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ADVANCED APPROACH IN SOLAR PV PLANT PROTECTION SYSTEM

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***Abstract*: Solar Photovoltaic (PV) technology has become one of the most promising and reliable source of renewable energy. The favorable conditions like decreasing prices of PV system, increased panel size and enhanced efficiency improved the solar PV power plants installations. PV Panel and Inverter are vital equipment's in functioning of solar PV system. As the solar power plant has various power electronics and other electrical components, there might be chance for power interruptions due to improper functioning of switch gear. Ensuring protection measures of the solar power plant plays a key role in smooth functioning of the system. The main objective of the paper is to explain various protection issues faced in solar roof top system and the necessary measures taken for resolving the issues with root cause analysis. This technical paper also showcases various preventive maintenance activities followed in the solar PV plant.**

***Keywords:* Solar photovoltaic, Switch gear**, **Inverter faults**, **Protection issues, Earthing.**

I. INTRODUCTION

Solar Photovoltaic (PV) technology is one of the most promising technologies in present scenario due to costing and ease of installation. In 2010 Jawaharlal Nehru National Solar Mission started by Government of India [1]. The initiative of this mission is to promote solar power in different phases and achieve target for the deployment of 100GW of solar power by 2022.Grid Connected Solar Rooftop programme is launched by Government of India to avail advantage of unutilized space above various buildings. The abovescheme targets to achieve a capacity of 40 GW by the year 2022.The Solar Energy installed capacity is 46.27 GW as on 30Sep 2021 as per Central Electricity Authority report [2]. As there is a need for India to increase the share of renewable energy to address various climate changes and sustainability goals, recently Indian Governmentalso enhanced its ambition to install 450 GW of renewableenergy capacity by 2030.

As part of the Solar roof top program National Council for Cement and Building Materials, Hyderabad (NCB-H) has taken a proactive step and installed 10 kWp solar PV planton roof top of administrative building.

The electricity generation from solar panel has been started after its commission and system is fully functional. During the course of time the plant generation was interrupted twice for short intervals due to various technical issues. This paper focus on necessary measures adopted to overcome the technical issues which can be replicated in similar size solar PV power plants.

Growatt 1000 TL3-S series solar string inverter [3] user manual briefs about the components used, application of various components, protection devices, inverter efficiency, safe earthing, operational measures and better construction practices. The manual also suggests various protective measures of inverter like avoiding installation of the inverter in an open area exposed to sunlight despite inverter being IP 65 protected. The manual stresses that inverter must be connected to AC grounding conductor and grounding for PV array must be connected with DC grounding conductor. The Inverter operates in four different modes viz: Normal mode, fault mode, shutdown mode, derating mode. The Inverter error and inverter faults are the two types of notifications displayed on the inverter screen and the complete details of it are available in the manual.

Low voltage installations, Requirements for special installations or locations – solar photovoltaic (PV) power supply system's **IEC 60364 Part 7-712**[4]. This code portrays many protective measures on solar photovoltaic supply installations, protection against over current, short circuit current, voltage disturbances, transient voltages etc. The code also explains about selection of wiring, surge protection devices, switching and control devices. Many PV installations operate at DC voltages are very capable of sustaining DC arcs. There are three main categories of arcs in PV installations. Series arc, parallel arc and arc to earth. Series arc result from faulty connection in wiring, parallel arc result from short circuit between adjacent wiring and arc to earth result from insulation failure to earth.

Design and Evaluation of Earthing and Lightning Arrester for Grid Connected Solar Prototype System, **Ms. Nilam P. Patil1, Prof. N.S.Shinde** [5]. The paper explains the importance of earthing in electrical installations is to enhance the safety by reducing the level of danger inherent to fault currents. This paper focuses on methods of

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construction of earth pit using conventional & advanced techniques, cable design calculation for maximum allowable voltage drop, design of lightning arrester etc. Direct contacts is defined as an event caused by a person or animal getting in contact with a live conductor of the electrical installation or a normally live conductive element. Indirect contact happens when a person or animal gets into contact with an exposed-conductive-part. The author made a study on earthing and lightning arrester design on grid connected 65 kW solar PV plant.

A Review of Design, Manufacturing of Grid Tied PV Inverter and Its Impact on Site Performance, Reliability and Safety by **Kiran Krishna Dhandale** [6]. The author presents a detailed analysis of protection devices used in solar PV system such as Surge protection device (SPD)protecting the electrical equipment damage from over voltage. SPDs can be of metal oxide varistors (MOV) or gas discharge tubes (GDT) and both has limited lifetime and can handle finite number of surge events. GDT type has high current handling capacity as compared to MOV. The types of SPDs within inverter are selected based on PV plant engineering, i.e for direct or indirect lighting strike, sizing of lightning arrestors and earthing system SPD selection is defined by IEC 61643-12, IEC 62305-4. The SPD's are categorized as Type 1, 2 and 3 based on duration of impulse current handling capacity as per the paper.

Earthing and Lightning over voltage protection for PV system by **Xavier Vallve, Maria Anzizu, Mariano Ribas** [7]-UNDP-DREG. In this report, protection parameters of solar photovoltaic systems have been studied by focusing on earthing and lightning arrester. Different assessment schemes are explained to have a proper earthing like visual identification of loose connections, formation of rust etc. The other assessment is measurement of earth resistance and maintaining the value under permissible limits. If earthing is not proper, new earthing scheme must be designed considering the soil resistivity, applied loads, identification of exposed conductive parts. The author claims that in case of PV plants without galvanic isolation, if the fault occurs on DC side, fault on the exposed conductive parts causes tripping of the residual current circuit breaker positioned on the AC side of the power conversion unit. Once the protection trips, the power conversion unit shifts to standby due to the lack of grid voltage at its output. If there is a fault on the DC side, residual current circuit breaker on the AC distribution board side should trip and Type B breaker should be used in AC distribution board.

II. TECHNICAL ASPECTS OF THE PROJECT

The capacity of the solar PV plant is 10 kWp with 32 No's of 315Wp poly crystalline PV modules connected in series and parallel connection to 10 kW string inverter. The project work started with identification of suitable location for mounting solar PV panels. NCB-H has identified three buildings for installation of plant, among which administrative building is selected after performing shadow analysis. Shadow analysis is done to analyze the day light conditions at different time periods on a day at preferred location of the rooftop of NCB-H administrative building.
Solar PV plant is designed in such a way that the modules are connected in strings to produce DC power output. Two strings are i.e. 16 No's of PV modules for eachstring making a total of 32 No of PV modules for two strings which are connected in parallel to the inverter. Inverter is provided with anti-islanding protection where inverter senses the power interruptions from the supply grid and shut itself to stop feeding power back to the grid. Protective devices for different DC and AC supplies are installed in inverter viz. DC reverse polarity protection, DC switch for MPPT, output AC over current protection, Output AC overvoltage protection, ground fault monitoring, grid monitoring and sensitive leakage current monitoring unit.

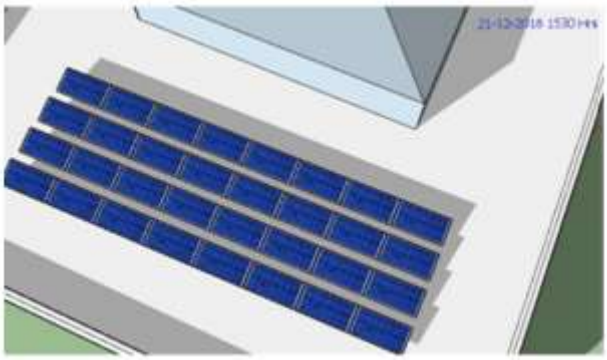

Figure 1: Shadow Analysis of rooftop

Figure 2: Solar PV Plant on rooftop of NCB-H

The Solar PV Plant comes with other components like DC & AC distribution boards, Cables, Lightning arrestor and suitable earthing Systems. The reference voltage for the solar PV plant has been taking from the existing panel available near the inverter. The plant has been commissioned by the executing team in a span of 3 days.

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The percentage costing of components out of the total project cost is shown below.

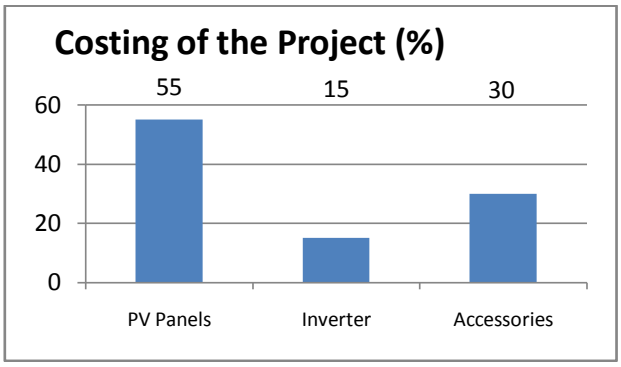

Figure 3: Costing of the solar (PV) plant

The energygeneratedtill December 2020 is 15301 units. The savings realized from the generation of solar PV plant is around 1.4 Lakhs.

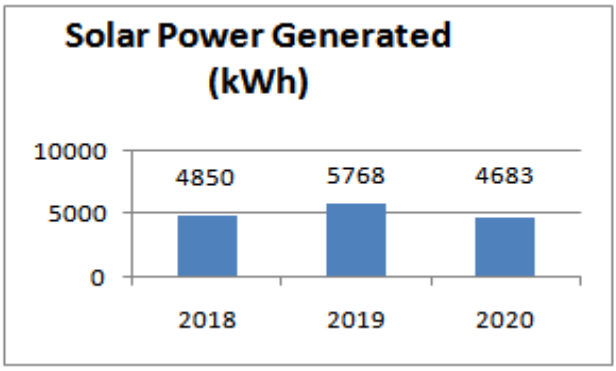

Figure 4: Solar PV plant generation trend

III. TECHNICAL ISSUES AND THE NECESSARY MEASURES ADOPTED IN SOLAR PV SYSTEM

The Solar PV Plant comprises of PV Array, DC Distribution Board, Inverter and AC Distribution Board with a reference voltage from the existing panel. The solar power plant has various power electronics and other electrical components, there might be chance for power interruptions due to improper functioning of switch gear. The power flow from array to the existing electrical panel has been shown in the below single line diagram:

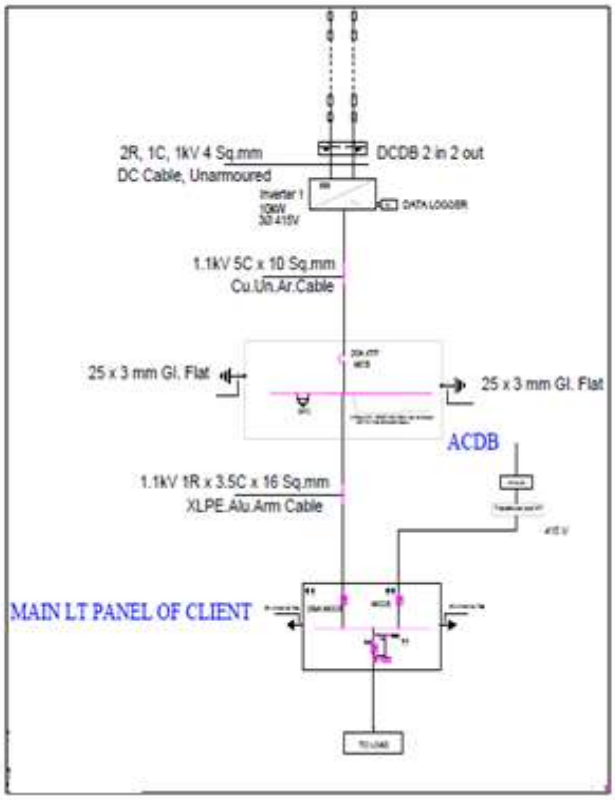

Figure 5: Single Line Diagram of Solar PV Plant

The smooth functioning of the solar PV plant depends on the various protection measures adopted as per the standards. Some of the technical issues faced in last three years of solar PV plant operation are failure of surge protection devices and inverter faults. The necessary measures adopted for resolving the above technical issueswith root cause analysis are described below:

3.1 Surge protection device (SPD)burnt: It is observed that SPD installed in AC distribution side burnt with red color indication in its health status.
Root cause analysis: Surge protection devices (SPD) are installed in the upstream of AC & DC electrical equipment. An SPD intended to limit the transient over voltage and divert the surge current to earth with a goal of preventing equipment damage. MERSEN make SPD of rating I_{max}40 KA installed in both AC Distribution Board and DC Distribution Board. The SPD has a feature to identify its health by its color, Green color indicates SPD is healthy and red colorresembles SPD is unhealthy and needs to replace. SPD has burnt twice since last three years and regular monitoring of SPD is necessary to ensure the smooth functioning of the solar PV plant.

3.2 Inverter faults: It is observed that inverter is showing Error-117 on the display of inverter which indicates that there is a fault in the relay circuit in the inverter.

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Root cause analysis: The healthiness of SPD in AC & DC Distribution Board, miniature circuit breaker of existing panel has been verified and found that AC Distribution board SPD burnt off. The other solar PV plant components like DC and AC cables have been thoroughly inspected and observed that there is no damage in the insulation. The SPD has been replaced with new SPD but inverter is showing the same fault code.

The inverter manual has been studied in detailed for additional technical information and manual is suggests to have separate earthing for AC and DC system. The earthing of the AC & DC system of solar PV plant has been studied in detail and found that earthing has been made common for AC & DC. The international standard (**IEC 60364 Part 7-712)**for Low voltage installations, requirements for special installations or locations – solar photovoltaic (PV) power supply systemsalso suggesting to have separate earthing system for AC and DC system in Solar PV plant. Based on the above technical deliberations and discussions with inverter manufacturer, earthing of AC and DC has been separated. The inverter became functional after replacement of relay componentwhich might got damaged due to infusion of fault current because of combined AC & DC earthing.

Figure 6: Technician providing dedicated DC Earthing

1.3 PV Isolation low: It is observed that inverter is showing Error-125 on the display of inverter which indicates that the inverter has detected a problem with the insulation of the system.

Root cause analysis: In humid weather conditions, it is often noticed that the occurrence of Error-125. The moisture ingress in the cable causes the DC current of the solar panel to leak to the earth on the array frame. The inverter senses the fault and shuts the system for its safety. Once the moisture is evaporated with rise in temperature from the sun the error extinguishes itself and the system starts to work again.

Figure 7: Error: 125 display on the inverter screen

IV. PREVENTIVE MAINTENANCE ACTIVITIES OF SOLAR PV PLANT

NCB-H is covered with dense natural habitat and frequent movement of monkeys was witnessed. In many occasions it was observed that the DC cables are pulled away from the connecters due to above external factors. Improper cable connections in the cables and junction boxes leads to short circuits. In one instance it is observed that one MC4 connector found burnt which is caused due to the loose connection in connector. The problem is addressed by replacing the damaged MC4 DC cable connector with a new connector and the PV plant started functioning. This issue is happened due to the cable pulling by monkeys. The periodic inspection of solar array structure and its components ensures the continuous functioning of solar PV power plant.

The accumulation of dust causes a significant reduction in the intensity of solar radiation reaching the surface of the PV module and results in a marked deterioration in the conversion of solar energy into electricity. The rate of dust accumulated on the surface of a solar cell depends on several factors, the most important of which are the concentrations of suspended particles in the atmosphere, particle size, and atmospheric conditions. NCB-H is located in a construction zone; accumulation of cement dust particles is more. Cleaning cycles of solar panels are improved resulted in enhanced generation.

Lightning arresters (LA) are designed to provide protection to solar array against damage from lightning strikes. Solar PV systems are usually located and exposed on the rooftop or outside areas, the chances of such a system to be struck by lightning are very high. Two meter long conventional lightning arrester is provided at the top of solar PV plant with proper earthing.

Regular checking of earth pits is the best preventive maintenance activity performed in any electrical system. The earth resistance is measured with the help of Digital Earth resistance tester for DC, AC and LA at regular intervals. The measured Earth pit resistance values of DC, AC and LA are shown in graph below:

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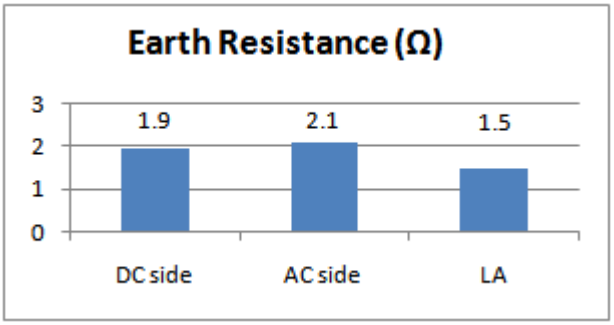

Figure 8: Earth pit resistance values of DC, AC and LA

V. FUTURE PLANS

The efficiency of solar PV plant can be enhanced by using reflectors to improve the power output of PV modules. The performance of the solar panel with reflector depends mainly on tilt angle and reflectivity of reflector. The optimum tilt angle needs to be adjusted and different materials can be used as reflectors such as mirrors, aluminum, stainless steel etc. to attain maximum power output.

NCB-H is planning to install another 10 kW rooftop solar PV plant with bifacial solar PV panels. Bifacial solar panels [8] provide up to 50%more energy output compared to conventional panels. The other advantages of bifacial panels are its durability, less space consumption etc.

VI. CONCLUSION

Solar PV Power plant is a promising renewable energy source with its ease of installation and operation. NCB-H installed roof top solar PV plant of capacity 10 kWp and contributed as part of Indian Government Solar roof top program. The technical issues like burning of SPD and inverter faults are resolved by taking the necessary protection measures with a detailed root cause analysis. The methods adopted here can be replicated in similar size solar PV plants. The preventive maintenance activities are discussed in detail which helps in smooth running of Solar PV Plant.

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