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Shahriar Shahbazpanahi
Islamic Azad University, Department of Civil Engineering, Sanandaj, Kurdistan, Iran,
PhD (Structural Engineering),
University Putra Malaysia, Malaysia, 2009-Present

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EDITORIAL

It is my proud privilege to welcome you all to the TheIRES International Conference at Oxford, United Kingdom. I am happy to see the papers from all part of the world and some of the best paper published in this proceedings. This proceeding brings out the various Research papers from diverse areas of Science, Engineering, Technology and Management. This platform is intended to provide a platform for researchers, educators and professionals to present their discoveries and innovative practice and to explore future trends and applications in the field Science and Engineering. However, this conference will also provide a forum for dissemination of knowledge on both theoretical and applied research on the above said area with an ultimate aim to bridge the gap between these coherent disciplines of knowledge. Thus the forum accelerates the trend of development of technology for next generation. Our goal is to make the Conference proceedings useful and interesting to audiences involved in research in these areas, as well as to those involved in design, implementation and operation, to achieve the goal.

I once again give thanks to the Institute of Research and Journals, TheIIER, TheIRES & University of Management and Technology (Sialkot) for organizing this event in Oxford, United Kingdom. I am sure the contributions by the authors shall add value to the research community. I also thank all the International Advisory members and Reviewers for making this event a Successful one.

Editor-In-Chief

Dr. P. Suresh
M.E, Ph.D. Professor and Controller of Examinations,
Karpagam College of Engineering.,
Coimbatore, India

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ROOFTOP SOLAR PV SYSTEMS

RATCHASAK SANNOK

Electrical Technology Department Suan Sunandha Rajabhat University, Thailand
Email: [1]ratchasak.sa@ssru.ac.th, [2]ratchasak@hotmail.com

Abstract - This paper presented the generation of electric energy from rooftop solar PV systems in Thailand. The PV system was intended for home-use or building basis. According to the parameter of the PV system, itwasnecessitated to distribute alternative power source to serve broadareas in the country. The advantage of using the PV systemwas exhibited through the enhancement of stability and quality of the electricity consumption. This system encompassed location, solar panels, inverters, circuit breakers, cables, conduits and installation of the devices and equipment. Installing the rooftop solar PV systems required proper material that met the specification requirements. Moreover, every part of the devices and the equipment were to be installed correctly to establish efficiency and safety when it came to real use.

Keywords - Solar PV Rooftop, Solar Rooftop Diagram.

I. INTRODUCTION

Photovoltaic (PV) devices produced electricity directly from sunlight and, unlike other solar technologies such as concentrated solar power (CSP) or solar thermal for heating and cooling. The key components of a PV power system were various types of photovoltaic cells (often called solar cells) interconnected and encapsulated to form a photovoltaic module (the commercial product), the mounting structure for the module or array, the inverter (essential for grid-connected systems and required for most off-grid systems), the storage battery and charge controller (for off-grid systems but also increasingly for grid-connected ones). [1]

The rooftop PVSolar system in Thailand had been operated to produce electricity for over 15 years.The total of 60 households were pre-installed with such system. Initially, 10 houses were installed with a 23.76 kilowatt-peak of the power generation system on the rooftops. Later the next 50 rooftops were installed with a 154.34 kilowatt-peak of the power generation system. The generated electricity was planned to sufficiently serve those 60 households, and the leftover was to be distributed to the MEA called "Net metering".

In 2013, the Energy Regulatory Commission of Thailand (ERC) had a project intended to purchase electricity produced from the rooftop PV solar system using the Feed-in Tariff (FiT). The goal was set at 200 megawatt-peak. Living homes were pre-installed with 0 - 10kilowatts for 100 megawatts.Small-medium-large commercial buildings were pre-installed with 10-1,000 kilowatts for 100 megawatts. The overall achievement in the 1st session lasted till August, 2016showed the total of 113.86megawatt-peak—including living homes for 20.12 megawatt-peak, small-to-medium commercial building for13.81megawatt-peak, and large commercial buildings for79.93megawatt-peak. As a result, it was crucial to purchase electricity from the rooftop solar PV systems in the 2nd stage in order to distribute the remaining power to the MEA as planned. The constraints in the operation were from the installation processalong with the safety of the buildings [2].

II. SOLAR POWER GENERATION SYSTEM

The Solar Power Generation System in Thailand was established with the requirements set for the installation process as well as for the device of rooftop PV Solar—which was connected with theLV. Such requirements were aimed to enhance the safety and orderliness of the system. The system encompassed a solar cell which obtained sunlight to generate Direct Current and distributed it through a grid connected inverter which modified the direct current to the Alternative Current. The alternative current was adhered with a low-voltage power distribution system that sent out the generated power from the solar cell to a Watt Hour Meter affixed with electricity distribution systems. The composition of the system was exhibited in Fig.1. Rooftop Solar PV connected Diagram.

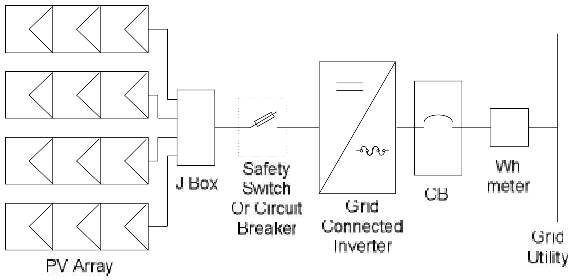

Fig.1. Rooftop Solar PV connected Diagram.

As seen in the Block diagram of the rooftop PV Solar in Fig 1, PV array, Safety switch or Circuit breaker, Grid connected inverter, Molded case circuit breakers

(MCCB), Watt Hour Meter (Wh meter) and Wires were comprised in the system. [3]

A PV Grid connected system was a power generation system designed for incepting power and processed through agrid connected inverter which converted a direct current to an alternative current and then directly distributed it to an electric power transmission system. Such system was used to produce electricity in metropolitan areas or places where a power grid was available. The main devices contained a solar cell and a grid connected inverter that modified the direct current to an alternative current and attached with an electric power transmission system[4].

III. SPECIAL CHARACTERISTICS IN THE COMPOSITION OF PV SOLAR ROOF TOP

In compliance with the electricity purchase announcement about the procured power produced from living houses rooftop Solar PV in a form of Feed-in Tariff notified by the Energy Regulatory Commission of Thailand (ERC), there were special criteria demanded at minimum for orderliness and safety purposes[3].

3.1 PV array

1) A PV array, Crystalline silicon type had to be approved by TIS. 1843 standard or certified by IEC 61215 Crystalline silicon terrestrial photovoltaic (PV) Modules - Design qualification and type approval.
2) A Thin-film solar cell had to be approved by TIS. 2210 standard or certified by IEC 61646 Thin-film terrestrial photovoltaic (PV) Modules - Design qualification and type approval.
3) A PV array had to be authorized by TIS. 2580 standard or certified by IEC 61730 Photovoltaic (PV) module safety qualification. Besides, a test and a test report from a lab accredited by TIS. 17025 standard or certified byISO/IEC. 17025 General requirements for the competence of testing and calibration laboratories was called for.

To obtain the best efficiency and minimize the mismatch, every single PV Module connected with a grid-tie inverter and installed at the same spots of the peak power was instructed to be the same type and the same series of circuits. Every PV Module joint with a grid connected inverter and located at the same peak power areas was obliged to own the same attributes in terms of electricity loads, short circuit loads, open-circuit voltage, peak power current, electrical power loads, and room temperature coefficient.

During the installation of the PV array, overheat beyond the peak operating temperature had to be avoided at all costs and in all setups within the PV system. A PV Module loads from manufacturers were derived from the test performed under a standardized test condition. In general, throughout the installation, temperature of a PV module was increased as it was anticipated that the PV Module would function at least at 25 C higher than a normal environmental temperature, at a decent air ventilation, and at the light intensity of1000W/m^2 (Full Sun). On a contrary, if the light intensity was more than 1000W/m^{2}and the air ventilation was unpleasant, the temperature of the PV Module would augment to an increasing extent (it was possible that its temperature hit more than40-50 C above the environmental temperature).

3.2 Solar Panel Mounting Hardware

1) Material used to build a solar panel mounting hardware had to be galvanized steel, type of Hot dip galvanizing complied with ASTM or non-rusting metal.
2) The components of a solar panel mounting hardware were to be capable of being effortlessly torn down and re-assembled.
3) Bolt & Nut had to be made from non-rusting materials.
4) The structured pillars had to be securely adhering to the roofs of the buildings. It could stand strongly against the wind, and could stand the wind speed that was higher than the highest wind speed of the tropical storm.

The design of the PV Module, the installation of the PV Module and the seizure method to hold the PV Module to be adherent with the pillars and to hold the pillars with the buildings or the ground had to be able to endure with the highest wind speed. When it came to installation, all above-mentioned materials were to be compatible with the wind speed level, wind types, direction of the wind and its location, and all those factors were calculated based on the requirements to assess the capability of those factors. The potential highest wind speed (if known) at the installation spots was to be brought into account for calculation and for feasible incidents foreseeing like Depression, Typhoon. Solar Panel Mounting Hardware for the PV Array was required to be sturdy and robust following requirements, disciplines, and standards of the buildings. Wind power going against the PV Array could cause loads to the structure of the building, so such loads played a significant art in the assessment to determine the resistance capability of the building.
The installed pillars of the PV Module as well as the seizure methods to hold thePV Module tightly with the pillars, and to secure the pillars with the building

or the ground were required to be made from erosion-resistant materials suitable for the lifespan and the system of the PV array such as aluminum, and galvanized steel. Provided that the composition of the roofs and the structure of the buildings were metal, aluminum, stainless steel, galvanized steel, woods, or polymer materials had to be employed. Using aluminum materials for the installation areas located near the seaside or the high-erosion environment, the thickness of the materials had to be increased through an odization.For the rooftop PV module installed near the coast, salt in vapor was intense in the surrounding air, and rain could not much cleanse the salt from the PV module surfaces. Thus, a PV Module and the rooftops had to be washed by water on a regular basis. All of the screws, bolts, and ring nuts were to be heavy-duty and suitable for the location where the PV was used—like those made from stainless steel and non-rusting materials. The attention regarding to the prevention of various electrical erosions between the 2 different objects was to put into account since the decay could be incurred between the rooftop and the building or between the building/the fasteners and the PV module. In order to mitigate such electrical erosion between the 2 different galvanizing surfaces of the 2 objects, a Stand-off Material had to be deployed such as nuts and bolts made from insulated nylon rubber.

3.3 Grid connected inverter

1) It had to be certified by the standard of IEC 61727 Photovoltaic (PV) systems – Characteristics of the utility interface and IEC 62116 Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters.

2) A test report had to be validated and approved by a lab accredited bTIS. 17025 standard or certified by ISO/IEC. 17025 General requirements for the competence of testing and calibration laboratories.

3) The Electrical specification had to be in compliance with the requirements stated by the Electricity Generating Authority of Thailand (EGAT) or Metropolitan Electricity Authority (MEA) or Provincial Electricity Authority (PEA).

In the event of the input circuits of the inverter devices following the input-split power peak points, prevention of the PV modules connected with those inputs of the inverter devices from encountering the current flowing over the configured value, and reverse current in each of the PV module part had to be reviewed. PV array isolators, and each isolator owned a relay device that acted where it was necessary to isolate the inverter and to protect electrical circuits from overload or faults.

3.4 Cut outSwitch

3.4.1 DC Side

3.4.1.1 Safety switch

1) Fusible Type, 1 Phase, 2 Wires or better.

2) The structure had to be interlock cover metal to support when the switch rocker arm moved to the "on".

3) It had to be pre-installed with a fuse that was direct current and rated current not less than1.5 times of the short circuit current rating, at the STC (Standard Test Conditions) or the solar cell series.

3.4.1.2 Circuit breaker

1) Molded case circuit breaker (MCCB)

2) Certified by IEC 898 or IEC 947-2 or other compatible or better standards.

3) Size of the Ampere Trip (AT) Size of the Ampere Trip (AT) had to be above1.25 time of the short circuit current rating, at STC (Standard Test Conditions) of the solar cell series. short circuit current rating, atSTC (Standard Test Conditions) of the solar cell series.

3.4.2 AC Disconnecting Switch

1) Molded case circuit breaker (MCCB)

2) Certified by IEC 898 or IEC 947-2 or other compatible or better standards.

3) Size of the Ampere Trip (AT) had to be above1.25 time of the Rate Power of Grid connected inverter at Unity Power Factor.

3.5 Cable

1) Photovoltaic Wire which tolerated not less than 80 C temperature, or 0.6/1 kv or CVcable following the IEC 60502 standard or any other wires with better qualification/spec.

2) The DC current rating had to be able to endure more than1.25 times of the short circuit current rating, at theSTC (Standard Test Conditions) of the solar cell series.

3) The AC current rating had to be able to endure more than1.25 times of the Rate Power of Grid connected inverter) at the Unity Power Factor.

4) The size of DC Sideon the electric cable connected from the solar cell series to the inverter had to abide at least more than 1.25 times of the peak power running through the circuits and having voltage drop in the cable not more than 3% of the peak current within the solar cell compared with the operating current (IMP) of the solar cell series atSTC.

5) The size ofAC Side on the electric cable connected from the output of the inverter to thegridunity had to bear with the electrical current for not less than 1.25 times of the peak current running through the circuits

and having a voltage drop not more than3% compared with the electrical current distributed based on the Rate Power of Grid connected inverter at theUnity Power Factor.

3.6 Electrical Conduit

1) A polyethylenewithhigh density polyethylene pipe, HDPE typePN8 or better and approvedTIS. 982 standard.
2) A metal conduit, type EMT or better.

The installation of the conduit was required with structured roofs to prevent the cable from being fragile due to wind or other possible severe/unpredictable environment. A pathway for the cable installed on structured roofs or in a pipe had to be pre-determined and planned upfront based on the electrical wiring and connection standard for Thailand. Knob and tube wiring paths located on the rooftops or the ground where no water or dust went in at all costs. The cable had to be protected from scratches, mechanical stress, pressure, and stripping force that could happen from the cycle of heat, wind, and others. Throughout the installation process and the lifespans of the conduit, and the tube, all of the materials were demanded to be ultraviolet-resistant. The cable belt could not be used as a main device to hold the cable unless otherwise the lifespan of the cable belts was equal or longer than the wiring system.

In case that a conductor was not tubed,when connected to the wires and those in a junction box, the tenseness had to be minimized to stop the wires from falling apart in the wire tube. For instance, GlandConnectorused for tube wiring or in a junction box was not toreduce the IP of the box or the tube, and this could be achieved by sealing as instructed by the manufacturers.

3.7 DC Junction Box

1) Made from metal or solid plastic, outdoor type.
2) Ingress Protection, IP at the level of IP45 or above.
3) Wire joints had to be correctly and securely installed in a junction box
4) Wires and tubes had to be inserted from the bottom of the box to prevent water from coming in over the long terms.

Every joint had to be verified and inspectedin terms of intensity and alignment of the electrode throughout the installation process to mitigate potential risk, faults, and arc flash during the Commissioning process, the real operating times, and the maintenance periods in the future.

CONCLUSIONS

In summary, Thailand was capable of manufacturing electrical solar power from PV cells, and the obtained electricity was linked to the 2 distribution systems within the Electricity Authority—firstly was the solar farm power generation which purchased the electricity from the traditional ground PV modules, and secondly was the rooftop solar power generation which the modules were installed on rooftops of the buildings. Solar power was a clean energy which was environmental-friendly. Such asset of the solar energy was aligned with the energy security and power provision policies of the country. Nonetheless, the limitation was the linkage to the electricity distribution system belonged to the Electricity Authority owing to the Authority's requirements and standards. If there were a large number of solar power generation facilities in the same areas, the quality of the electricity distribution would be impacted particularly on the electrical voltage in the areas where lots of solar generation plants produced significant electricity amount but with low consumption—the stability of the power distribution would be affected in this case. Therefore,installing solar cell power generation system had to be in line with the product requirements and the installation guidelines as explained earlier.

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