High Resistance Grounding - Case Study: Marathon Oil Company

Protecting Down-Hole Submersible Pumps and Motors from Damaging Fault Related Voltage Transients

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Objective

Marathon Oil Company wanted to improve the life and reliability of their Electrical Submersible Pump (ESP) systems.

Strategy

Apply High Resistance Grounding (HRG) units to the electrical system. This technology, proven effective in other industrial environments, reduces the unsafe and damaging overvoltage conditions that may occur under arcing ground fault conditions. The HRG unit can detect, identify, and control the ground fault.

What makes this technology so desirable to the application is that it does not necessarily have to take the ground fault system off-line. Once the HRG unit has detected and located the ground fault, Marathon would be able to evaluate the situation and determine the best course of corrective action. If the location of the fault is determined to be down-hole and not in a classified wellhead area, then the well could be run with the ground fault on it indefinitely.

Results

Marathon applied HRG units to two wells on their Tchatamba Marin platform located off the coast of Gabon, Africa. Six weeks after the installation of the HRG units, both wells experienced failures. Well #2 failed first, experiencing a phase to ground fault and then a phase to phase fault. The well operated for six hours with the phase to ground fault since the HRG unit was able to control the overvoltages.

Marathon production engineers pulled well #2 to find that a packer penetrator ground fault. Further investigation indicated that after the original ground fault occurred, the HRG unit kept the system on line and operating until the phase to phase fault occurred. The motor, cable, and down-hole sensors were all undamaged and still functional. However, the motor was replaced with a spare as a precautionary measure.

While the work was being done on well #2, well #3 experienced the identical failure mode. Unfortunately, the HRG unit on well #3 was off-line at the time. Well #3 failed instantly since it did not have any protection from the ground fault induced overvoltages.

"If both motors had burned, Marathon Oil would have spent another $300K - $400K"

Immediately after finishing well #2, Marathon pulled well #3. The #3 motor was burned at the star point. The Phoenix down-hole sensing system was also destroyed. Marathon did not have a spare motor for well #3 so elected to rerun the motor pulled from the #2 well in #3.

At the time this document was written (six months later), there have been no additional problems with either well. Both ESP systems are running with the HRG units on line and

Technical Notes

Seventy percent of all faults start out as arcing ground faults. This can lead to transient overvoltages. When the overvoltage reaches about 700%, the system insulation breaks down.

High transient voltages can result in:

- Motor Failure
- Down-Hole Sensing Equipment Failure
- Cable Insulation Failure
- Penetrator Failure

The solution was to design a high resistance grounding (HRG) unit tailored to the specific needs of the petroleum industry. When an HRG unit is applied to an electrical system, you have the benefit of a ground protected system without necessarily impairing the continuity of service. When it is determined that there is a ground fault on the system, the HRG unit can alarm or, if desired, trip the system.

HGR technology is as close to an ungrounded system as you can get but without the negatives of an ungrounded system. The HRG unit was designed to handle up to 5kV. It can be applied to a delta or wye ungrounded three wire distribution systems.

Interface with Down-Hole Sensor Technology – when down-hole sensing equipment is utilized on a well, the Cutler-Hammer HRG unit can be equipped with customized signal blocker circuitry. This signal blocker keeps the down-hole sensor signal from erroneously flowing through the HRG unit's ground connection and resulting in an incorrect alarm or trip condition. With the signal blocker circuitry to guard possible nuisance tripping, the down-hole sensing equipment

A Prudent Design Approach

A rational, deliberate approach to the design of a practical surge protection system must balance, simultaneously, at least four variables:

1. The frequency of lightning strikes (or, the degree of environmental hostility), depends heavily on geography, and is generally expressed as strikes/square km/year (see Figures 4a and 4b).
2. The amplitude of lightning strikes, which has already been addressed.
3. The degree of protection desired based on the integrity and sensitivities of the equipment to be protected, the characteristics of the electrical system, and the performance of surge protective devices, including...
4. The life expectancy of arresters/suppressors, which is directly related to the rating of the device and the frequency and amplitude of strikes.

UL requires that facility surge suppressors in service entrance applications be tested to 10 kA per phase to assure safety and reliability. Yet, Cutler-Hammer recommends actual ratings from 50 kA up to 250 kA per phase. The reason is life expectancy, not added protection.

A service entrance suppressor will be subjected to thousands of surges of various magnitudes; each will shorten the life of the suppressor by various degrees. Statistical data indicate that suppressors installed in, say, Florida, the lightening capital of North America, and rated 250 kA per phase, can be expected to remain in service for 25 years or more, even longer in areas where lightning strikes are less frequent.

Failure of a suppressor is extremely rare, and is generally caused by a swell or temporary overvoltage (TOV) on the utility's power line, i.e., when the voltage on a 120 V line rises to 170 V or higher for short periods of time. Therefore, it's apparent that no engineering or other value is derived from ratings of suppressors that exceed 250 kA/phase.

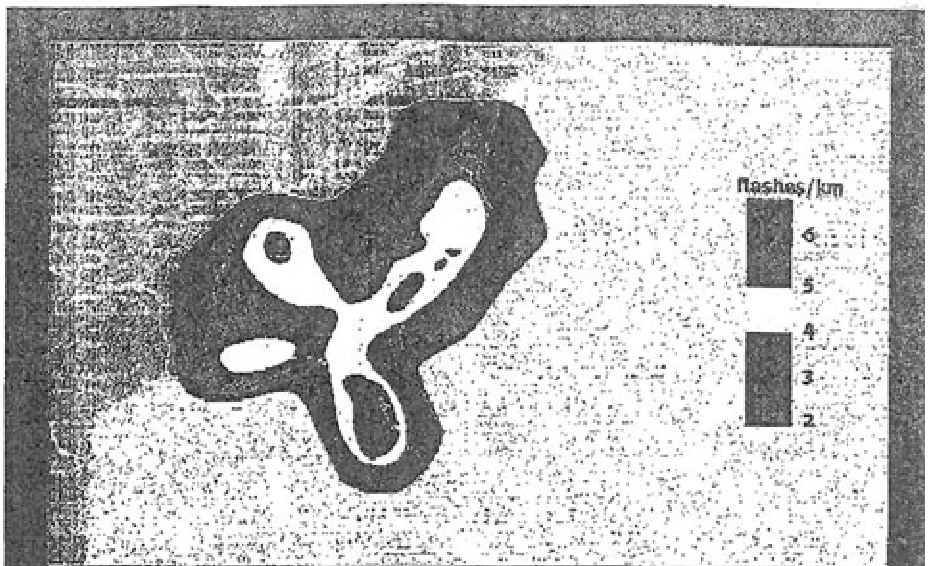

Figure 4a: Exposure to lightning can be related to the number of thunderstorm days/year in a geographic area. The area just south of Tampa, Florida, is highest, at more than 100 thunderstorms/year, followed by the rest of Florida and a good part of the Southeaster United States. Suppressors of higher ratings should be specified in areas of higher densities, not because they offer greater protection, but because their service lives will be longer.

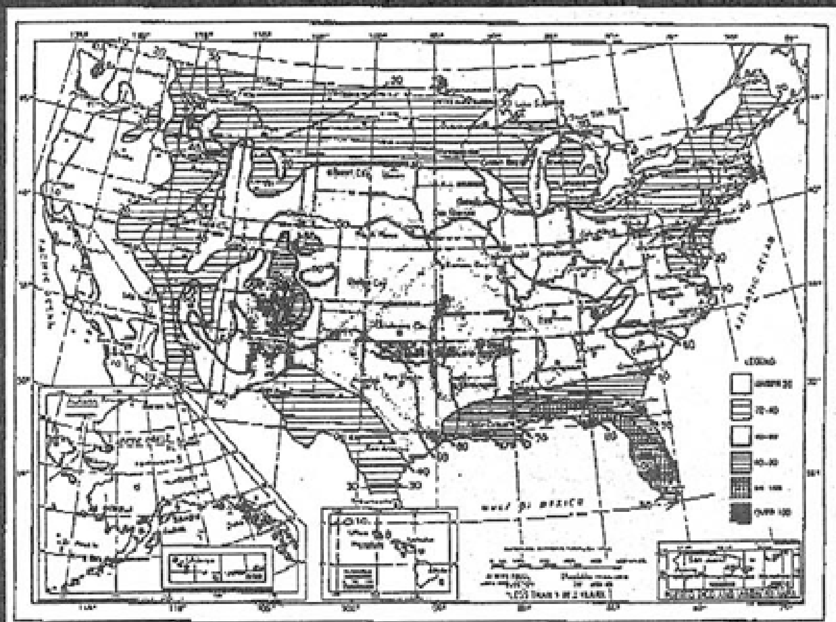

Figure 4b: The density of lightning strikes in the Eastern and Midwestern states varies widely from 6 km²/year in Central Florida, Coastal South Carolina, and South Central Tennessee to only 1 km²/year throughout most of the Midwest and Northeast.

Conclusion: Specify Up To 250kA/Phase

There is absolutely no direct relationship between the amplitude of lightning strikes and the amplitude of surges—also called transient impulses—on power lines.

Surges can enter the facility's incoming electrical, telephone, and coaxial conductors, requiring that prudent design protect all three paths. Surge suppressors rated 250 kA per phase will protect AC power lines against all recorded lightning strikes, and will remain in service for 25 years or longer even where lightning strikes are most frequent. Protection is not increased by specifying suppressors rated higher than 250 kA, but cost is, and facility owners will pay for protection that is unwarranted.

1 IEEE 62.41-1991, Reaffirmed 1996. 2 IEEE 62.41-1991, Appendix B, paragraph B1. 3 Surge and Temporary Over Voltage Protection Considerations for Remote and Wireless Telecommunications Sites, by Russell Barss and James Funke, Cutler-Hammer. 4 Orvill, R. E., Henderson, R.W., and Pyle, R. B. Lightning Flash Characteristics: