Optimal Design and Analysis of Roof Top Grid Connected Solar Photovoltaic System

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Abstract : The aim of this study is to design the grid connected rooftop photovoltaic system for the residential building. The detail analysis of design before implementation of solar photovoltaic system project is the important criteria for any of the project. A design and feasibility analysis for the proposed design is carried out using PVsyst simulation software. The analysis of solar photovoltaic system using PVsyst is helpful for detecting the key area of consideration. The simulation analysis result shows that the project yields 173 MWh for single building of the residential complex. The PVsyst analysis is helpful for the implementation of solar photovoltaic system with pure commercial consideration.

***IndexTerms* - Renewable Energy System; Grid Connected PV System, Solar Photovoltaic System, Rooftop PV System, PVsyst, Solar Design.**

I. INTRODUCTION

The need of energy specially in term of electrical energy is increasing day by day due to rapid development and improvement in human lifestyle. Until few years ago, the main source of electrical energy is fossil fuels which are limited and also create environment pollution [1-2]. The new and renewable form of energy is explored for reducing the burden on fossil fuel. The renewable energy like solar, wind, hydro, geothermal and biogas are available for free and inexhaustible and it is considered as a lifeline for the future generation, when very little amount of fossil fuel left on earth.

India, due to its geographical location, has an abundant amount of solar radiation and mostly has a good number of clear days when solar energy is available. The solar energy can be utilized either as a thermal energy or electrical energy by direct conversion. The Indian Government has taken initiatives for the promotion and use of off-grid and grid connected Solar Photovoltaic System. Due to Government of India flagship program, the solar PV system becomes a commercially accepted source of electrical energy[3]. In the grid connected PV system employ the direct conversion of solar energy into electricity which is fed directly into the electrical grid without storing it in batteries. On the other hand, off-grid PV system is implemented for the location with no electrical grid or weak grid and batteries are employed as a source of backup energy when solar radiation is not available.

The average clear number of sunny weather in most part of India is approximately 250-300 days a year. The average available solar radiation varies from 1600 to 2200 KWh/m^2 which is a good amount for tropical region. The estimated solar energy for India is approximately 6000 million GWh per year. India launched Jawahar Lal Nehru Solar Mission in 2010 with aim to install 20GW by 2022 which was later increased to 100GW [4]. The installed capacity of solar PV plant as on March 2019 is 28.1GW. Apart from grid connected solar plant, large number of solar street light, solar agriculture pump and off-grid solar are installed in large number.

The site considered for the analysis of rooftop grid connected PV system is a residential complex (Sarvodaya Nagar) with group of 16 buildings with around 3000 apartment. The site is located in Thane, sub-urban of Mumbai Metropolitan Region and the coordinate of site is 19.18N (latitude) and 73.22E (longitude) with good solar radiation. The solar radiation data for the selected site based on Meteonorm is shown in Fig 1. The Fig. 1 shows the global horizontal radiation and clearness index of the site. The clearness index (0-1) shows the friction of radiation which reaches the surface. The paper is formulated in a way to describe the design and numerical analysis of a PV system for the production of energy. The numerical analysis is used to design the optimum size of grid connected PV system and it feasibility in term of economic analysis.

II. SITE SURVEY AND FEASIBILITY STUDY

On buildings of residential complex, there is enough space to install solar photovoltaic system. The roof of the building is lying ideal and can be used for mounting and installation of Photovoltaic module. The installation of PV module on the roof has some additional benefit like reducing heat absorbing area in summer and reduces risk of water leakage during rainy season. The grid connected PV system is a first choice for such big project. Generally, grid connected PV system does not have a battery backup. But in the residential project, some backup for essential load like lift and common area light is always required, as grid is not 100% reliable. Also, the residential complex must need to compile the rule of local authority and safety norms which mandatory mentioned that each complex with lift has a provision of backup in case of power failure. So, the proposed design considers a grid connected battery backup solar PV system.

The selected site is a residential complex with 16 buildings. The obstruction for solar shadow is a water tank installed on the top of building. The PV array layout is planned in a way to avoid such any shadow from water tank. As per the survey of site, the building roof has a plenty of space for installation of PV panel. The residential complex aerial view and the sample building 3D view are shown in Fig. 2 and Fig. 3. The PV array is designed to lay down in a way, so that there is no shading from one row to other row [5]. A simple rule for minimum spacing in between the row is to allow a space equal to three times the height of the top of the row. The physical orientation and tilt of PV panel is according to site geographical location.

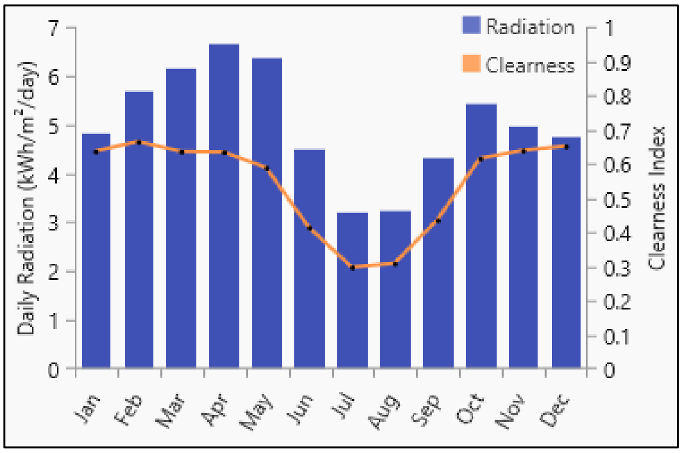

Fig. 1. Global Solar Radiation and Clearness Index at site location

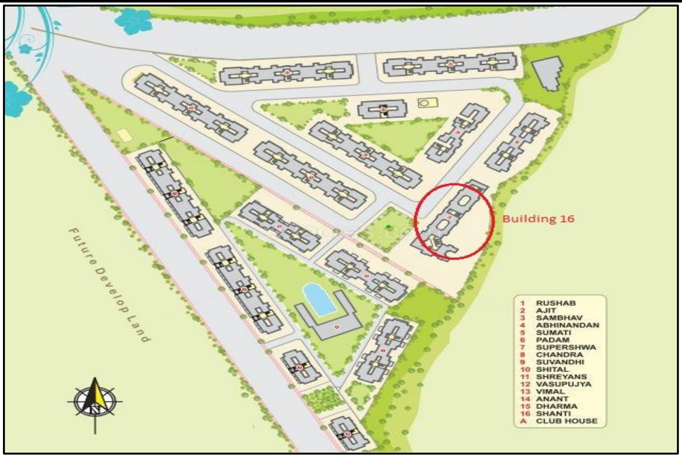

Fig. 2. The aerial view of residential complex

As the analysis is performed for the site located in northerm hemisphere, solar panel should be faced toward south. The tilt angle is the optimal angle when maximum solar radiation is received by panel and it is approximately equal to latitude of that location. So, the tilt angle for this design is 23˚. For design purpose, one of the building of residential complex is considered, whose 3D view is shown in Fig. 3. The area of roof is used to implement solar PV system. The approx. total area for PV array installation is 750 m2. The inspection has been performed on parameters such as roof area, roof type, pitch & orientation and the strength of roof. The total area of 750 m2 is further divided into three sub-groups of 244 m2, 210 m2 and 198m2 respectively. The purpose is to reduce the size of individual system (as building has a three wings) and the system can be installed and manage easily. One the important purpose of design is to calculate the solar PV potential of the rooftop of building. In the first case, total available area for the installation is calculated using architecture drawing of the building. The 3D view of building shown in Fig. 3 is developed in PVsyst environment for the analysis of partial shading event. In the proposed analysis, partial shading effect is minimum and that why it is not considered in the final analysis.

III. TECHNICAL CONSIDERATION AND INPUT PARAMETERS

The PVsyst is dynamic simulation software for the analysis different type of PV system [11-13]. It uses hourly data from database for the analysis and compute a result based upon the user input. The database of the PVsyst has a data of solar radiation, weather condition, Component rating, component cost, financial rate etc. The PVsyst uses the data in dynamic way to evaluate the result with due consideration of probability. The detailed economic evaluation can be performed using real component data, installation rate and investment rule. The PVsyst has tool to use the result data for the generation of graph and table. The result in user friendly way is helpful for engineer to decide the final course of action.

The photovoltaic panel is the basic component for solar project. The solar cell is a semiconductor specially diode. The diode configuration creates a voltage difference across the junction and when incident light fall on PV cell, electron is produce. This phenomenon is known as photovoltaic effect and it generate current and potential difference across the cell. The two type of PV cell is mono-crystalline and poly crystalline. The electrical characteristics of PV panel are rated at STC (Standard Test Condition), where cell temperature is 25˚C, Solar Irradiation 1000W/m2 and air mass 1.5 [6-7]. The high performance poly-crystalline PV module of 320W, Make Jinkosolar, is selected for design purpose. The reason behind the selection of poly-crystalline module is to reduce the per watt cost. The average cost of 33.59 INR/W for PV panel is decided after market survey. The output from the PV array is totally depends up on the solar radiation and environment condition and it is essential to select input parameter properly. The environment condition includes temperature, air flow direction, environment pollution and geographical situation etc.

The DC-DC converter and DC-AC inverter along with smart controller is a heart of grid-connected PV system. The function of DC-DC converter is to control the output voltage of PV array in a way to extract maximum power at any type of environment condition. Actually, the PV panel output voltage and current is totally depends upon the connected load across it and there is only one optimal load for the available environment condition. At this optimal load, power extracted by PV panel is maximum and in standard term, known as Maximum Power Point. In practical case, the optimal load is not always available. The DC-DC converter has a power electronics converter to adjust the load at PV array terminal and in this way, helps to extract maximum power at all time. The Solar Inverter configuration is slight different from the normally available Inverter. The solar inverter has special features like anti-islanding, grid synchronization, under voltage protection, smart selection of load, battery management (optional), harmonic filter etc. The solar inverter keeps the sinusoidal output synchronized to the grid frequency (50 Hz). The three Canadian Solar Inverter with rating 40 KW, 30 KW and 30 KW is chosen from the list of available inverter. It has a nominal efficiency of 97% and transformer less operation with multiple MPPT [8-9].

The selected mounting structure for PV array is made of non-corrosive material with provision to set the tilt manually to maximize the output yield. The structure will riveted on the roof with RCC block and one layer of water proofing is also done in order to avoid any leakage. The size of cable (module and array interconnection to junction) and junction to power control unit shall be selected in a way to reduce the drop in voltage. All the electrical wiring should be in insulated PVC pipe with standard grade [10]. The junction box is made to resist dust, vermin and water. During designing, the provision of data logging features is also considered. It is helpful for the future course of analysis. At present, most of the standard available inverter has an inbuilt feature of data logging. The available data can be extracted locally or remotely using GSM modem system. In this design of cost of data logging system is also considered. The weak grid is a common feature of residential load; as there is numerous reason that why the grid is fail occasionally. The Diesel Genset or battery with inverter is an only option to provide backup in that case. In the survey, it is found that some of the essential load in the residential complex has a Diesel Genset backup. In the design system, the solar is assumed as a backup during daytime (with condition of good weather) and battery as a supportive backup, when solar is not available. The Diesel Genset will be a secondary backup to avoid any emergency condition especially in rainy period when solar is not available for long period of time. The 12V, 176Ah Lead Acid battery is selected for this design and DC voltage of 48V is chosen.

IV. THE PROPOSED SYSTEM DESIGN CONFIGURATION

It is assumed that IEEE international standard for design and installation of PV system is considered. Some of the important aspect of PV system is a PV module, type of cable, temperature consideration, wiring estimation, inverter configuration, protection devices, disconnect devices, grounding & surge protection, load monitoring etc. The block diagram of the proposed design of grid connected PV system is shown in Fig. 4. The battery backup is not shown in Fig. 4, as it is an inbuilt part of inverter.

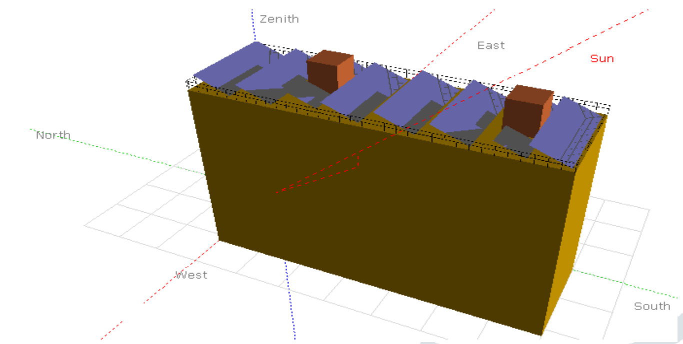

Fig. 3. The 3D view of building

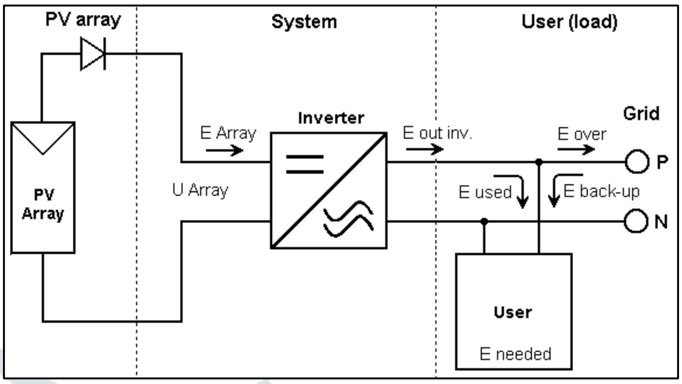

Fig. 4. The block diagram of proposed grid connected PV system

The configurations of three sub-arrays PV system are as follow:

1. Sub-array 1: The available area 250m^2, 126 Nos of 320W PV module, in series: 18 PV module connected, in parallel: 7 strings, 40KW Inverter with 4 MPPT input, Battery Bank (48V, Size: 4*2 (12V, 176Ah)), Power Rating: 40.32KW.
2. Sub-array 2: The available area 210m^2, 108 Nos of 320W PV module, in series: 18 PV module connected, in parallel: 6 strings, 30KW Inverter with 3 MPPT input, Battery Bank (48V, Size: 4*2 (12V, 176Ah)), Power Rating: 34.56KW.
3. Sub-array 3: The available area 250m^2, 102 Nos of 320W PV module, in series: 17 PV module connected, in parallel: 6 strings, 40KW Inverter with 3 MPPT input, Battery Bank (48V, Size: 4*2 (12V, 176Ah)), Power Rating: 32.64KW.

V. SIMULATION RESULT AND ANALYSIS

The overall simulation using PVsyst is performed after careful selection of input parameters like meteo data, solar panel type, inverter & battery rating, site location, partial shading condition and probability criteria. The annual power yield for this power plant is a net power generated after considering all kinds of generation and system losses. The PVsyst simulation result for power generation is shown in Fig.5.

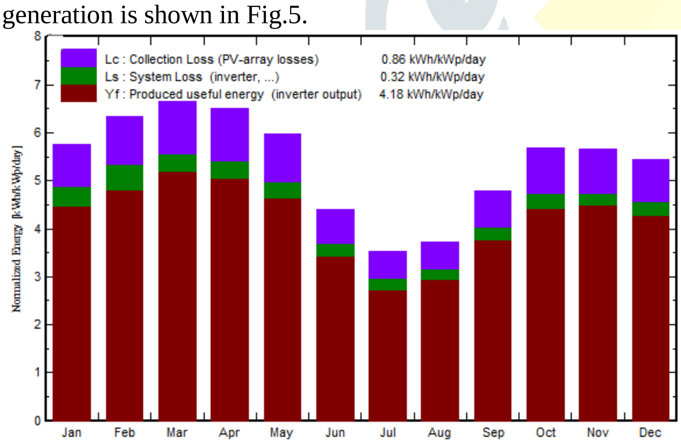

Fig. 5. Nominal Power production for the proposed plant of 108 KW

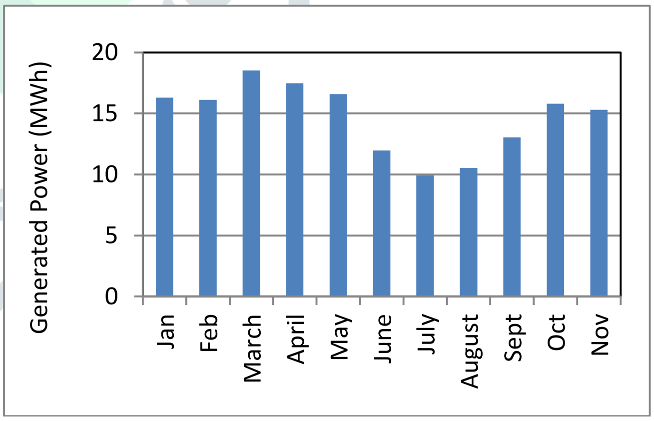

Fig. 6. Month wise generated power from the plant

The overall capacity of rooftop solar PV system is 108KW. The nominal yearly power generated by plant is approximately 173 MWh and month wise average power generation is shown in Fig. 6. The performance ratio for this design is 0.78. The array and system loss are 0.86 KWh/KW/day and 0.32 KWh/KW/day respectively.

VI. CONCLUSIONS

This energy demand of residential buildings is increasing continuously due to improvement in lifestyle. The part of energy requirement can be fulfilled by using renewable energy source. The grid connected solar photovoltaic is a good option for big residential complex as it reduces the dependency on existing grid. The solar energy design is essential for pre assessment of project. It provides the complete detail of proposed solar power plant throughout the life cycle. The design and analysis of optimum solar system using PVsyst is performed in this paper. This paper helps researcher and engineer working in the field of solar energy.

VII. Acknowledgment

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