Electrical Insulation for field-aged PV modules

Tadanori Tanahashi and Takashi Oozeki
PV System and Application Team, Renewable Energy Research Center,
National Institute of Advanced Industrial Science and Technology (AIST), Japan

Reuse of photovoltaic (PV) modules is an integral part of the circular economy in solar PV system, and the electrical safety is the most crucial issue for the reuse of field-used PV modules. The greatest threat to electrical safety of PV modules is the integrity of backsheet, which secures their electrical insulation. Although the wet leakage current test (WLCT) specified in IEC 61215 series has been used as a gauge for this soundness, there have been few cases even where PV modules with severe cracks in the backsheet have failed this test. Furthermore, since the extended WLCT (for several dozen hours) may induce potential-induced degradation (PID), this would not be an appropriate test for reuse of PV modules.

In this study, we continuously measured the leakage current (between PV circuit and PV frame) under damp-heat (DH) with positive high-system voltage (p-HV) stress conditions on the commercially available PV module with p-type PV cells, in which intense backsheet-cracks has been observed by the exposure in the area adjoining to a coastline for ca. 7 years, to elucidate the degradation behavior (including safety defects) of this field-aged PV modules, as a worst case exposed under the harsh environmental stressors. In the field-aged PV module prior to the indoor stress tests, slight power-loss (ca. -3%) compared to those of the pristine PV modules was observed, as well as the high insulation resistance of over 600 $M\Omega \cdot m^2$ had maintained (the pass/fail threshold in IEC 61215-2 is defined at 40 $M\Omega \cdot m^2$), even when the severe backsheet defects were identified. During DH with p-HV stress conditions, the hourly rate of transferred charges (HRTC) was linearly increased, and reached at ca. 2×10^4 C/h after 100 h. In this state, the insulation resistance could not be evaluated with WLCT due to high leakage. For the I-V characteristics of this PV module with high HRTC, the higher power-loss (ca. -85%) was found with the obvious decrease in Voc and FF. From these I-V characteristics accompanied with the specific EL image, we assumed that the PID-s (but not PID-p) occurred in this PV module during these combined stressors were applied, even when the p-HV stress was loaded to the PV module with p-type PV cells. To confirm the occurrence of PID-s in this PV module, the PV module were stored in a warehouse conditions over 220 days. The power-loss was recovered to ca. -50% (to those of the pristine PV modules) with the moderate regaining in the EL image. Unfortunately, the insulation resistance of this warehoused PV module was not determined, by the value indicated in the ohm meter was fixed below its measurable range. As expected, the second round of DH with p-HV test again induced the critical power-loss (ca. -85%) with the diminish of EL signals. Interestingly, the HRTC was started again from around 1×10^4 C/h in the second round DH with p-HV test, but not from around several tens' C/h observed in the first round. This HRTC was finally come up over 1×10^6 C/h for 100 h test in the second round.

Based on these results, we demonstrate that the HRTC measurement under DH with p-HV stress conditions would be a valuable indicator for the detection of electrical-insulation breakage responsible for electrical safety issues in the PV modules comprised of p-type PV cells. In addition, the severe PID-s could be induced by the leakage current with opposite direction, because the PID-s is clearly identified by in the p-type PV module with serious backsheet cracks, probably by the effect of ions penetrated (through backsheet defects) from atmosphere in the neighbor of coast. These suggestions should be further investigated to ensure the electrical safety of PV system (in particular, those installed as a floating PV system).

We thank the members of PVQAT-JP and JET (Japan Electrical Safety and Environment Technology Laboratories) for their helpful discussion. This abstract is based on results obtained from a project, JPNP20015, commissioned by the New Energy and Industrial Technology Development Organization (NEDO). We wish to thank NEDO for their supports.