CASE STUDY

THE CASE FOR A STANDARDIZED COMMISSIONING TEST

IMCORP™ Power Cable Reliability

0.1Hz VLF PD vs. the IMCORP Factory Grade® Technology

HIGHLIGHTS

OVERVIEW

- VLF PD and the Factory Grade® technology assessment results are compared in the field and in the laboratory.

CHALLENGE

- Multiple parties did not believe the Factory Grade® technology assessment results.

RESULTS

- The Factory Grade® technology is proven 100% effective and 0.1 Hz VLF PD was completely discredited.

The Manufacturers' Standards

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

Table I: Manufacturers' Standards

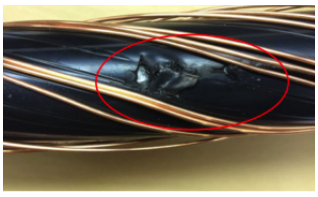
Overview

Concerned with the number of outages at newly commissioned collector systems, a leading renewable site developer specified IMCORP's Factory Grade® technology, with its unmatched 5 pC field sensitivity, as part of its site commissioning process. After several cable defects were identified, the site contractor questioned the validity of the IMCORP assessment and retested the substandard cable segments using very low frequency (VLF) power source partial discharge (PD) testing. A formal investigation at an independent laboratory using Factory Grade® technology and thorough dissection analysis confirmed that all identified defects did not meet the cable manufacturers' quality control testing standards. In contrast, the VLF PD method failed to locate any of the defects in the same analyzed segments.

The developer has since adopted a specification requiring offline 50/60 Hz PD assessment with a sensitivity of at least 5 pC, a move that will potentially prevent hundreds of thousands of dollars in lost energy production.

Challenge

Cable systems fail due to an insulation erosion process associated with PD activity that can originate during manufacturing, shipping, construction, accessory installation and aging of operable sites. The cost of outages that occur directly after newly installed collector systems are commissioned can impact the system owner in terms of lost energy production, where warranties for workmanship and manufacturing issues typically do not recover this cost during downtime. Recent surveys have concluded that the typical cost of failure at solar and wind farms is somewhere between $30k and $100k per incident. In addition, an annual index compiled by IMCORP since 2006, to measure the cable system quality rating (CSQR) for utility-scale renewable energy sites in the United States revealed that 15% of 3-phase collector systems had at least one substandard component that required extensive repair actions. IMCORP performs field assessments of cable systems to the same standards to which cable and accessory manufacturers adhere. All factory produced cable and components must meet standards such as ICEA (Insulated Cable Engineers Association) and IEEE (Institute of Electrical and Electronics Engineers). These manufacturers' quality control tests require 50/60 Hz PD diagnostics at elevated voltage levels, with better than 5 or 10 pC sensitivity [Table 1].



Sample 1: Discontinuity in outer semiconducting layer

Sample 2: Installation damage

Sample 3: Contaminants introduced during manufacturing

Sample 4: Protrusion in outer semiconducting layer

Results

The comparison was conducted during commissioning of a 161 MW, 87 turbine wind farm located in Texas. The initial assessments were accomplished using IMCORP's Factory Grade® technology where PD activity was identified in several cable segments. Questioning the results, the site contractor retested the same segments using 0.1 Hz VLF PD testing technology. As a measure of due diligence, the same segments were reassessed a second time using IMCORP's technology and the results once again indicated the same PD activity in the same locations as the first assessment revealed.

In order to verify the results from each assessment procedure, four cable segments were identified for extraction and evaluation by an independent laboratory. In each of the four cases, the IMCORP assessment had identified PD activity within the cable segments, while the 0.1 Hz VLF test had reported all to be PD free. IMCORP deployed its 'location matching' technology to determine the position of the PD sites and a rigorous recovery process was followed in order to extract each segment. A 100% chain of custody was established and maintained during the extraction and shipping process. Detailed tagging, marking and photographs of each cable segment were documented while assist crews extracted each length of cable. As an added measure of security, tamper-proof tape was used on the shipping crates to prevent interference with the cable sections between the collector site and laboratory.

After arriving at the independent testing laboratory, PD testing of each cable segment was performed in a shielded room to manufacturers' standards [Table 1]. In all four cables, the off-line 60 Hz PD test results revealed the same electronic PD signatures as those that were identified by IMCORP's Factory Grade® technology in the field. Finally, laboratory dissection results on all four cables verified the serious insulation defects at each PD site, reaffirming the results provided by the IMCORP field assessments.

Conclusion

In summary, 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 and repair costs. This cost of failure is avoidable through the practice of field testing cable systems to the manufacturers' standards during commissioning and at planned maintenance outages.

In addition:

- Renewable collector cable systems operate with higher stress (35 kV versus 5 and 15 kV), are often constructed by installers with lesser experience, and are placed in a configuration that makes large portions of the plant more vulnerable to an outage.
- Renewable collector system outage costs are typically on the order of $30K to $100K.
- The average 100MW renewable site has approximately 15 substandard components requiring significant remedial action.
- Cable systems fail in reaction to voltage stress and an erosion process associated with PD at discrete locations where there are installation, aging, or manufacturing defects.
- Voltage transients are the primary driver of PD and its associated insulation degradation.
- VLF PD tests measure for PD at a sensitivity level that is at least an order of magnitude lower than the manufacturers' standards (5 pC). At reduced sensitivity levels, half or more of all PD activity may go undetected.
- Manufacturers' standards require PD detection at power frequency (50/60 Hz) in order to emulate system operating conditions. VLF solutions that deviate from power frequency are unlikely to create PD events that would happen under operating conditions.

IMCORP's technology to field assess cable systems has been used at over 250 renewable sites worldwide, to assess over 90,000, 5 kV to 500 kV class cable systems and enabling significant reliability improvements for both new and aged systems.

A summary of the four secured samples and shipping carton sent to the independent laboratory

Sample	Feeder	From	To	Location	Loc. (ft)	PDIV Uo	Avg. pC
1	1	JBOX SC1-3	JBOX SC1-2	Cable, C phase	2772	1.0	424
2	6	Subst	JBOX SC6-1	Cable, B phase	2366	1.0	31
3	6	Subst	JBOX SC6-1	Cable, C phase	116	1.55	157
4	7	JBOX SC7-5	JBOX SC7-4	Cable, C phase	267	1.7	110