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Design, Validation and Monitoring of 1MW solar Rooftop On-grid PV System

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ABSTRACT: Our body needs energy to work in the same way machine needs electricity or energy of any substance to run. For different machines and automobiles we use different means of energy such as coal, petroleum and natural gas. The supply of these fuels is physically limited and their use threatens our health and environment. To overcome these problems the recent trend has been to give importance to renewable sources of energy such as solar, wind, geothermal etc .this entire project is based on the solar energy and explains how solar energy is used to generate electricity using photovoltaic cells. The advantages of using solar energy for electricity generation are as follows:

- Freely available in nature.
- Non polluting.
- Extremely reliable.
- Its availability is limitless.

This paper about the Design, Validation and Monitoring of 1MW solar Rooftop On-grid PV System at Emmvee Solar Energy Private Limited, Dabaspet, Bangalore District, Karnataka proposes to install a 1MWp Solar Photovoltaic (SPV) power plant under Karnataka Solar Policy of new grid connected projects. The generated electricity supplied to Grid on Net-metering basis.

KEYWORDS: Solar Power, PV, Mathematical Models, environmental impact, monitoring system, Validation, Capacity utilization Factor (CUF)

I.INTRODUCTION

India lies in the southern portion of Asia. It is a peninsula, surrounded on three sides by water and one side with land. India lies between 8°4' to 37°6' north latitude and 68°7' to 97°25' east longitude. It covers nearly 2 million square km of land area. In 2015 the population of India was 1.311 billion with an annual growth rate of 1.2%

India is a fast growing country with a large economy. India's electricity demand is increasing at the rate of 8.5%. it will be presently shown that large part of the electricity demand in urban areas is due to a phenomenal rise of industrialization and air conditioner installations in buildings.

In India about 70% of overall electricity generation is based upon thermal energy. Huge amounts of non renewable sources such as coal are being consumed for the production of thermal power which leads us to degradation of the environment. Hence it is imperative to shift to renewable sources like solar energy for the generation of electricity. At present scenario generation using solar power is perceived be too costly. Installation of solar equipment for the typical house hold is difficult as enough technical awareness is lacking in choosing suitable components with appropriate ratings.

As of November 2015, the installed generation capacity of India is 281 GW of which, the thermal, hydro, nuclear, and renewable capacities are about 195GW, 43GW, 6GW and 37GW respectively [1]. The renewable installed capacity is at 13.2%, where as the thermal installed capacity is 69.3 %, which is a major source of carbon dioxide emissions in India. For reducing the CO_2 emissions fuel substitution by the way of increased use of renewable energy sources is an attractive option. Solar power is the one of the cleanest form of renewable energy available ,and it can be converted and

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used in different forms, such as heat and electricity to help power homes and business. Solar panels, also known as PV modules, contain photovoltaic (PV) cells made from silicon that transform incoming sunlight into electricity. "Photovoltaic" means electricity from light (photo = light, voltaic = electricity). The conventional view that the solar photovoltaic electricity is more expensive compared with the grid provided electricity at retail level [2], is being challenged by the continuous trend of reducing the cost of solar technologies and raising cost of fossil fuels.

Fig.1. Block Diagram of on-grid rooftop solar system

Typical household receives power from the local utility at the prices pre-determined in the tariff plans of the utility. However, due to lack of sufficient generation capacity there are shortages and the utility may have to resort to load shedding leading to power cuts for the end consumers. Moreover, as the prices of fossil fuels increase, the electricity tariffs are also raising. In this scenario, some consumers may want to explore and shift to alternate sources for meeting their demand. However, shifting to solar power requires upfront investment. The economic benefit has to be justified in order to convince the consumer to make the initial investment. A normal consumer may not have the technical and commercial knowledge to install and operate the solar equipment. Consumer has to get expert advice from third party companies which may not be reliable and customized to specific requirements. The concept of rooftop PV has been successfully demonstrated in a project under the Italian PV rooftop programme [5]. In that project, the architectural system design, data acquisition system has been presented, along with the calculation of payback time and economic profitability of the project. The benefits of on-grid rooftop solar PV system can be summarized as follows. (i) the return on investment is better than other alternative sources (ii) avoid use of polluting diesel generator set, (iii) low maintenance, and no need to purchase fuel regularly, compared to diesel generator set (iv) only one time initial investment is needed and power generated is practically free over the life time, and (v) protection from raising regular power taxes. The approach utilized as a part of that review is to consider framework associated PV framework where a small amount of vitality is produced from sustainable source. The PV era limit is assessed from the space accessibility, where as in this paper, we consider design, Validate and remote monitoring of 1MW on grid system.

Block Diagram

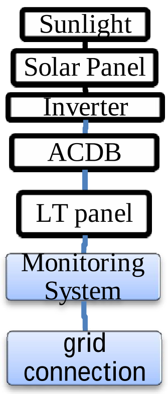

Fig.2 Block diagram of on-grid solar system.

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II. METHEMATICAL MODEL FOR ROOFTOP SOLAR POWER PLANT

Appropriate estimating of the Roof top PV system regarding number of PV models and the measuring of the Inverter are essential parts of the outline. In this area we introduce a scientific model, in which we build up the expressions for estimating and number of solar model and inverter as an element of load necessity. The model incorporates both the technical and economical Analysis.

A. Technical Analysis

1) Calculation of number of solar panels required:

$$NP = Ppv/Po \qquad (1)$$

Where, NP is Number of PV panel required, Ppv is capacity of solar plant in Watts, Po is maximum power of each module.

2) Calculation of size of inverter:

Based on the block diagram shown in Fig. 2 the calculation of size of inverter is plays a important role in on grid solar PV system. Mainly there are two methods is available to calculate the size of inverter, one method is based on specification of inverter and string parameters (current and voltage).And other one is determined by the expected peak demand of the load. The peak demand of the load is estimated by using the relation between the connected load and the diversity factor (DF) of the load where diversity factor is ratio of maximum demand to total load connected.

$$Pinv = \frac{grid\ connected\ load}{DF} \qquad (2)$$

Where, DF is Diversity factor.

b. Environmental Impact

According to the CO2 baseline database [9] prepared by central electricity authority (CEA) under the ministry of power, Government of India, the weighted average emission factor for thermal power plants is 0.82 Tonnes of CO2 per MWh of energy generated. Using this factor we can determine the reduction of CO2 emission on account of shifting to rooftop solar for a lifetime of 25 years as shown in eq(3)

$$CO2_{emission} = E_{day} * 0.82 * 365 * 25/1000\ t/MWh \qquad (3)$$

III. DESIGN OF MONITORING SYSTEM

The mathematical model for technical analysis described in section II, has been incorporated into a software tool, which helps monitoring the solar plant remotely. The software tool is developed using some html and java script, but it can be used as a standalone graphical user interface. This interface will take the inputs from the data logger, the Data logger having connection of all individual Inverters, The interface of the monitoring system is conveniently divided into five sections, namely (i) inverter output (SLD view) (ii) daily energy produced (iii) total energy production (iv) generation details (v) individual inverter generation details. The data logger receives the information from the each inverters and feed into our monitoring software. Based on the information from the data logger the monitoring system can run the inputs getting from the data and obtain the output. Complete technical and environmental analysis is displayed in the output. The interface of the simulator and the output generated are shown in Figure.3 and Figure.4 respectively.

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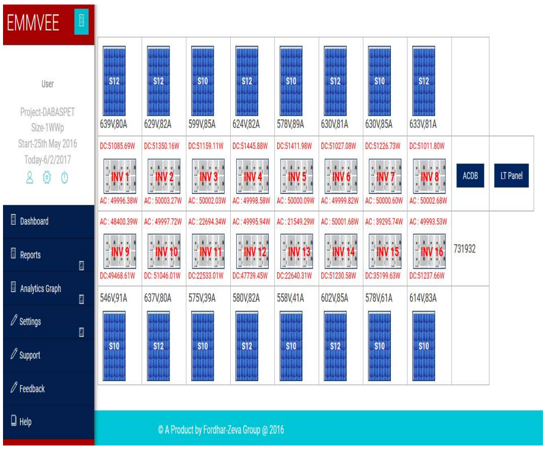


Figure.3 Inverters output SLD view

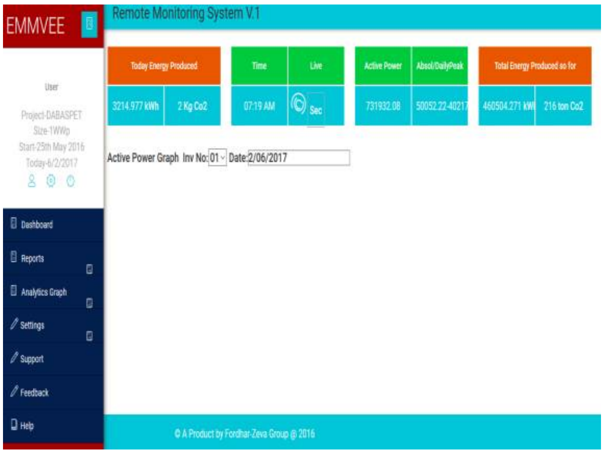
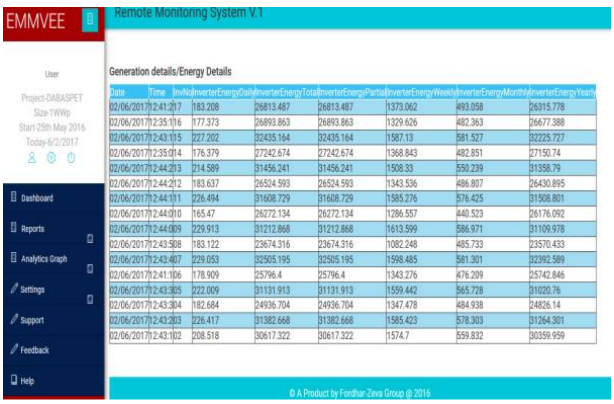


Figure. 4 Energy production of the plant



Date	Time	InvNo	InverterEnergyDaily	InverterEnergyTotal	InverterEnergyPartial	InverterEnergyWeekly	InverterEnergyMonthly	InverterEnergyYearly
02/06/2017	12:41:2	17	183.208	26813.487	26813.487	1373.062	493.058	26315.778
02/06/2017	12:35:1	16	177.373	26893.863	26893.863	1329.626	482.363	26677.388
02/06/2017	12:43:1	15	227.202	32435.164	32435.164	1587.13	581.527	32225.727
02/06/2017	12:35:0	14	176.379	27242.674	27242.674	1368.843	482.851	27150.74
02/06/2017	12:44:2	13	214.589	31456.241	31456.241	1508.33	550.239	31358.79
02/06/2017	12:44:2	12	183.637	26524.593	26524.593	1343.536	486.807	26430.895
02/06/2017	12:44:1	11	226.494	31608.729	31608.729	1585.276	576.425	31508.801
02/06/2017	12:44:0	10	165.47	26272.134	26272.134	1286.557	440.523	26176.092
02/06/2017	12:44:0	09	229.913	31212.868	31212.868	1613.599	586.971	31109.978
02/06/2017	12:43:5	08	183.122	23674.316	23674.316	1082.248	485.733	23570.433
02/06/2017	12:43:4	07	229.053	32505.195	32505.195	1598.485	581.301	32392.589
02/06/2017	12:41:1	06	178.909	25796.4	25796.4	1343.276	476.209	25742.846
02/06/2017	12:43:3	05	222.009	31131.913	31131.913	1559.442	565.728	31020.76
02/06/2017	12:43:3	04	182.684	24936.704	24936.704	1347.478	484.938	24826.14
02/06/2017	12:43:2	03	226.417	31382.668	31382.668	1585.423	578.303	31264.301
02/06/2017	12:43:1	02	208.518	30617.322	30617.322	1574.7	559.832	30359.959

Figure 5 Individual inverters generation details

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IV. VALIDATION

Validation is the way toward building up documentary evidence exhibiting that a system, process, or movement done in testing and afterward creation keeps up the desired level of consistence at all stages. In any design of solar power plant, it is essential that in addition to last testing and consistence of items, it is additionally guaranteed that the procedure will reliably create the normal results. The desired outcomes are set up as far as details for result of the procedure.
The bellow figure 6 and table 2 gives the comparison between actual generation and expected generation of the power plant for a month of an April 2017.

Components	Minimum Temperature in °C	Maximum Temperature in °C	Comments
Module	46.3	55.3	All temperature of the different components are analyzed and its less than 60°C, operating temperature conditions
Dc cables inverter (input side)	33.2	36.5	
Inside of the inverter (input side) DC power	35.3	43.8	
Inside of the inverter (output side) AC power	36.3	58.7	
at AC Distribution Box	29.7	48.7	

Table. 1 Temperature analysis report.

The table 1 shows the actual measured temperature valuesof different compoments of a solar power plant and this values are less than 60°C, it is the normal operating temperature of a solar power plant

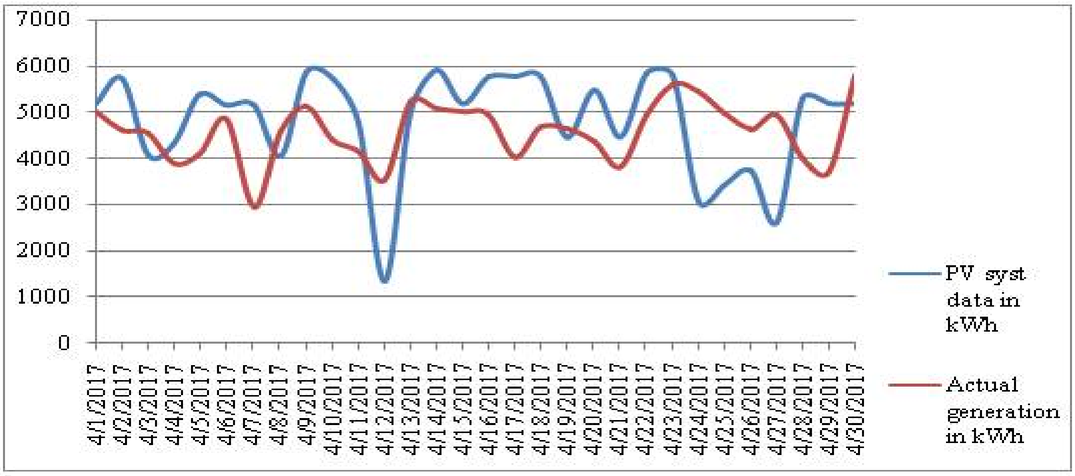

Figure.6 Validating the Designed And Actual Generating Power

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Date	Designed (Pvsyst data) In kwh	Actual generation In kWh
01-04-2017	5196	5024
02-04-2017	5735	4608
03-04-2017	4077	4544
04-04-2017	4342	3904
05-04-2017	5393	4128
06-04-2017	5169	4864
07-04-2017	5164	2944
08-04-2017	4039	4576
09-04-2017	5875	5120
10-04-2017	5730	4416
11-04-2017	4749	4160
12-04-2017	1351	3520
13-04-2017	5001	5248
14-04-2017	5908	5088
15-04-2017	5198	5024
16-04-2017	5764	4960
17-04-2017	5776	4032
18-04-2017	5781	4672
19-04-2017	4468	4640
20-04-2017	5488	4352
21-04-2017	4465	3808
22-04-2017	5849	4928
23-04-2017	5796	5600
24-04-2017	3058	5440
25-04-2017	3417	4992
26-04-2017	3735	4640
27-04-2017	2608	4960
28-04-2017	5303	4000
29-04-2017	5178	3712
30-04-2017	5179	5792

Table.2 Comparison between designed and actual generating power of solar power plant for a month of April 2017.

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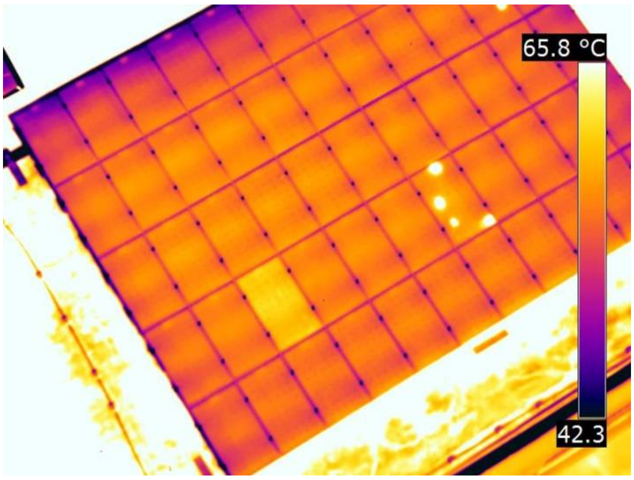

Figure.7a Temperature at 50mm clearance between roof and modules

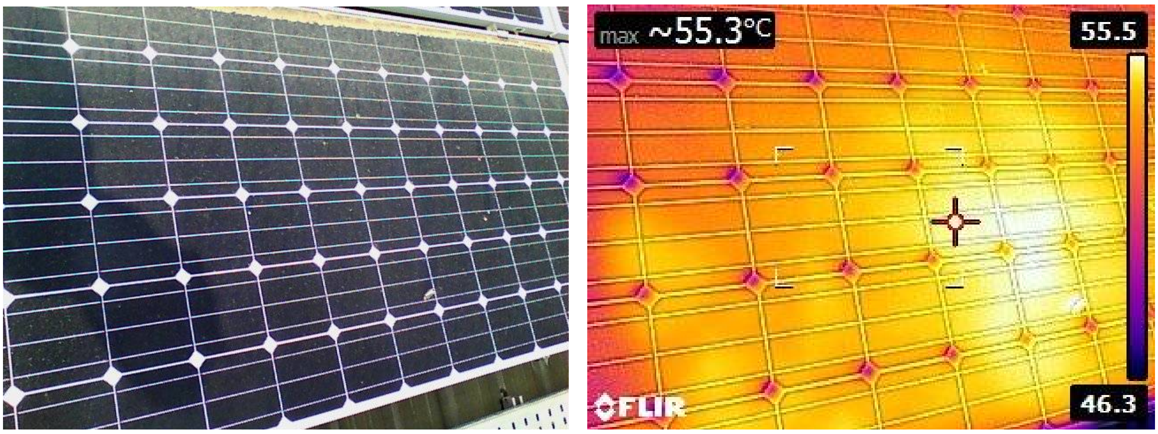

Figure.7b Temperature at 140mm clearance between roof and modules

The above figure.7a shows the surface temperature of the panel at clearance distance of 50 mm between the module and roof. As per the IEC standard, clearance distance to be maintained is 150mm in order to maximize the roof top solar power plant generation. However, we maintained (figure.7b) 140mm clearance as against the general practice of 40-50mm. Hence, the clearance which we have designed would help in the movement of air behind the modules, which in turn increases the efficiency of the solar panels.

V. CONCLUSION

This report presents the results of 1MW designing and validation which are tested and characterized originally at the installed site. The performance of the solar power plant is matching with the estimated generation.

The estimated CUF for this solar power plant is 19.39% and actual CUF is 18.4% and it also depends on the design parameters. But since there are several variables which are contribute to the final output from a solar plant, the CUF varies over a wide range. These could be on account derating of modules at higher temperatures, other design parameters like ohmic loss, atmospheric factors such as prolonged cloud cover and mist. Therefore, it is essential to consider the uncertainty factor of metronome meteo data in order to achieve the expected CUF and the better performance of the plant.

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As per the experimental study the clearance between the modules and rooftop is indirectly proportional to the surface temperature of the modules. Meanwhile it improves the efficiency of the PV modules.
Accordingly, we are able to conclude that this is the proper time to transfer over to rooftop solar systems. Moreover, there is benefit to the environment as properly.

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