DESIGN OPTIMIZATION OF ROOF TOP GRID CONNECTED SOLAR PHOTOVOLTAIC SYSTEM

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Abstract : The purpose of this study is to design the grid connected rooftop photovoltaic system for the industrial complex. The detail design methodology for the grid-connected PV system is presented. A PVsyst is used for the feasibility analysis of plant. For the same design, 300 KW grid-connected PV plant is installed in factory. The detail of implemented plant is also discussed in this paper. The data monitoring and analysis is the important features for any solar system. In this paper, IOT based data logging system implementation is discussed. The analysis presented in this paper is helpful for the implementation of solar photovoltaic system with pure commercial consideration.

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

I. INTRODUCTION

The electrical energy is the important part of civilized society and it is considered as a lifeline for anyone. Until few years ago, the generation of electricity is mainly from fossil fuels, which are limited and causes environment pollution. The non-exhaustible and environment friendly energy sources are discovered in recent years and it is considered as a complimentary source for reducing the consumption of conventional energy.

The solar energy is the favorable source of renewable energy for India. India 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 [1]. The grid connected PV system becomes more commercialized due to it features to directly feed the generated electricity to grid without storing it in batteries. In parallel, off-grid PV system is used for remote location or weak grid condition and backup in term of battery storage system is the important feature. The flagship Jawahar Lal Nehru Solar Program is launched by India in 2010 with aim to install 20 GW grid connected solar PV plant by 2022 which is further amended with target of 100 GW [2-3].

The initial designing for the optimization of PV plant is very much essential as it provides a detail configuration of the purposed system with the available parameters. It helps to identify the system flaw at initial stage of implementation. The site considered for the analysis of rooftop grid connected PV system is a manufacturing factory complex in Thane, Maharashtra. It has various workshops with flat and sloped roof. 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 Metanorm solar radiation data (global horizontal radiation and clearness index) for the site is shown in Fig 1. The clearness index (0-1) shows the friction of radiation which reaches the surface.

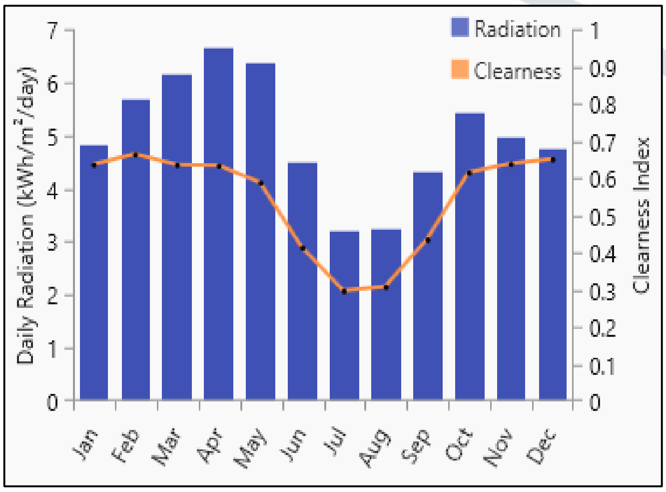


Fig. 1.Single diode model of PV module

TABLE I. Detail of building available for roof top pv installation

Name of Bldg.	Roof Type	Flat roof area in sq.m	Potential Capacity	Remarks
Testing Area	AC sheets + RCC slab	1250	174 KW	Approx. 30% partial shading
Electrical Sub Station 1	RCC slab	280	39 KW	Approx. 10% partial shading
Workshop GT 1	AC sheets + RCC slab	825	Nil	Nearly 50% partial shading
Workshop Drive unit	AC sheets + RCC slab	930	90 KW	Approx. 10% partial shading
Store Drive Unit	RCC slab	750	60 KW	No shading

The paper is crafted in a way to provide the optimal design of grid-PV system using PVsyst and at the same time, the data logging and recording implementation method is discussed.

II. SITE SURVEY AND FEASIBILITY STUDY

The selected factory has various workshops and office building with plane and inclined rooftop. Before the estimation of available area for the installation of grid connected PV system, the whole factory is surveyed to identify the potential to install roof type system. The plain roof with structure stability is only considered due to simplicity to utilize the mounting structure. The inclined cemented sheet roof is not preferred for installation as it required major investment to provide a proper mounting frame for installation.

The building available with roof top is listed in Table I. The first two buildings are near to Electrical sub-station 1 and the last two building are near to Electrical sub-station 2. From the table it is observed that total installation potential is approximate 363 KW. For the initial face of installation, it is decided to install 300 KW grid connected PV system with 2 sub system. The sub-system-1 covers first two building. Similarly, the sub-system-2 covers last three buildings.

Manual design estimation is avoided as it does not provide reliable result and at the same time, optimization is not possible in manual method [4]. For designing and optimization, PVsyst simulation is used. It is a software package which allow user to do full analysis of solar photovoltaic project. It is a software with full integration of PV system simulation with prefeasibilty , sizing, losses estimation and feasibilty analysis. This software is compatiable for standalone, grid connected, roof top, pumping and DC grid system. In Pvsyst, metrological data for around 1200 geographical sites is provided by Meteonorm [5-9]. Meteonorm contains monthly and hourly and hourly average data. The data available from Meteonorm is the avaerge value of irradiance measurement during the period of 1960-1991. The data provided by metonorm is the actual site data or the interpolation of nearby three site data.

The key parameter inputs for the simulation are location, weather data, rating of PV module, inverter type, battery configuration etc. The proper selection of this data is very much essential for accurate result. The weather data was procured from Meteonorm 7.2 with file format of TMY2 file [10-11]. This file contains one year of hourly solar radiation, illuminance, wind speed, temperature and snow depth. For this simulation, it is decided to use standard albedo value of 0.2 which was suggested by PVsyst itself [12].

The simulation itself has a database for vide range of solar photovoltaic PV panel and solar inverter which is currently available in the market. The database has been an option to add generic model manually if the particular model is not available in database. The inverter of Make: GrowWatt, Model No.: MAX80KTL3LV – 2 Nos and MAX70KTL3LV -2 Nos are used for sub-system1 and sub-system-2 respectively. The inverter datasheet stated that the night time consumption of the inverter could be taken as 1W. The minimum and maximum allowable MPP voltage for this voltage is 200 V and 1200 V respectively. Similarly, the poly-si Photovoltaic panel of 330W, Make: Waaree is considered. The detail specification of photovoltaic panel is shown in Fig. 2.

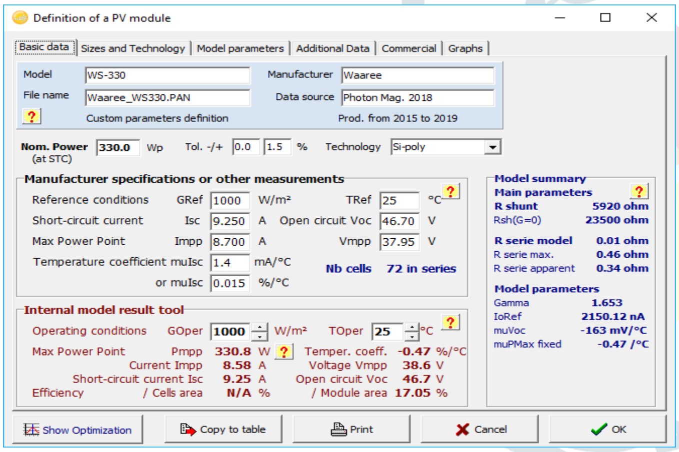


Fig. 2.The detail specification of solar photovoltaic module available from database

TABLE II. Simulation result and system components detail

Sub-Array 1
Available Area: 1184 m^2
Solar PV module: 330W, 32V, si-poly, Quantity 504 NOS
Inverter: 3P, 80KW, 50Hz, 6 MPPTs, Quantity 2 Nos
24 Stings with module in series 21 Nos
Sub-Array 2
Available Area: 796 m^2
Solar PV module: 330W, 32V, si-poly, Quantity 400 NOS
Inverter: 3P, 70KW, 50Hz, 6 MPPTs, Quantity 2 Nos
20 Stings with module in series 20 Nos

This simulation considers various losses which may be added during the actual operation of solar power plant such as Thermal Parameter loss, Ohmic loss, Module Quality – LID – Mismatch loss, Soiling loss, Ageing loss and Spectral loss etc [14]. The ohmic loss is calculated from the wiring layout. After approximating the wire length of the circuit, the PVsyst in turn calculated the 'global wiring resistance' in loss fraction at STC to be 1.13%. The module efficiency loss was taken as 0.1% per year, which was the default value recommended by PVsyst. The dust on the top of the PV module is commonly referred to as PV 'soiling loss'. Generally, there are two types of shading i.e. horizon shading and partial shading. The 3D model of mounting structure and obstacles for the near shading analysis is used.

III. SIMULATION RESULTS AND ANALYSIS

The grid connected PV system model is designed using PVsyst. The simulation result after proper selection of data is produced. The simulation result helps to see the performance of grid connected PV system with consideration of various aspects. The site location is extracted through geographical coordinates (19.24oE, 73.13oN) at Kalyan, Maharashtra at the sea height of 1313 m. The tilt angle and azimuth angle for this location are 19^o and 0^o respectively. In the initial case of analysis, the nearby shading effect is neglected. The month wise average daily radiation and clearness factor for this site is shown in Fig. 3.

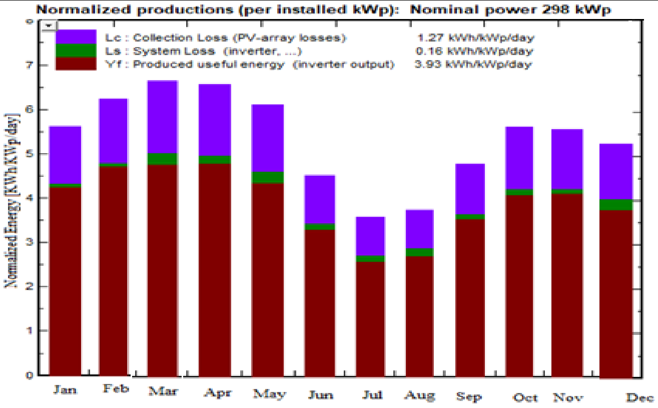


Fig. 3.System collection loss, system loss and useful produced energy at the site location

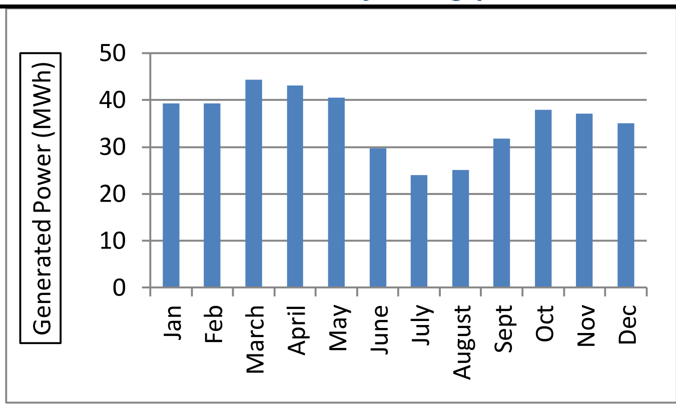


Fig. 4.Month wise generated power from the plant

The total system power production will be 428MWh/yr. In specific energy production term, it is equivalent to 1434 KWh/KW/Yr. Overall system efficiency is 73%. The payback period of the system is 3.8 years. The monthly estimated energy production from the system is shown in Fig. 4.

As per the estimate, the total cost for implementation of 300 KW grid connected PV plant is approximately 108 Lakhs INR. As the plant is maintain by the already deployed electrical maintenance manpower, the yearly cost of maintenance of plant is considered as 90000 INR. This includes consumable item for cleaning of plant and minor repair work. The major maintenance cost is not considered as most of the installation company provide free of cost maintenance service for 5 years from the date of installation. It is found that cost of energy is 1.628 INR/KWh.

IV. THE PROPOSED SYSTEM DESIGN CONFIGURATION

For monitoring and analysis, bulk amount of important data must be available. It is used for checking the performance of the system in regular interval and also it helps to identify the issue related to under performance. In this system, all the electrical parameters are the important data which is recorded by the measuring devices integrated inside the inverter or the smart energy meter. The available data can be seen on the display window or it can be extracted to computer using data transfer technique. It is the main reason behind the utilization of smart meter. In this project Secure Elite 440 bidirectional programmable energy meter is used. Apart from the program architecture, smart meter of different manufacturer has nearly same features. In general, Elite 440 is a multi-line three phase digital panel meter for accurate and reliable measurement of electrical parameters (voltage, current, power and frequency etc.) for industrial and commercial use. The multi-line backlit display enables four line display at a time. The latest communication protocol and the expansion module are the important features for integration with energy monitoring system.

The large number of Elite 440 meter variants can be interrogated over Modbus protocol for collecting energy and instantaneous parameter values using ConfigView [18]. Also, certain configuration can be updated in the meter using ConfigView. The RS-485 port is provided for this purpose which is used to communicate with computer com port via any RS-232 to RS-485 converter [16]. The baud rate is adjusted for proper communication and general value is 9600 bps. With Modbus communication, more than one Elite 440 meter can be communicated with software by transferring the data in serial way. Each Elite 440 meter has identification number known as Device ID which is used by software for identification of device. The meter communication model is shown in Fig. 5.

At present IOT based data logging is not a costly affair and there is N number of option in market with low budget solution is also available. During implementation, Trackso Data logger is used. It has a capability to extract almost any device with Modbus communication port. In some case, Ethernet port can be utilize for data extraction. Almost all the solar inverters that exist in market have an open source data communication protocol called MODBUS. This protocol is used by 3rd party to communicate with inverter over a serial connection and request for data. In this architecture, the request making device is MASTER and device that provide data is called SLAVE. Each inverter has a unique address on which different values such as current, voltage, power etc. is stored. When MASTER send a request with said unique address, particularly that inverter respond and send back the data to data logger. The configuration study to connect Growatt Inverter and Trackso IOT data logger is also performed. The communication port RS-485 is located at the bottom of inverter. There is two connection pins, known as RS485 A/B (Rx and Tx). The inverter ID is set so that each inverter is defined in RS-485 MODBUS communication. For the plant, set different ID no. for each inverter otherwise inverter cannot be identified by receiver and data transmission cannot be performed. If there is more than one Inverter in series than the dip switch of last inverter in the string must be on for the purpose to provide a signal of last inverter in a rung. After this the system hardware is ready for communicate. The IOT Trackso data logger is GSM enabled device with provision for Sim [17]. The data activated Sim must be placed for storing the received data in Trackso cloud. Foe activation of Trackso data logger, configuration setting must be provided. The SMS based configuration just like GSM modem configuration is also possible in this case. Once the communication is established, the data can be easily accessed for cloud network from anywhere. With the user login, one can see the list of connected devices and the data received from that device. The data logger configuration method is shown in Fig. 6. The data logger data is recorded in a systematic manner using the above mentioned arrangement. It provides real time information of system working and also it helps to calculate the overall output energy and profit. The graph of total generated energy is displayed in Fig. 7.

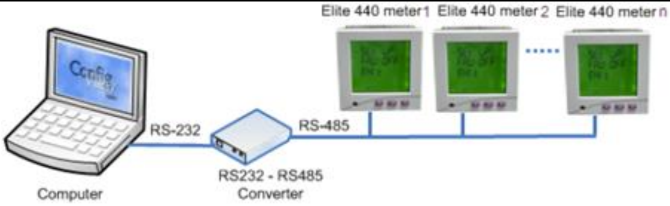


Fig. 5.Month wise generated power from the plant

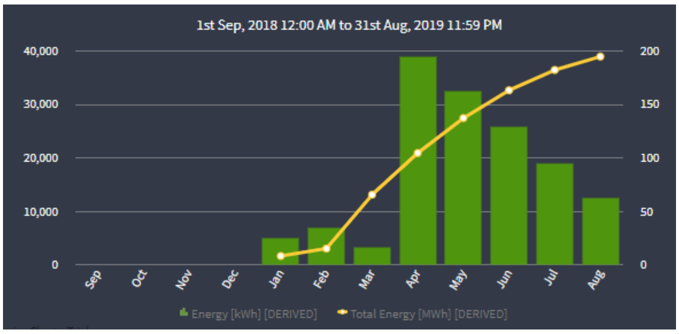


Fig. 7. Output active power of solar plant in year 2019

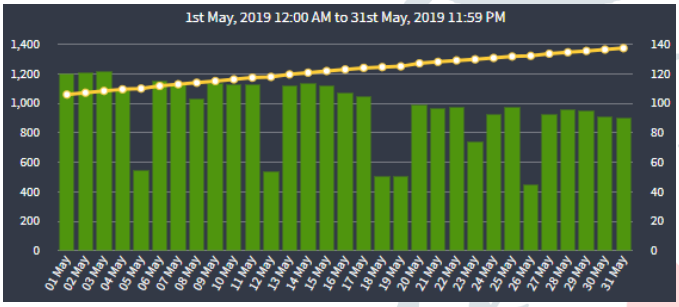
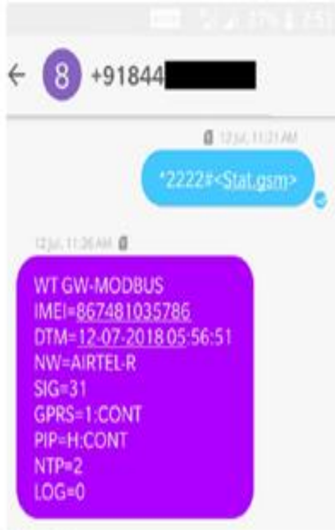


Fig. 8.Output active power of solar plant in May 2019



SMS Command= *2222#<Stat.gsm>	
IMEI	IMEI No. of the data logger (Device Key)
NW	Network
SIGN	Signal Strength out of 31
GPRS	CONT- connected , NC- not connected
PIP	Connected to TrackSo Server or not CONT- connected, NC- not connected
LOG	no. of data points stored in devices incase of no interet

Fig. 6.Data logger configuration procedure.

It shows that total energy generated by system is around 196 MWh (this is for 8 months only). Similarly, the daily production of energy for May 2019 is presented in Fig. 8. The result shows that on 5thMay, 12th May, 18-19thMay and 26thMay, the output power is much less despite the fact that full irradiation is available for said period. This type of anomalies in output is due to no recording of data from Inverter 1 and Inverter 2.

V. Conclusions

The design and optimization of grid connected solar PV system helps to identify the pre system requirement. The analysis helps to implement the system in better way. For the above industrial complex, the estimated capacity of PV plant is 300 KW. The financial analysis and cost benefit analysis is also performed for the same system. For the monitoring of actual implemented system, IOT based data logger is installed. It provides a real time data of energy production and at the same time helps to do a post implementation analysis.

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