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Avoiding Eleventh-Hour Calamities During Wind Farm Commissioning

The quality and durability of collector system cables can go a long way in successfully interconnecting your wind farm to the grid.

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Imagine this: You have just commissioned your new wind farm, and it's a perfect site with perfect wind, and your power purchase agreement is in place. The wind is blowing, the blades are spinning, and the turbines are producing clean renewable energy. However, there is no electricity to distribute at the substation; your collector system has failed, and the installation contractor left the site weeks ago. In this situation, you would need to locate the fault immediately in order to minimize the lost production revenue. But it's winter; the ground is frozen, and it is snowing. It could take fault location crews days or even weeks to locate the fault and repair the problem, assuming that weather conditions are favorable to even begin the reparation process. The harsh reality of this situation is surprisingly common in that underground shielded power cable system failures can occur during the first few months or after several years of operation due to either product defects or installation quality deficiencies.

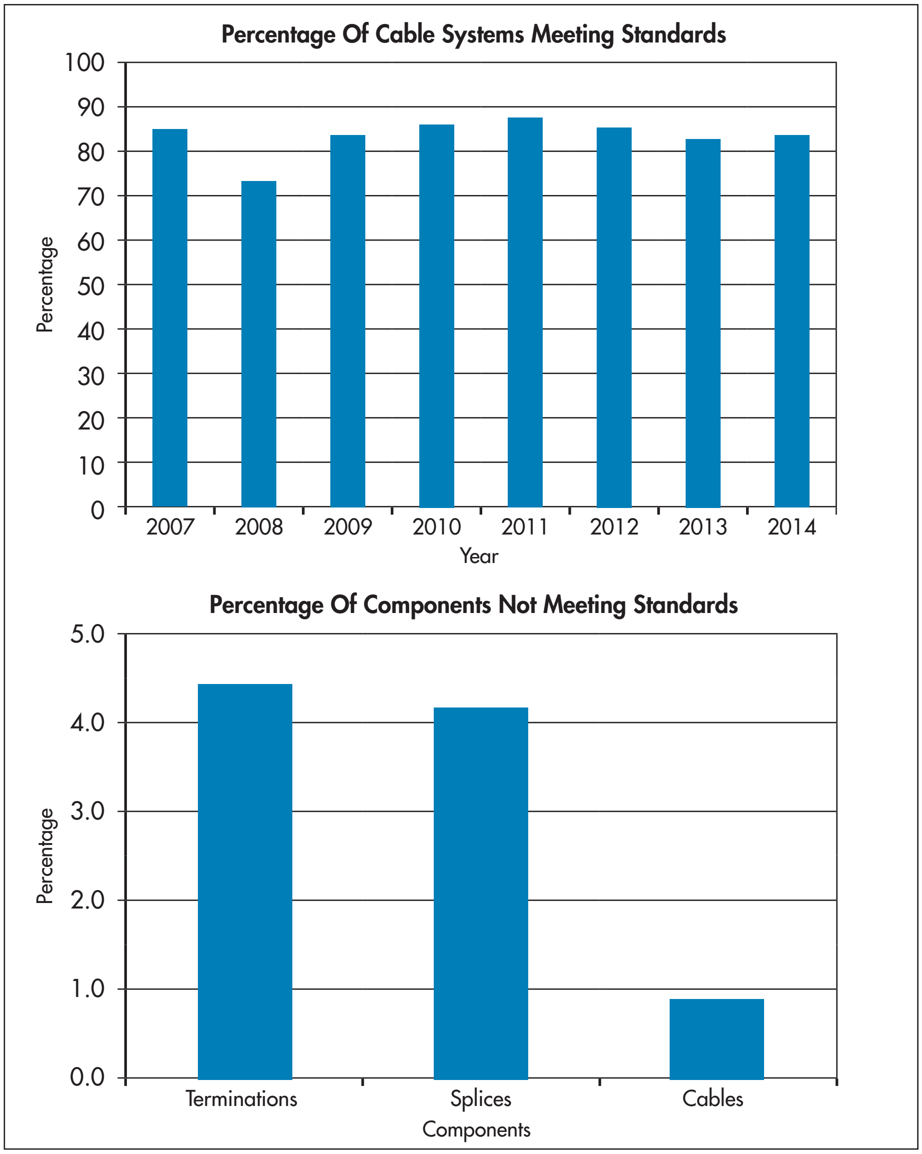
Defects in cable systems have a serious impact on renewable energy suppliers, as downtime impacts both the top and bottom lines in terms of lost revenue, emergency fault location expenses, and excavation and repair costs. Recent surveys have concluded that the typical cost of failure can top $100,000 per incident. In addition, an annual report measuring the cable system quality rating for utility-scale renewable energy sites in the U.S. revealed that approximately 15% of cable collector systems had at least one substandard component that required extensive repair actions.

This cost of failure is avoidable by field testing cable systems to manufacturers' standards during commissioning and planned maintenance outages of your new wind site.

Cable systems fail in reaction to voltage stress and an erosion process associated with partial discharge (PD) at discrete locations due to installation damage, manufacturing defects and aging issues. Renewable collector cable systems typically operate at

Although laying medium-voltage cabling underground is commonplace, much of what drives reliability is not. Photo courtesy of Joan Sullivan/Image Verde

Figure 1



Source: IMCORP

the 35 kV voltage class compared to their 5 kV and 15 kV class fossil-fuel counterparts – as such, these systems continually experience higher electric stress, making them more vulnerable to embedded installation voltage stress issues. This fact is further compounded by the reality that contractors generally have less industry experience installing these 35 kV systems in comparison to the 40+ years of knowledge about the utility installations of 5 kV and 15 kV systems. The collector systems at wind sites are constructed using underground cables to connect the wind turbines together in series, unlike fossil fuel plants, which typically tie generators in parallel. The one vulnerability of this design is that if one of these cable systems fail, then the production from all of the turbines downstream in that feeder circuit will be lost until a repair is made.

How to avoid failure

As shown in Figure 2, all factory-produced cable and components should meet industry minimum performance standards, such as those from the Insulated Cable Engineers Association (ICEA) and the Institute of Electrical and Electronics Engineers (IEEE). These manufacturers' quality control tests require 50/60 Hz PD diagnostics at elevated voltage levels, with better than 5 picocoloumb (pC) – a measure of electrical charge can be used as a measure of sensitivity.

Today, technological advancements have made it possible to perform factory-quality PD methods in the field that are comparable to the IEEE and ICEA manufacturers' standards. The results pinpoint the defect location, identify the component (joint, termination or cable insulation) and indicate the urgency of the repair, while being compared to acceptable thresholds defined by those standards. With the knowledge gained from over 250 renewable sites, utilizing this technology is now widely accepted as the best practice for commissioning newly installed collector systems, and it has become a standard operating procedure for assessing aged cable systems at many investor-owned utilities globally. In addition, this capability has saved hundreds of millions of dollars in aged asset replacement costs and lost energy production for prudent energy suppliers across the world.

Concerned with the number of outages at newly commissioned collector sites, a leading renewable energy developer specified the 50/60 Hz PD diagnostic assessment method as part of its site commissioning process. While assessing the system cables at a 161 MW, 87-turbine wind farm located in Texas, several defects were identified. The results were questioned by the site contractor, who made the decision to retest each substandard cable segment using very low frequency (VLF) power source PD testing. All of the cable systems passed, indicating there was no PD activity even though the defects pinpointed by the 50/60 Hz 5 pC assessment indicated significant defects. A formal investigation of four suspect cable segments at an independent laboratory using the manufacturers' specifications and thorough dissection analysis confirmed that all four defects did not meet the cable manufacturers' quality control testing standards. The developer has since adopted a specification requiring an offline 50/60 Hz PD assessment with

Figure 2

The Manufacturers' Standards

Component Standard	Testing Frequency	Thresholds* Sensitivity	Thresholds* Voltage
Terminations IEEE 48	50/60 Hz	5 pC	≤1.5 Uo**
Joints IEEE 404	50/60 Hz	5 pC	≤1.5 Uo
Separable Connectors IEEE 386	50/60 Hz	3 pC	≤1.3 Uo
MV Extruded Cable ANSIICEAS-97/94-682/649	50/60 Hz	5 pC	≤4.0 Uo^
HV/EHV Extruded Cable ANSIICEAS-108-720	50/60 Hz	5 pC	≤2.0 Uo

*No partial discharge should be observable above the sensitivity threshold up to the voltage threshold.

**Uo is the RMS operating voltage line to ground

^200 V/mil

Source: IEEE, ICEA

a sensitivity of at least 5 pC – a move that will potentially prevent hundreds of thousands of dollars in lost energy production.

In order to understand the impact of circuit outages caused by installation defects within newly commissioned collector cable systems, another site developer began documenting system failures over a four-year period (2008 through 2011). The population included 1,600 miles of newly installed TRXLPE cable systems, consisting of 1,563 three-phase cables, 9,278 terminations and 1,839 joints. Studying the performance of the accessories and joints when using offline 50/60 Hz PD diagnostics versus VLF withstand, the following results were observed.

The VLF-tested cable systems had a 100-times-higher in-service failure rate over a three-year period than a factory-comparable PD-tested population did over a four-year period. Thousands of miles of underground medium-voltage cable systems have been installed at renewable energy sites across North America during the past decade; however, much of the knowledge and experience that drives the reliability and performance of these collector systems is relatively new. There are many guides and opinions that emphasize the benefits of proactively testing cables, but few tests meet or even come close to the requirements of cable and accessory manufacturers' standards. It is practical then that renewable sites' cable collector systems are commissioned using a field assessment technology and process that is comparable to these standards because they operate with higher stress, are installed with lower experience and are placed in a configuration that makes large portions of the site vulnerable to an outage. NWP

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