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Design Estimation and IOT Based Monitoring of Roof Top Solar Photovoltaic System for Data Analysis

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Abstract*: *In this paper, a study is performed for designing of Solar Rooftop photovoltaic system for factory complex. The detail design analysis for the accurate design is presented. The suitability of proposed plant is analyzed using PVsyst software. Taking consideration of proposed design, 300 KW solar rooftop photovoltaic plant is installed. The data monitoring of installed solar plant is an essential part for accessing efficiency of plant with respect to estimated capacity. In this paper, implemented IOT model for cloud based data monitoring system is presented. The presented data analysis of this paper is helpful for commercial analysis of solar photovoltaic project.

Keywords* : *Rooftop Photovoltaic System; Renewable Energy System; PVsyst, Grid Connected PV System, Solar, Energy Analysis, IOT, Data Monitoring.

I. INTRODUCTION

The electricity is an another important lifeline for civilized society and the shortage of electricity has a potential to cripple every other essential services like water works supply, transportation, production and communication etc. The electricity is a secondary form of energy which is mainly generated from fossil fuel like coal, nuclear energy and hydro energy. This conventional method of electricity is a cause of environment pollution and rapid depletion of natural resources. The global warming and environment degradation force various governments to explore non-exhaustible and clean source of energy. In this direction, the renewable electricity generation methods are explored and research is still carried out for improvement in system efficiency. The renewable energy source has a capability to support main stream electricity generation and in recent scenario, it is emerged as an important source of electricity generation. Due to geographical location of India, solar energy is the best alternative source of energy.

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The number of clear days in a year and level of solar radiation signpost, that India has abundant solar resource. This natural energy can be converted into electricity by two modes: solar thermal energy conversion and solar photovoltaic energy conversion. The solar photovoltaic system of energy conversion is most popular and used in almost all the solar project due to its low cost system requirement. In the same line, commercial solar project preferably consider grid connected PV system as there is no requirement to store generated energy in batteries. The grid connected PV system is more maintenance free and there is no constraint for system size. The battery connected PV system is preferred in a place where grid is not much reliable and the system implementer want solar energy as a backup source. The solar energy project is well implemented in India due to flagship Jawahar Lal Nehru Solar Program which has aim to install 100GW of grid connected solar PV system by 2022. The initial design and system constrain analysis is essential for a systematic solar photovoltaic plant design. The design of solar photovoltaic system consists of proper selection of site location, rating of solar panel, technical specification of converter & inverter, wiring consideration, losses estimation, commercial estimation and cost benefit analysis. The above optimization is essential for pre-project approval and detail system estimation. In this paper, the implemented project consists of grid connected rooftop PV system for industrial compound in Kalyan, Maharashtra. The site has fair solar radiation with site coordinate of 19.21N and 73.19E. The site monthly solar radiation statistics is figured in Fig. 1. In this figure, the clearness index is a percentage of radiation which reached to earth.

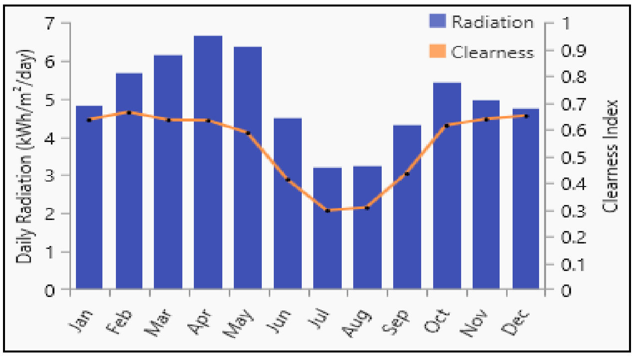

Fig. 1. Month wise solar radiation and clearness index at site

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 methods are discussed.

II. SURVEY AND SYSTEM ESTIMATION

The factory has a workshops and other industrial building with inclined and plane roof. The potential of rooftop solar is accessed and it is observed during the survey that inclined surface must not consider due to requirement of measure structural modification. So, after initial survey, it is decided to consider the plain rooftop area with structural ability will be considered. The different available buildings for installation are testing buildings, Electrical Sub Station 1, Gear Cutting Workshop and Assembly Line Workshop. The approximate installation capacity of rooftop PV plant is 363KW. In the rough estimation, 300KW plant design is considered in initial case. As the shops are at different location, it is better to design a system with two sub-system which are isolated and connected to main system at different sub-station. The pictorial view of site location is shown in Fig.2.

Fig. 2. Satellite view of complex and the sub-array

A formula based simple estimation is not a good idea, as it is not capable to estimate accurate result. In order to increase the reliability of design, a proper optimization tool must be considered. There are various offline and online optimization tool for solar system available in market. The choice of selection is totally depend upon purpose of analysis. Some of the powerful tools are PVsyst, PVSOL, HOMER, Solar Design Tool and PV Watt etc [15-18]. In this case, PVsyst is considered for designing and optimization, as this is quite user friendly and every aspect of project like can be considered in real time scenario. This software has a full integration support for user data collection, inbuilt system optimization tool, resizing with user interference, cost justification and system component detail. In this simulation tool, option is provided for selection of system estimation for off-grid system, on-grid system, roof top system, DC pump system. The environment metrological data of approx. 1200 site is stored in PVsyst database. The available weather data is fair enough to do a near good estimation of any geographical location. Actually, metrological data (irradiance, temperature and clearness index) for the period of 1960-1991 is averaged and it provides a good result. Apart from this, the software has a option to export the metrological data provide by local weather station. In Pvsyst, metrological data for around 1200. Before starting an actual optimization, the software required some of the basic information regarding the project and it is the important point in term of real engineering. The key input parameters are geographical location, PV module detail, inverter size & features, battery requirement etc. The radiation data is accessed from Meteonorm 7.2 with TMY2 format [10-13]. It contains hourly data of radiation, temperature, wind speed and snow level. The selected albedo value is 0.2 which is guessed by software itself. The software itself has a list of vide range of catalogue for solar PV panel, solar inverter, battery, cables etc. The above list is updated from time to time for including new product. Apart from this, it has an option to include particular model manual, if the same is not available in list. The two 80KW and two 70KW inverter, Make: GrowWatt, are selected for sub-PV-system1 and sub-PV-system-2. The real-time data of inverter like harmonics, system inbuilt loss is added manually [14-15]. The 200V and 1200V are the allowable min-max maximum power point (MPP) voltage. The Polycarbonate silicon PV panel of 330W, Make: Waaree is selected. The detail specification of photovoltaic panel is shown in Fig. 3.

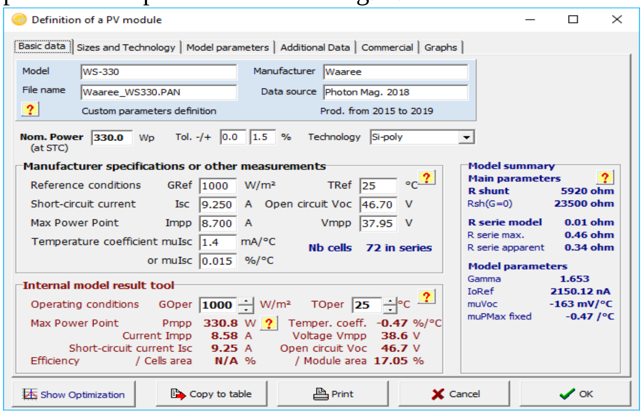

Fig. 3. PVsyst page for design of solar PV plant design

The simulation software ask for various inputs for consideration of real time losses such as ohmic loss, soiling loss, thermal parameter loss, module manufacturing loss, and ageing loss etc.

Table- I: System components specification after simulation

Sub Array-I, 24 stings with 21 modules in series	
Available area	1184m^2
Solar PV Module	330W, 32V, Si-poly, 504 Nos.
Inverter	3P, 80KW, 50Hz, 6MPPTS, 2Nos.
Sub Array-II, 20 stings with 20 modules in series	
Available area	796m^2
Solar PV Module	330W, 32V, Si-poly, 400 Nos.
Inverter	3P, 70KW, 50Hz, 6MPPTS, 2Nos.

The ohmic loss is an important factor for calculating real time loss and the wiring layout is considered for the calculation of it actual value. Similarly, the module efficiency loss of 0.1% per year is considered by PVsyst [16]. The loss due to environment factor like dust is come under soiling loss. Another important loss is due to shading. There is a two type of shading: Horizon shading and partial shading. The 3D view of structure is used for estimation of shading loss and it effect on total energy output [17].

III. PVSYST RESULT 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 19o and 0o 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. 4.

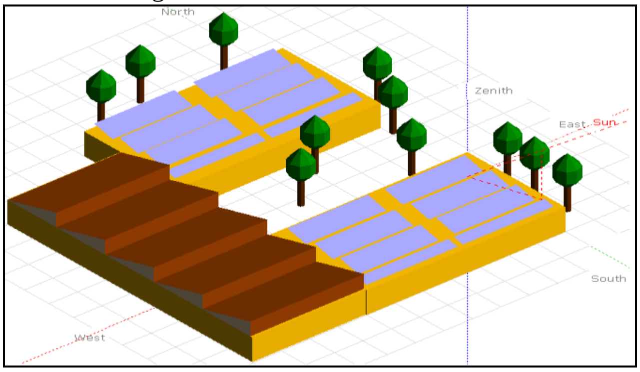

Fig. 4. Satellite view of complex and the sub-array

The estimated cost for the implementation of this project is 108 lakhs. Apart from this, there is a running cost like cleaning, repairing and maintenance of system. The considered running cost for a system is 10% of project value. It is found in estimation that the cost of electricity is 1.628 INR/KWh. The month wise estimated energy production is shown in Fig. 5.

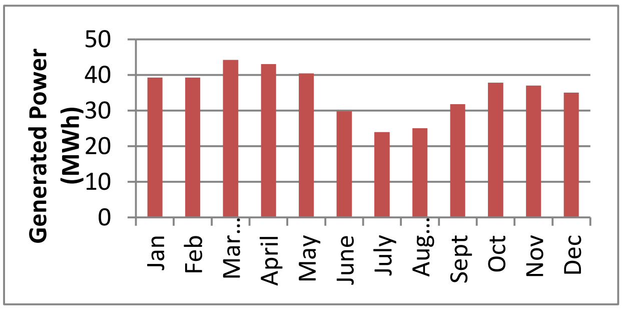

Fig. 5. Estimated monthly generated power of solar PV system

IV. IOT SYSTEM DESIGN AND CONFIGURATION

The above design system is implemented with grid integration at two different sub-stations. The electricity generation from solar PV system and it utilization percentage must be recorded for smooth system operation. The 3-phase smart energy meters are used for the purpose to record electricity generation and consumption. These meters have a capability to store information in digital form, which can be transfer to other devices using various communication protocols. Some of the common industrial communication protocols are RS232, RS485, and Ethernet [19]. The block diagram of data transfer protocol is shown in Fig. 6. In our case, Modbus RS485 communication is used to extract the data from Smart Panel Meter. The data logger acts as a central command device and asks for data from particular device using slave ID number and Coil Register address [21]. The data transfer and logging process is shown in Fig. 6.

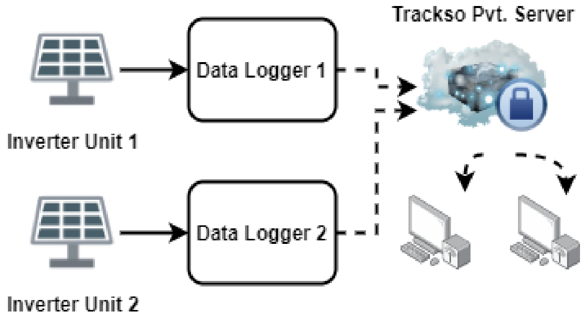

Fig. 6. Data logging transfer protocol using modbus and cloud server

In this data logging method, data logger is used to logged the data from inveter using modbus technology. In this method, data logger is act as master and inverters are act as a slave. The master device can call slave for any information which is stored in its coil registers. An exchange of data consists of master request for data follwed by retort from slave. There is a exact format for data transfer which is well documented in modbus protocol. The general outline of modbus data consists of device address, function code, register number, register count, data and checksum. With the specific packet data, master collects a specific information from slave. After collecting the data, data logger transmit it to the server database using GET/POST command. In this project, trackso server database is used for storing the data and the configuration of data logging system using trackso web software is very easy and user friendly [20].

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. 7. SMS based GSM modem and data logger config. setting

As the complete data of plant is stored in web server database, it can be use to see real time plant information which includes trend generation, solar irrandiance, plant status, power output, comulative energy pumped etc. After connecting communication cable between data logger and inverter with RS485 protocol, the system is ready to work.

The data logger can be connected to server using ethernet connection or GSM modem. In this case GSM enabled device is used for connectivity.

The software setting can be done using SMS based configuration. Once GSM modem is configured for communication, data logger starts to transmit data to cloud network of trackso. The configuration method for system is shown in Fig. 7.

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

A systematic data is recorded using above arrangement. It helps to realise real time data of the PV plant. The recorded data is helpful for realization of actual system performance which includes overall output energy and profit. The system overview in IOT platform is shown in Fig. 8.

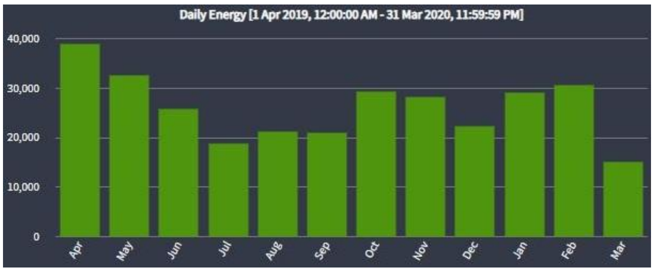

Fig. 9. Output active power of solar plant in May 2019

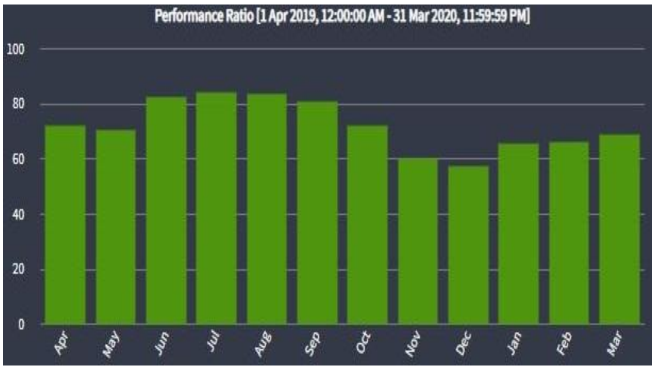

Fig. 10. Performance Ratio of plant between 1st Ap 2019 to 31st Mar 2020

Similarly, monthly output power graph is shown in Fig. 9. It shows that monthly energy output is mainly depends upon environment condition of that month. It shows that energy output from July-Sept is low due to continuous rainy season in the given location. The performance ration of plant for 1st Apr 2019 to 31st March 2020 is shown in Fig. 10. In the same fashion, other information for each inverter is available separately. The online IOT solution is helpful to monitor the plant status as it helps to reduce the task of operating staff for monitoring of plant condition.

V. CONCLUSION

The proper design and analysis are essential part of solar power system optimization. It provides detail information of required system with best standard practice. The analysis provides a complete life cycle detail of solar PV plant. In this paper, 300 KW grid connected PV system for industrial complex is taken as a case study for designing. The same system which is implemented here is installed in the complex. For analysis of design output and real time output, IOT based data monitoring system is installed. The data output from logger shows that system is up to a mark and performing as per the design.

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