Verification of Balance of System for Solar Photovoltaic Power Plant

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Abstract

This paper presents results of the initial field inspection report of 10kWp Grid Connected Power Plant using Multi-crystalline PV Modules at IIT Gandhinagar-Ahmedabad. The inspection was carried out according to standard IEC 62446, Grid Connected Photovoltaic Systems - Minimum requirements for system documentation, commissioning tests and inspection, Edition 1, May 2009. Qualitative studies are made on physically visible defects such as gridline fading, corrosion of module frame, absence of grounding, hanging of wire cords, terminal box labeling etc. Initial verification takes place upon completion of a new installation or completion of additions/ alterations to existing installations. Periodic verification is to determine whether the installation and all its constituent equipment remain in a satisfactory condition for use. Here, the initial inspection is carried out and the effect of initial field exposure on the modules indicates that the qualification standard (s) needs to be reviewed and revised if the modules are to perform for long term under operating conditions.

1. Introduction

In a photovoltaic system, the term 'balance of system' refers to all of the system components except the PV modules. These components include but are not limited to: conductors and terminations; disconnects and overcurrent protection devices; charge controllers; batteries and inverters; grounding and lightning protection systems; support structures and enclosures; and instrumentation and monitoring equipment and these frequently account for half of the system cost and, unfortunately, most of the system maintenance.

The market access requirements for PV equipment are segmented in two main areas - safety and performance - that are integral to each other in the overall construction. The focus of the IEC requirements is in terms and symbols, testing, design qualification and type approval. Other focuses on safety parameters. These certifications include materials (such as polymeric used for back-sheets, encapsulants, and adhesives), components (junction boxes) and end-products (inverters and meters).

At Indian Institute of Technology Gandhinagar, a 10kWp Solar Photovoltaic Power Plant using Multi-crystalline PV Modules was commissioned in year 2011-12 and was verified in June 2012 according to standard IEC 62246. However, it should be mentioned here that not all tests were conducted and clauses were left out because the elementary part of electrical insulation i.e. grounding was absent. Therefore, the plant didn't qualify for testing procedures of IEC 62446.

In this paper, report on visual inspection performed according to Clause 4: System documentation requirements (Clause 4.3: Wiring diagram) and Clause 5: Verification (Clause 5.3: Inspection) of standard IEC 62445 is discussed. These verifications have been devised to assess the safety and performance of power plant in operating condition for a long span of time.

2. Observations

In absence of earthing, much of the verification of a grid connected PV system is done with reference to IEC 60364-6 which provides the requirements for initial and periodic verification of any electrical installation.

The Clause 5: Verification; of standard IEC 62446 provides the requirements for the initial and periodic verification of a grid connected PV electrical installation in particular. It references IEC 60364-6 where appropriate and also details additional requirements or considerations for the verification of a PV system.

DC by nature is generally more difficult to interrupt. It has no natural zero crossings. However, AC contains two zero crossings per cycle. Therefore, DC must be artificially forced to zero. Whenever a switch is opened under DC load, the current does not stop immediately and the flow remains there over the open gap between the switch contacts via a low energy arc. When voltage over the arc becomes high enough, only then the current flow stops. It is vital to suppress the arc and break the current as it may increase the temperature up to 20 000 K).

According to the clause 5.3.2, all DC components should be rated for continuous operation at DC and at the maximum possible DC system voltage and maximum possible DC fault current (V_{oc} stc corrected for local temperature range

and based on module type; and current at 1.25 × I_{sc} stc according to IEC 60364-7-712.433:2002). However, it was found that the DC disconnect device provided in a Junction box (JB box) inside the control room is rated for AC application at 415V, 63A, 3pole AC MCB. The other DC components including lightning resistor, fuse and array junction box weren't rated and were used without proper labeling.

According to clause 5.3.2; protection by use of class II or equivalent insulation adopted on the DC side is to be verified which was not done. There being no reliance on protective earthing. The cables provided were also local made. Although the cable provided was sized (4 mm2) for the application, since it was exposed to direct sunlight it should have had UV protection but it wasn't there. The race ways provided for the cable protection were also found to be degraded.

Between the AC and DC sides and that earth connections have been constructed so as to avoid corrosion (IEC 60364-7-712.312.2:2002). However, it was found that the mounting structure provided was considered as the means of grounding. The connection bolts of the structures were found to be corroded. Moreover the bolt was mounted over polymeric washer (Refer Figure 1) which rules out the continuity of grounding means.

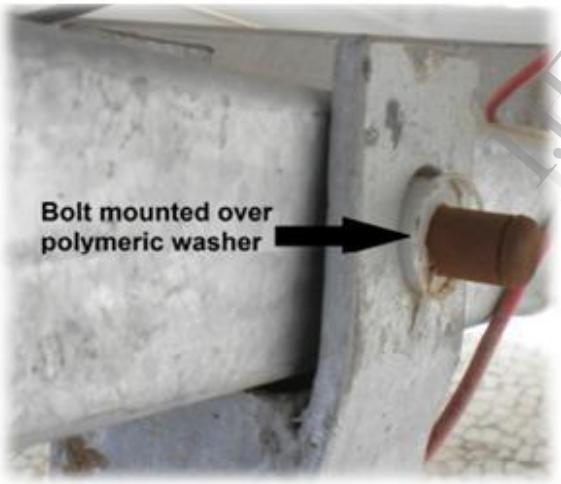

Figure 1: Bolt position at the frame

By this clause, PV string cables, PV array cables and PV DC main cables must be selected and erected so as to minimize the risk of earth faults and short-circuits (IEC 60364-7-712.522.8.1:2002) which can be typically achieved by the use of cables with protective and reinforced insulation. The cables in the premises of the power plant were of suitable size and rating; however, they weren't protected from UV and are vulnerable to degradation after extensive use in sunlight.

This clause also speaks of wiring systems been selected and erected to withstand the expected external influences such as wind, ice formation, temperature and solar radiation (IEC 60364-7-712.522.8.3:2002). The conditions in the field didn't comply with the clause. The average wind speed on the roof of site measured for the day was more than 40 m/s2. Inspite of using the cable tie, the wires are found to be hanging (Refer Figure 2) which may result in losing the property in due course of time.

Figure 2 Wires hanging down the module

According to clause 5.3.3; Protection against overvoltage / electric shock; verification that array frame and/or module frame protective earthing conductors have been correctly installed and are connected to earth is required and where protective earthing and/or equipotential bonding conductors are installed, verification that they are parallel to, and bundled with, the DC cables (IEC 60364-7-712.54:2002) is required. In contrast to this, the modules were mounted over the mounting structure, which was considered as the grounding means but the frames were not properly bonded with structure.

Again by the same clause, area of all wiring loops should be kept as small as possible (IEC 60364-7-712.444.4:2002) in order to minimize voltages induced by lightning. The plant abided by the clause with proper wiring of the loops. Array frame equipotential bonding should be installed but the same was missing.

According to clause 4.3.5, Earthing and Overvoltage protection, the wiring diagram shall include earthing and overvoltage protection information, however, it was found missing on the field. The absence of grounding made the plant unsafe under operation.

Lightning arrestor was installed as Lightning Protection System; however, it was not installed at the right place (Refer Figure 3).

Figure 3 Position of lightning arrester

One more metal structure was present next to the existing lightning arrester (Refer figure 4). Also the lightning arrester fixed is slightly away from the PV Array installation (4 to 5m form the PV Array) which will not cover the entire PV Array within its protection area limit.

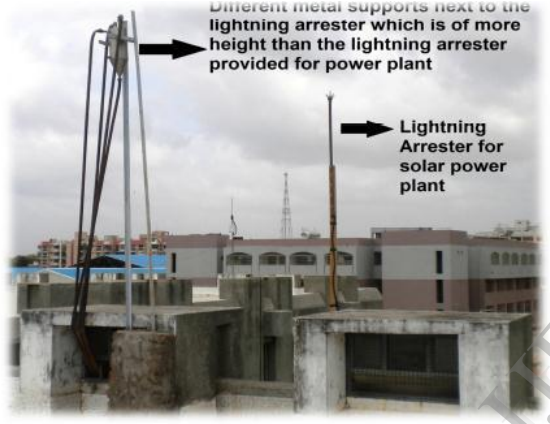

Figure 4 Length of lightning arrester falling

All DC junction boxes (PV generator and array boxes) should carry a warning label indicating that active parts inside the boxes are fed from a PV array and may still be live after isolation from the PV inverter and public supply but the warning was missing from the box.

There were no dual supply warning labels fitted at point of interconnection, no single line wiring diagram was displayed on site, nor were there any emergency shutdown procedures are displayed on site. It was found during the inspection that all signs and labels were not suitably affixed and durable.

With a mechanical aspect, there was no corrosion proof frames installed, the frame was not stable and the wiring was not weatherproof.

A mark of adhesive was observed on almost all the panels. These marks were because of the tape used during the Packing (Refer Figure 5). These leftover marks may result in further degradation of system performance due to the shade phenomenon and lead to hot spot issues.

Figure 5 Leftover Marks

More than six modules installed in the plant showed the defect of fading Grid lines. These modules were tested individually using IV curve tracer, where the power output was observed to be on lower side compared with other modules. It will create the imbalance in the system (Hot spot) in due course of time and hence recommended to be replaced.

3. CONCLUSION

After monitoring the setup and installation of 10kWp Multi-crystalline PV Module Solar photovoltaic power plant at Indian Institute of Technology-Gandhinagar, the above data certainly indicates that in general deterioration in the performance is expected. The safety is compromised and even the qualified manufacturers failed under actual field conditions and so, in the present qualification standards severity of the test(s) may not necessarily simulate the end use conditions in India. Periodic inspection shall be carried out in terms of safety as well as for the performance.

4. REFERENCES

1. IEC 60364-7-712.444.4:2002-Requirements for special installations or locations–Solar photovoltaic (PV) power supply systems
2. IEC 62246–Grid connected photovoltaic systems–Minimum requirements for system documentation, commissioning tests and inspection