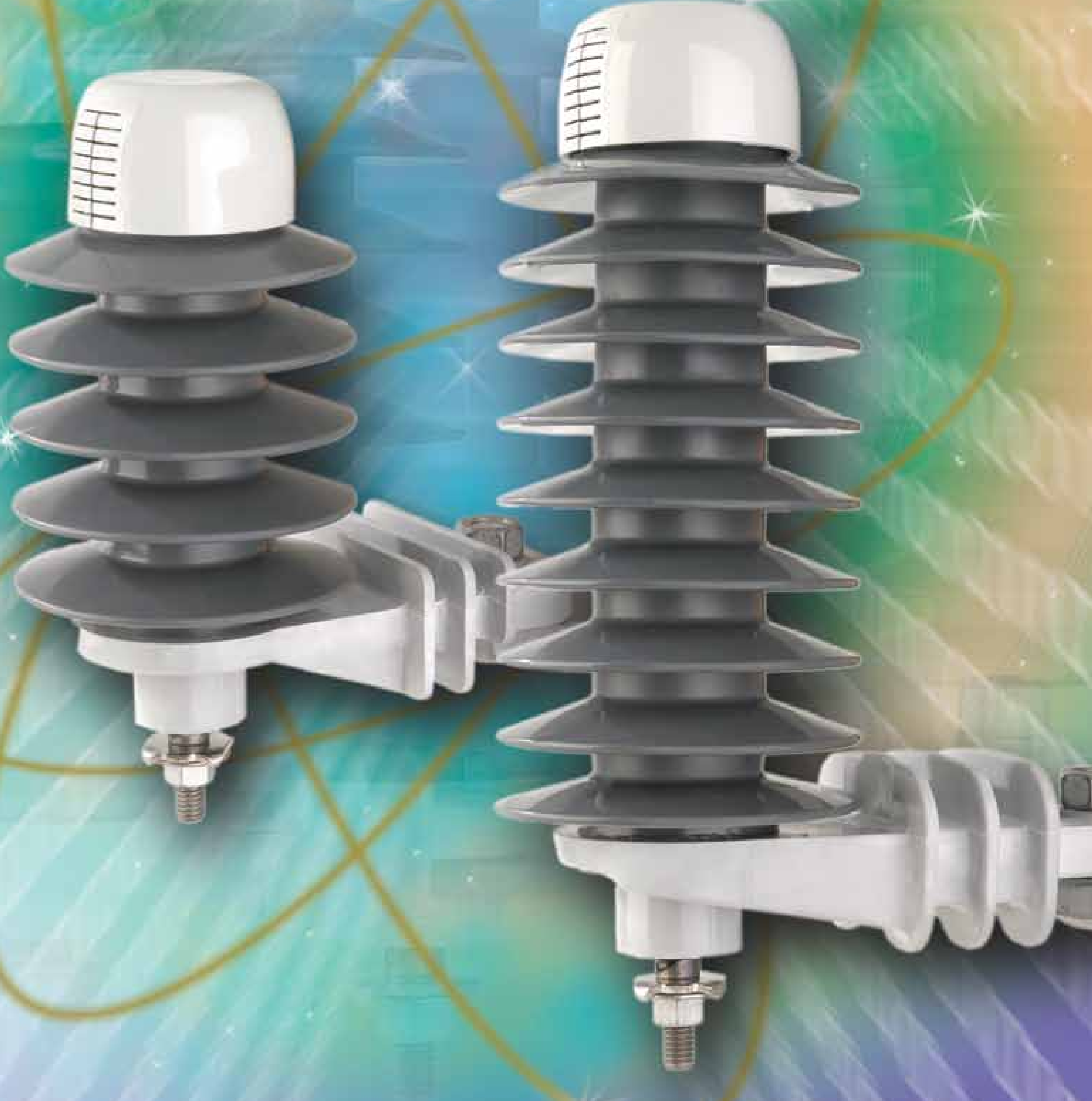
HUBBELL® TIPS & NEWS

www.hubbellpowersystems.com Vol. 9 No. 3 DECEMBER 2004



NEW ARRESTER ENHANCES PERFORMANCE

PDV-100 OPTIMA

New Heavy Duty Distribution Class Arrester Ground Lead Disconnector Design Enhances Reliability and Improves Arrester Performance

By: Denny Lenk,
Principal Engineer,Ohio Brass

Electric utility operating system reliability is a critical parameter of utility performance. For distribution systems, one factor that can affect system reliability is a failure rate of surge arresters. The related factor is the consistency of operation of the arrester ground lead disconnector in the unlikely event of an arrester failure.

Utilities protect distribution class equipment, particularly pole top transformers, with distribution class arresters. Protection of the dielectric integrity of a transformer is provided by the closely connected arrester. Approximately twenty years ago, the traditional gapped-silicon carbide distribution class arrester design was replaced by the improved gapless arrester, based on metal oxide varistor (MOV) technology. In addition to performance improvements associated with this new MOV technology, traditional porcelain-housed arresters were replaced during this same time period by polymer-housed arresters.

Conversion to MOV results in lowering of arrester protective levels, particularly under fast front rate of rise surges. This provides improved protection to the internal insulation of the transformer. Implementation of polymer housings significantly improve the performance of arresters in the unlikely event of arrester failures. Specifically, the polymer housed arrester removes the concern of violent porcelain fragmentation associated with porcelain-housed distribution class arresters. To validate this characteristic, the IEEE C62.11 Standard instituted a short circuit test for polymer-housed arresters. The predecessor porcelain-housed distribution class arrester had no required short circuit performance requirement.

Conversion from porcelain to polymer-housed distribution class arresters allowed manufacturers to reduce the active element length of arrester designs. Porcelain designs traditionally had a ground lead disconnector attached to the base end of the arrester and the arrester was supported by a grounded metal "bellyband" bracket, typically attached around the porcelain housing approximately one-third the distance from the bottom end of the arrester housing. The distance from the top edge of the metal bellyband to the arrester top end cap provided the required line to ground insulation clearance as specified for each arrester rating in the C62.11 Standard. The distance from the bottom of the grounded bellyband to the ground lead disconnector provided the necessary clearance to prevent the intact, failed porcelain arrester from locking out the system if the arrester should fail but remain intact.

For the polymer-housed designs, this "lockout prevention" clearance was relocated to the supporting bracket, which typically attaches to the base end of the polymer-housed arrester. Because this member now has the added requirement of voltage withstand after arrester failure, its composition changed from metal to an insulating plastic material. Should the polymer-housed arrester fail and remain intact (typical), the ground lead disconnector, connected between the base of the arrester and the arrester ground lead, will detonate. Disconnection of the ground lead causes the base end of the failed (intact) arrester to assume system line potential. The composition and shed design of the insulated bracket allows the arrester location to remain energized until utility operating personnel replace the failed arrester.

The above description is valid, assuming that the ground lead disconnector reliably detonates during arrester failure. Should the disconnector fail to operate, the base end of the failed arrester remains connected to system ground and the line locks out until upstream protection operates and the failed arrester is replaced.

Industry standards (1, 2) define the performance requirements of the ground lead disconnector. The performance requirements are divided into two areas of concern. The first addresses the detonation characteristic of the disconnector, essentially the current-time curve. This test specifies that the disconnector is subjected to 60 Hz power frequency currents of 20, 80, 200, and 800 Amps rms and the time to detonation at each current level is measured. From this test series, the disconnector detonation curve is established. An application engineer can use the arrester detonation curve to develop proper coordination with upstream protection, e.g., fuses (3).

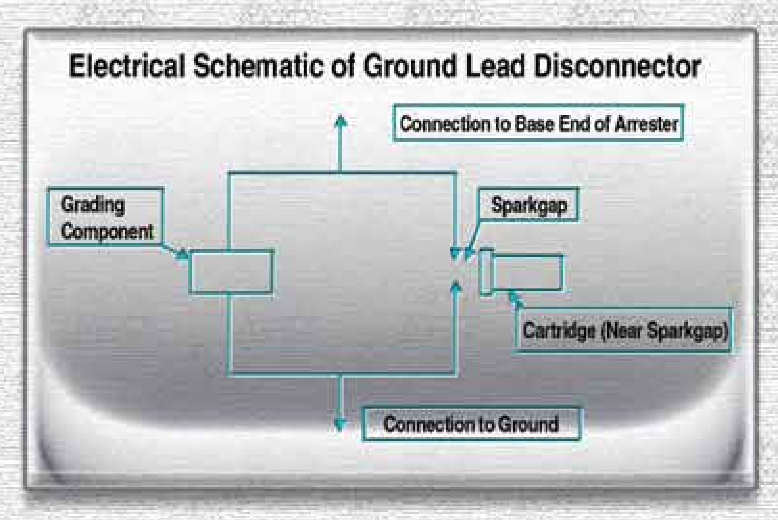


Figure 1

The second aspect of performance is that the disconnector will not detonate when subjected to required arrester durability tests, including high current-short duration, low current-long duration, and duty cycle tests. Another test requirement is that the disconnector will not detonate as a result of arrester surface currents when the arrester assembly is subjected to contamination testing. Essentially, the disconnector is designed to withstand (without detonating) the same durability tests that the arrester must withstand; however, it must detonate, disconnecting the arrester ground lead, when the arrester fails and conducts system fault current.

The above standards requirements have assured that distribution class arrester disconnectors meet a minimum performance requirement. Arresters designed to meet this standard have, in general, a good service history. However, with the increased emphasis on system reliability, there is mounting concern that improvements are needed to address nagging issues relating to arrester detonator reliability.

Disconnector Designs

There are two basic detonator designs used in disconnectors currently being manufactured in the US. As noted earlier, virtually all designs attach the isolator to the ground end of the arrester. One design mounts the arrester base end on an insulating bracket and holds the arrester to the bracket by attaching a disconnector to the underside of the assembly. This design was a

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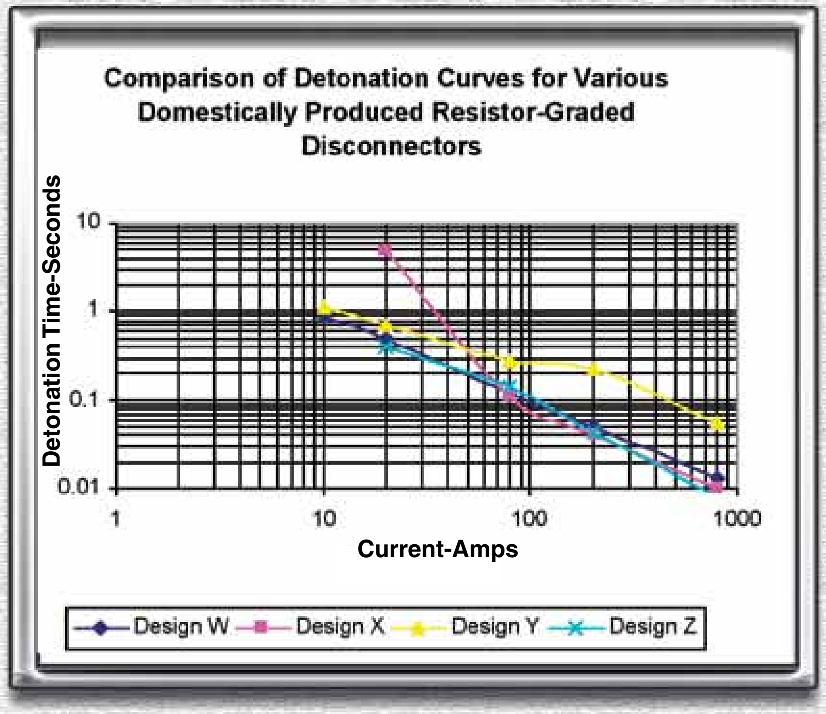


Figure 2

carryover from porcelain arresters. The second design, targeted specifically to polymer arresters, integrates the disconnector into the body of the insulating bracket. This integrated design attaches to the base end of the arrester.

Regardless of which approach is utilized, both designs use the same basic internal design approach. An unprimed cartridge is used to promote separation of the disconnector. This cartridge is typically located in the vicinity of a sparkgap, which is oriented in parallel with some type of electrical grading component. Manufacturers have utilized a variety of grading components, including electronic capacitors, electronic resistors, conductive polymers, and higher wattage resistors. Figure 1 shows an electrical schematic of a typical ground lead disconnector.

The grading component, typically a molded resistor in currently manufactured US designs, provides a path for normal arrester internal grading and external leakage currents to flow from the base of the arrester to ground. The sparkgap, located electrically in parallel with the resistor, provides a bypass function when the arrester assembly is subjected to abnormal surge duty. Voltage drop across the grading component during this abnormal surge duty causes the bypass gap to sparkover.

For required arrester durability tests defined in the standard, the arrester is expected to withstand the duty without failing and the detonator is expected to withstand the duty without detonating. The thermal design of the disconnector is such that there is not sufficient coulomb content in the sparkgap region to cause the adjacent cartridge to detonate during arrester durability tests. However, if the surge duty is sufficient to cause the arrester to fail, the subsequent flow of system fault current available at the arrester location is intended to provide sufficient heating of the cartridge to cause it to detonate. The design of the disconnector is such that this detonation then causes the ground lead to be separated from the base end of the arrester.

Disconnector Design Issues

As noted, the disconnector current detonation range specified in the standard is 20 to 800 amps. The standard does not specify the shape of the current-time detonation curve. It merely defines the procedure for performing the test on new disconnectors. Above 800 amps, all designs should detonate very quickly from the high heat associated with the high 60 Hz fault current. Problems can be encountered on arresters applied to non-effectively grounded systems or on arresters located on weak feeders where only low fault currents are available (< 20amps). Specifically, the cartridge relies on heating from the system 60 Hz fault current to cause detonation. Inherent in these weak source current locations is the possibility that the cartridge is not heated sufficiently by the available 60 Hz current to detonate before upstream protection triggers. Reliable detonation of the disconnector under this weak source condition is an issue of concern. Figure 2 shows the detonation curve for disconnectors tested per the current ANSI standard.

It has also been seen that the molded grading resistor adds a vulnerability to the resistance-graded isolator. Typically under weak source, low level (1.35-1.45 PU MCOV) arrester temporary overvoltage conditions, the interaction of the nominally linear grading resistor

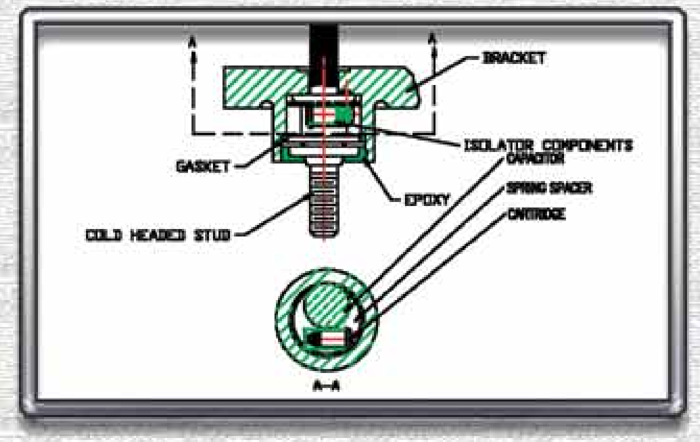


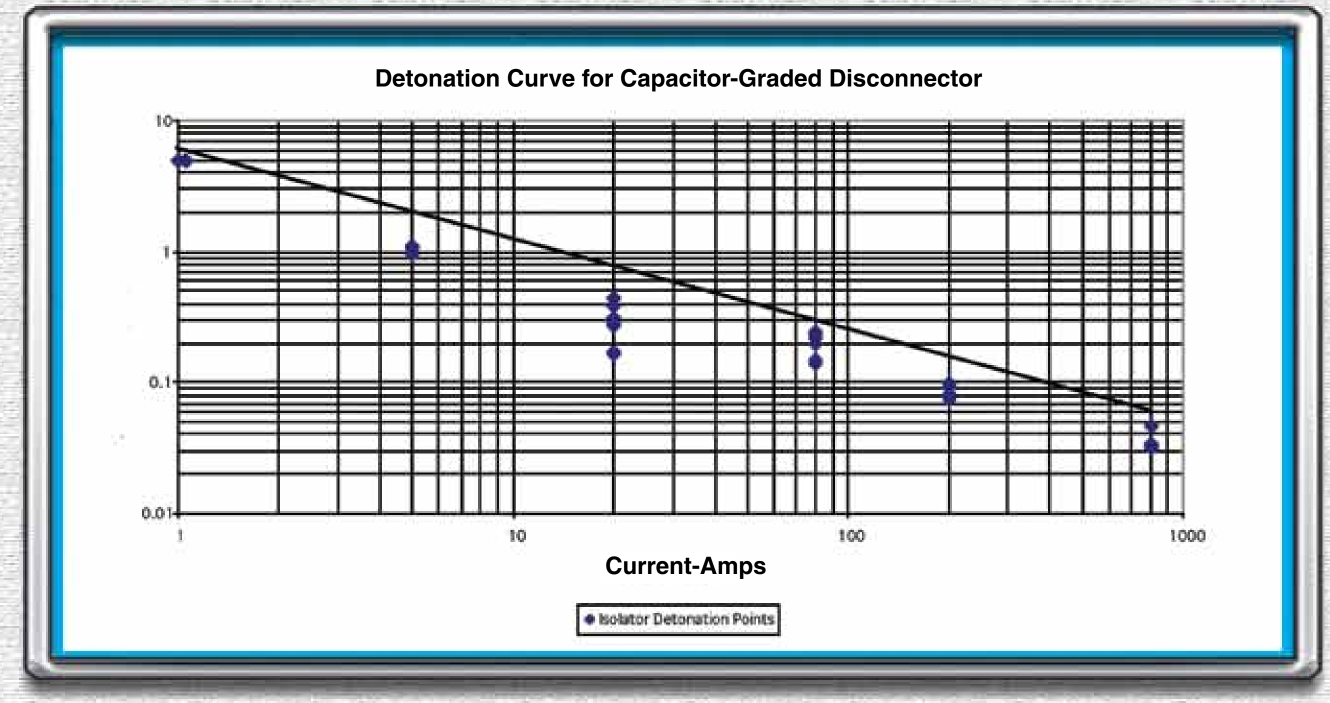
Figure 3

with the non-linear arrester mov disc elements can result in significant voltage developing across the disconnector grading resistor. If the overvoltage persists for an extended time, the disconnector grading resistor's inherent energy absorbing capability can be exceeded, causing the grading resistor to electrically puncture. When this occurs, total system overvoltage is then placed across the arrester mov disc stack, causing the discs to fail almost instantaneously. Again, assuming a weak source location and an electrically punctured isolator resistor, the system fault current may not cause the disconnector gap to spark over. Rather than sparking over the disconnector gap, instead the low current will flow thru the punctured section of the resistor. If this puncture occurs away from the cartridge, there is a possibility that the disconnector cartridge will not detonate. If the TOV persists , the arrester may ultimately fail, possibly without detonating the isolator and leaving the ground lead attached, again with the assumption of a weak current source at the arrester location. As described earlier, this condition requires upstream protection to operate, disconnecting the phase-ground fault through the still-connected failed arrester.

To address the detonation reliability concerns of the ground lead disconnector, the molded resistance grading component of the disconnector was replaced with a high voltage ceramic capacitor. Figure 3 shows a cross-sectional view of a capacitively graded disconnector designed as an integral part of the insulating bracket.

A primary advantage of the high voltage capacitor grading is that the capacitor will not fail from thermal runaway when the arrester assembly is subjected to a prolonged overvoltage condition. Unlike the grading resistor, which can heat up and fail from I^2R loss, the capacitor design will withstand the capacitance portion of the total overvoltage. Ultimate arrester failure will occur when the arrester metal oxide discs fail from thermal runaway or when voltage across the capacitance-graded sparkgap becomes high enough to cause the gap to spark over.

Figure 4



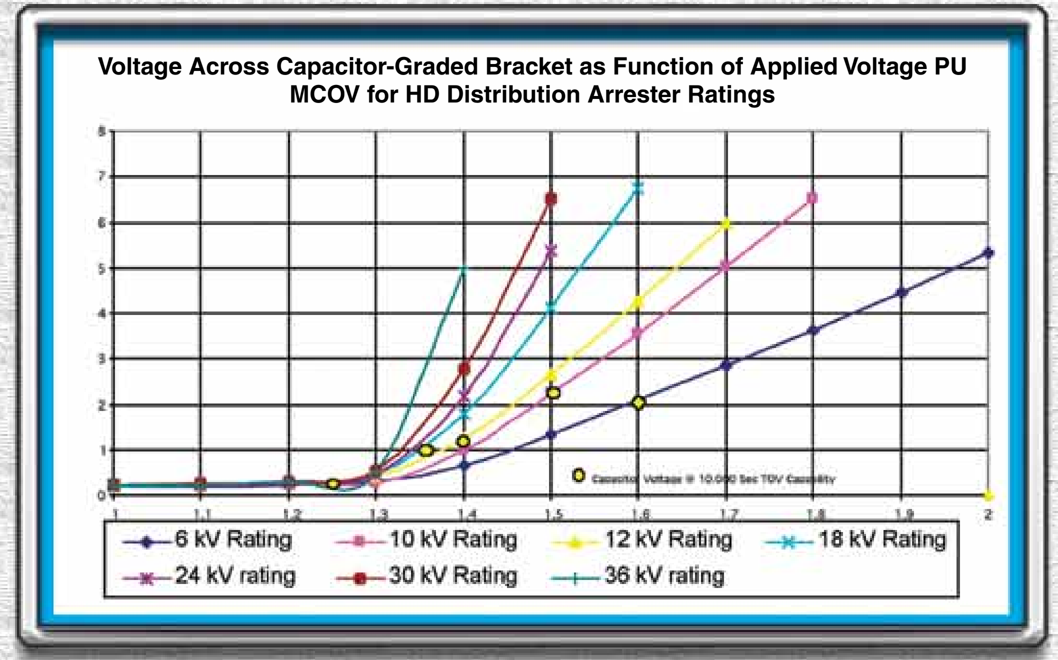


Figure 5

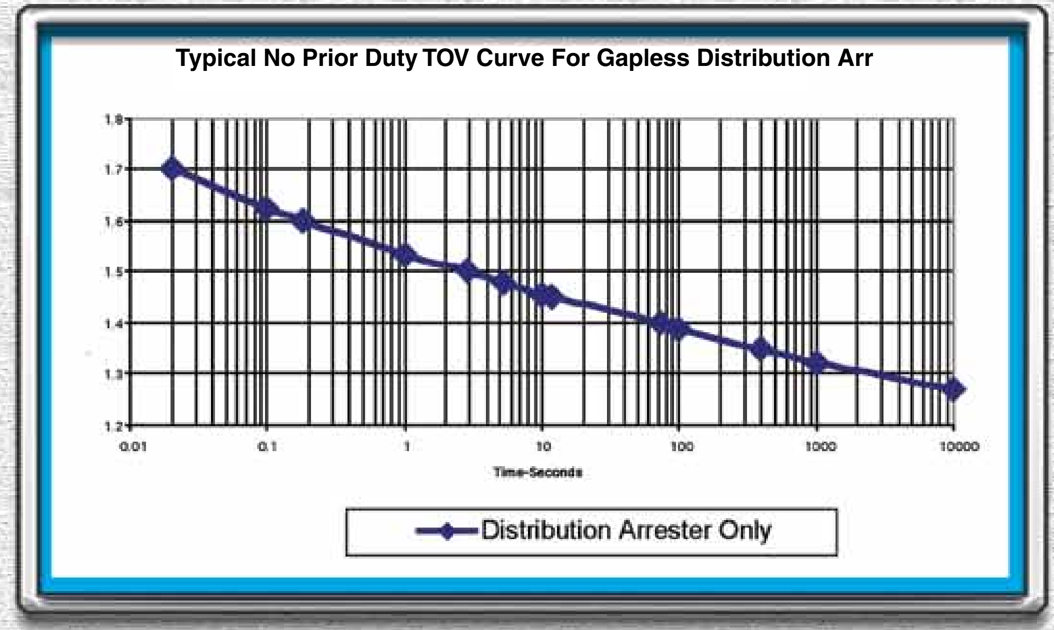


Figure 6

Under these conditions, the arrester 60 Hz fault current will, as designed, cause the disconnector gap to sparkover, placing the internal arc at the cartridge location, resulting in detonation and ground lead disconnection. This assumes that protection upstream does not disconnect the arrester from system voltage before the cartridge is heated sufficiently to cause detonation. Because the capacitor-graded disconnector removes failure concerns associated with the resistor-graded disconnector, time to detonation for low fault current applications becomes strictly an issue related to the thermal design of the disconnector sparkgap.

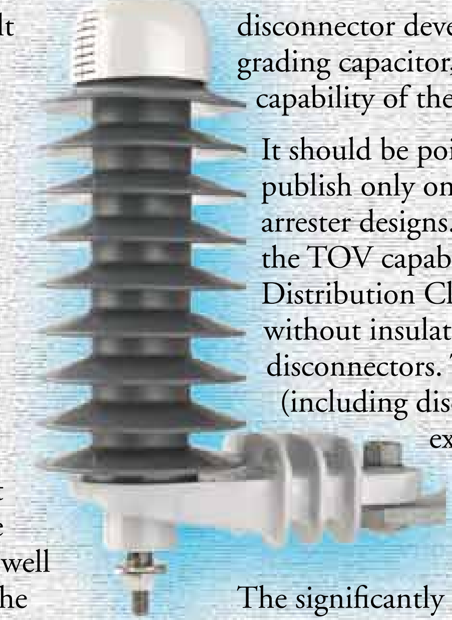
To validate the detonation curve for the capacitor-graded design, tests were performed per Section 8.18.2.3 of IEEE C62.11-1999 Standard, except the detonating current range was extended to 5 and 1 amp fault current levels. Figure 4 shows the resultant detonation curve. Note that all (5) samples tested at 1 and 5 amp current levels detonated. There was no damage to the grading capacitor other than the external arcing damage associated with the fault current arc.

The new capacitor-graded disconnector will detonate down to 1 ampere. As the design becomes more sensitive to low current detonation, there is a concern that the disconnector might become too sensitive and detonate on required arrester durability tests. Section 8.18.2 of IEEE C62.11-1999 standard defines required design tests. To address this concern, the following durability tests were performed.

Five arresters with capacitor-graded insulating brackets were subjected to (18) shots of 400 amp, 2ms duration, exceeding the 18 shot, 250 amp test requirement for Heavy Duty Distribution Class arresters. While not detonating as a result of the repetitive duty, all five disconnectors detonated when subjected to a 1 amp fault current.

Six capacitor-graded disconnectors were also subjected to (2) 100 kA 5.5/12 discharges with no detonation occurring. In addition, the measured capacitance changed less than 5% and there was no partial discharge measured as a result of this severe duty.

As a final confirmation of the electrical integrity, three disconnectors that successfully passed the (2) 100 kA shots were tested for detonation in a 6-amp test circuit. Time to detonation on these three samples was .983, 1.0, and 1.43 seconds, well within the claimed detonation curve for the new disconnector.



A limited number of disconnector designs currently in the marketplace were subjected to (2) 100 kA 4/10 current discharges. Design A successfully withstood the (2) shot test without detonating. Design B had the disconnector detonate on the first 100 kA surge on both samples tested. A third sample withstood two discharges without detonation. Three disconnectors of design C and design D successfully withstood (2) 100 kA discharges without detonation.

Design A disconnectors were then subjected to a 20-amp and a 5-amp detonation tests. At 20-amp, detonation occurred. At 5-amp, there was no detonation. The third sample of design B did not detonate at 20-amp. One of the design C disconnectors detonated at 20-amps while two did not detonate at 5-amps. Design D detonated at both 5 and 20 amps.

Arrester-Disconnector Interaction Issues

The impedance of the capacitor-graded isolator is significantly higher than that of the existing domestic resistor-graded disconnector designs. This has a significant impact on the voltage sharing that exists between the connected arrester metal oxide disc elements and the series connected disconnector. Figure 5 displays the 60 Hz voltage measured across the disconnector as a function of total voltage applied to the arrester-disconnector combination. Note that below 1.25 per unit MCOV, the disconnector develops less than 1 kV across the grading capacitor, well below the continuous AC capability of the device.

It should be pointed out that most manufacturers publish only one TOV curve for their distribution arrester designs. This curve is typically based on the TOV capability of the arrester only, since Distribution Class arresters can be installed without insulating brackets and ground lead disconnectors. The actual arrester assembly (including disconnector) TOV capability may exceed that claimed for the arrester alone. Figure 6 shows a typical gapless distribution class arrester temporary overvoltage curve.

The significantly higher impedance of the capacitor-graded disconnector electrically interacts with the capacitive and non-linear resistance characteristic of the metal oxide discs. At system operating voltage levels, the voltage across the capacitively graded disconnector is typically a few hundred volts, compared with tens of volts for the resistively graded disconnector. As applied voltage increases above operating levels, the parallel combination of the disconnector capacitor and its sparkgap assume a higher percentage of total voltage than does the resistively graded disconnector. Because the capacitor does not experience I^2R loss, in contrast to the resistance graded design, the disconnector can withstand overvoltages for extended periods of time, as long as the capacitor voltage does not exceed the bypass gap sparkover level. Unlike an arrester with a resistively graded disconnector, which has a claimed TOV capability that is independent

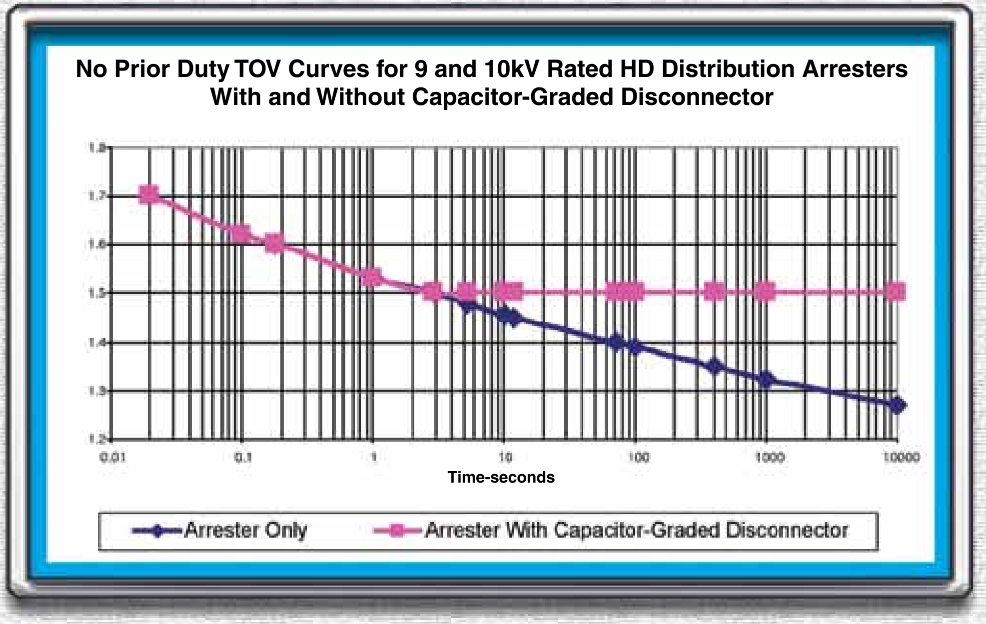


Figure 7

of arrester voltage rating, arresters with capacitively graded disconnectors have a rating-dependent TOV curve. Figure 7 shows the TOV curve for 9 and 10 kV rated HD Distribution Class arresters.

Introduction of a high voltage capacitor-graded arrester ground lead disconnector addresses utility concerns regarding reliable detonation of the Distribution Class arrester disconnector. Test data confirms the detonation integrity of the disconnector is maintained even after the arrester is subjected to high current surge duty prevalent in the distribution system environment. Even under weak source temporary overvoltage conditions, which can damage the resistance-graded design affecting detonation reliability, the capacitor-graded design performs properly. The detonation range of this design has also been reliably extended to 1 amp, below the 20 amps required by the C62.11 arrester design standard. Finally, the interaction of the disconnector grading capacitor with the series-connected arrester metal oxide disc elements actually improves the arrester assembly temporary overvoltage withstand capability, making the design less vulnerable to TOV failures. Since the vast majority of distribution class arresters are sold domestically with ground lead disconnectors, this design improvement in the disconnector to improve detonation reliability also translates into a significantly improved distribution class arrester design. ■

References

Standards:
(1) IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1 kV) IEEE Std C62.11-1999

(2) CEI IEC 60099-4 (2001-12) Ed. 1.2 Consolidated Edition: Surge Arresters- Part 4: Metal Oxide Surge arresters Without Gaps for AC Systems

(3) IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems IEEE Std C62.22-1997

Bibliography

Dennis W. Lenk (F, 1999) has 35 years of experience in the design and testing of surge arresters. He has been actively involved in the IEEE PES Surge Protective Devices Committee for 25 years, most recently serving as Past Chair of the committee. Dennis is also a member of the US TAG to IEC TC 37. He is the SPDC Editor to the IEEE Transactions on Power Delivery. He is a Registered Professional Engineer in Ohio and currently a Principal Engineer for Hubbell Power Systems.

GROUNDING-SET TESTER MEETS NEW ASTM STANDARD

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- Resettable thresholds make readout easy
- Probes accurately isolate trouble areas

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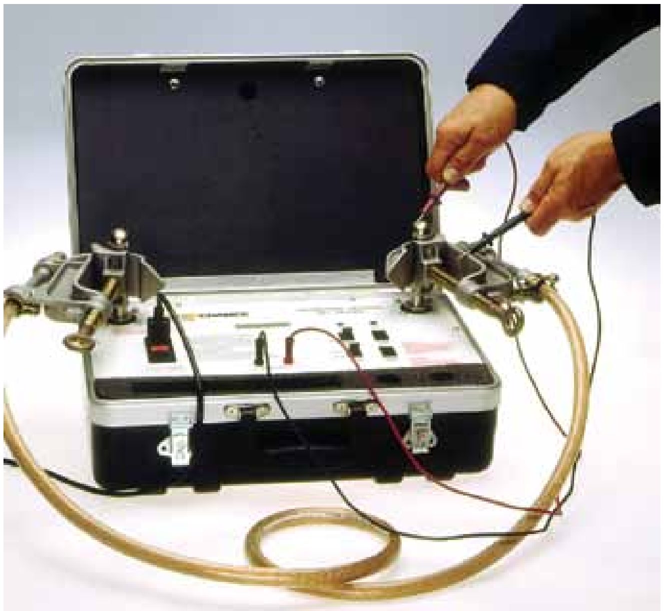
Protective-Grounding-Set Tester Catalog No. C403-3220

Ball-studs accept grounding sets with standard clamps (above) and Chance ball-socket clamps (below).

test result's relation to the threshold.

For system-specific requirements, the user can easily change the Tester's basis for voltage allowed across a lineworker, which comes factory preset at 50 Volts. Adjusting this limit automatically causes a corresponding shift in the resistance thresholds for all the grounding cable sizes.

Regardless of the voltage-allowed setting or cable size selected, the Tester displays the resistance of each specimen in milliohms with ±1% accuracy. (The Tester is capable of measuring resistance from 1 micro ohm to 6.5 ohms.)



Probes are used to calibrate before each test and to isolate cable trouble spots.

The utility must establish the maximum resistance allowed for protective grounding sets used on each specific area of its systems. How the utility calculates these values depends on several factors outlined in the Tester instructions. Reference examples are given in the manual.

TROUBLESHOOTING MODE ISOLATES CABLE PROBLEMS

If a ground set does not pass the initial test, the Tester can help isolate the problems. Often, the source of high resistance can be remedied by simple repairs to the cable set. Retesting then can quickly verify the effects of repairs.

For this troubleshooting mode, a pair of test probes are furnished to plug into the Tester. A switch activates the probes. They are used to test across each contact interface in the ground set. The results display in milliohms, just as in the first test mode.

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The Tester's standard ball-stud terminals accept most types of ground clamps, including Chance ball-socket clamps.

To test special-application grounding sets for underground-distribution transformers or switchgear, two optional adapters shown below are available as separate items. ■

Optional Straight Stud Terminal T403-3159 for testing grounded-parking-stand temporary grounding sets.

Optional Elbow Adapter C403-3449 for testing temporary grounding sets fitted with a grounding elbow.

For more information, contact your Hubbell Power Systems representative, fax 573-682-8714 or e-mail hpsliterature@hps.hubbell.com.

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It will be a busy show year for Hubbell Power Systems during 2005. Please encourage your customers to visit the Hubbell booth at these upcoming events.

1. DistribuTech Show, Jan. 25 – 27, 2005
   San Diego Convention Center, San Diego, CA
2. National Rural Electric Cooperative Assn., Show (NRECA), Feb. 25 – 28, 2005 San Diego Conv. Center, San Diego, CA
3. Northwest Public Power Assn., Show (NWPPA)
   Apr. 19 – 21, 2005, Reno, NV
4. Lineman's Rodeo, Sept. 15 – 17, 2005
   Overland Park Conv. Center, Overland Park, KS
5. International Construction and Utility Equipment Exposition - ICUEEE, Sept. 27 – 29, 2005
   Kentucky Fair and Expo Center, Louisville, KY
6. IEEE PES Transmission & Distribution Conference
   Oct. 10 –12, 2005, Ernest N. Morial Convention Center
   New Orleans.

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- **BP3 Recloser By-Pass Switches**
- **AR (Automation-Ready) Three-Phase Switches**

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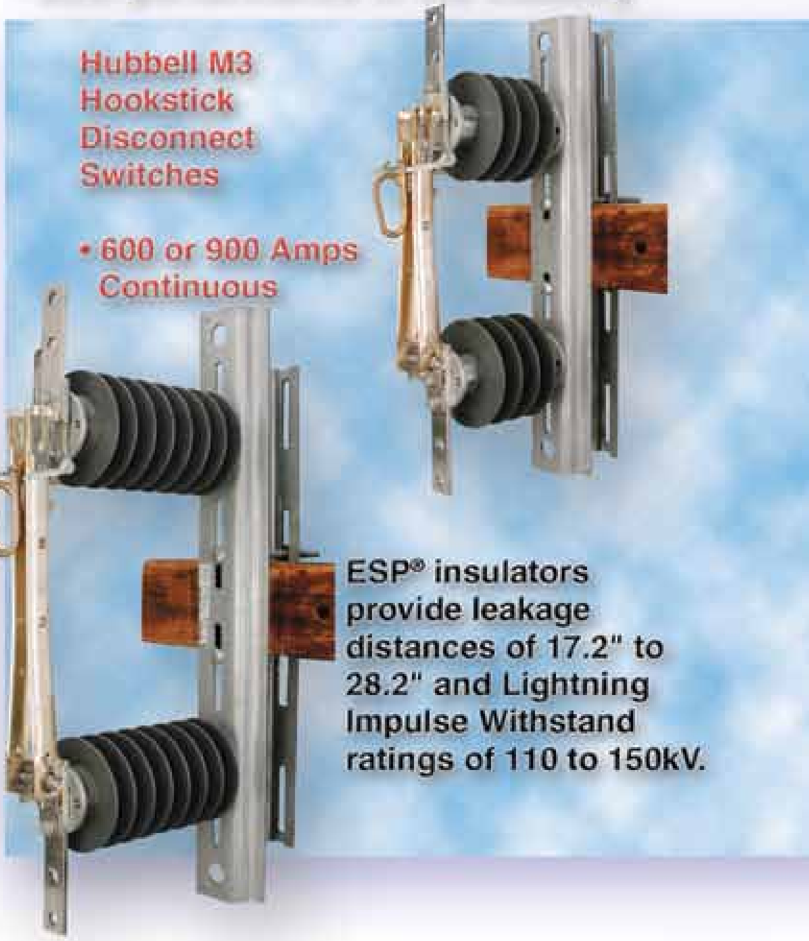
ESP® silicone alloy rubber, the same material used in Ohio Brass PDV arresters and Hi*Lite® Insulators. ESP is a polymer compound made by alloying silicone and EPDM rubber. This alloy offers the desirable toughness and resistance to tracking of Ohio Brass's original EPR with the hydrophobic characteristics derived from low molecular weight silicone oils. Also much more resistant to fractures than porcelain, the polymer insulator can reduce or eliminate losses from routine shipping, storage and handling.

BENEFITS: INCREASED LEAKAGE AT LOWER WEIGHT

In our Distribution Switches, this insulator offers as much as 65% more leakage distance (110 kV LIW size) than its porcelain counterpart. This is achieved by the relationship between the outer weathershed diameter and that of the central shank, the polymer insulator's "form factor," which means it will dry faster even when contaminated. This stops the flow of leakage current and supports the system voltage across the dry bands.



Hubbell M3 Hookstick Disconnect Switches

- 600 or 900 Amps Continuous

ESP® insulators provide leakage distances of 17.2" to 28.2" and Lightning Impulse Withstand ratings of 110 to 150kV.

Hubbell ALTD Line Tension Disconnect Switches
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The Ohio Brass research laboratories use several tests to evaluate materials. Tracking, QUV, corona cutting, salt fog, oxidative stability and variations of differential thermal analysis tests assure the quality of the shed material. For further information on our polymers, ask your Hubbell representative for the publication: "Polymer Materials for Insulator Weathersheds" EU1264-H. ■

Hubbell BP3 By-Pass Switches
• 600 Amps Continous

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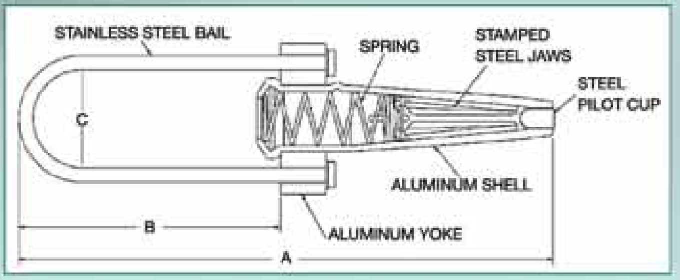

Customers save time and money by using these new automatics. Used by utilities, telecommunications and departments of transportation to deadend guy wires. Three sizes meet customer requirements. Made of high-strength aluminum tubing, stamped steel jaws and stainless steel bail. Tamper proof guy wire connection.

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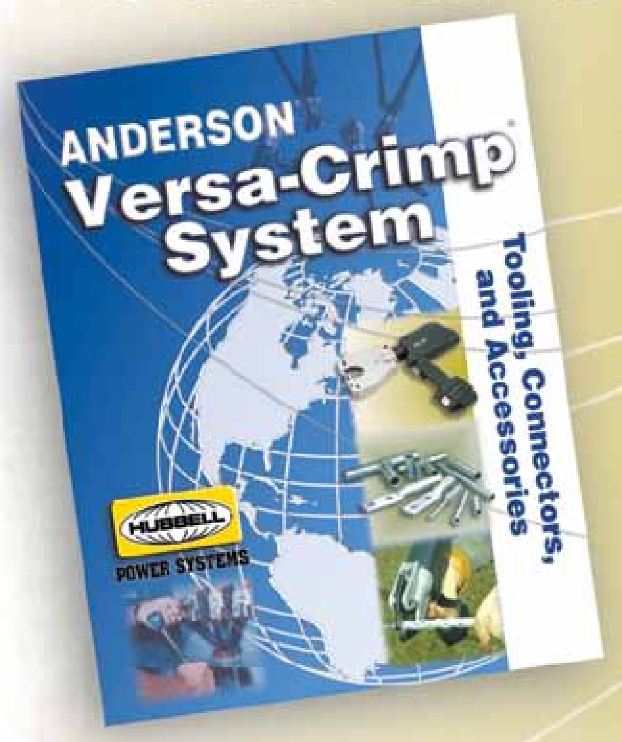

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Vol. 9 No. 3 DECEMBER 2004

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Your suggestions and editorial or photographic contributions are invited and may be submitted to **Hubbell TIPS & NEWS.**

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