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Comparison of Experimental and Theoretical Output Power of Grid Connected Photovoltaic System in Super Mega Factory

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Abstract: In this paper, the performance of grid connected PV system that is installed in Super Mega Factory is presented. The output parameters of 4 kW PV is collected and analyzed. Then, according to the results the weak points of the system were found and the theoretical output power was compared. After that we try to get the maximum output power making the correction of collector angle and place suitable panel position.

Key words: Grid connected PV system, output parameters, theoretical output power.

1. Introduction

Myanmar has experienced a number of power crises, mainly due to the heavy reliance on hydroelectric power renewable sources that are sources of energy which can support easily the place where electricity cannot be supplied and sent to the grid line in the daytime to be stable the main grid. In 2015, Thailand has more solar power capacity than all of Southeast Asia combined. Germany is the world's largest producer of solar power with an overall installed capacity of 38.2 GW. Solar power in Myanmar has the potential to generate 51,973.8 TWh/year, with an average of over 5 sun hours per day [7]. In rural areas, PV (photovoltaic) is used for charging batteries and pumping water. Small scale grid connected PV system is installed in some factory and factory zone. The main advantage of a grid connected PV system is its simplicity, relatively low operating and maintenance costs as well as reduced electricity bills.

In this paper, the grid connected PV system without battery back-up is described. The capacity of PV power is 4 kW. Eighteen numbers of PV modules, metering panel and conditioner are used in this system. This system supports the electricity to factory not all the capacity their needs. The output power of PV modules may vary according to different weather conditions and the mounting position of the panel and other factors [1]. So as to vary the output power, this system needs to monitor the output power. If there is no much difference between the rated power and actual output power, this system is good whereas there is much difference between the rated and actual output power, the weakness of the system is found out.

Corresponding author: Kyaw Kyaw Htet, Ph.D. in electrical power engineering, research fields: renewable energy system, especially photovoltaic system.

2. Grid Connected Photovoltaic System

The types of PV system can be divided into grid connected system and standalone system. The installation of grid-connected PV systems is increasing due to several advantages over standalone PV systems. At night or on cloudy days, when the output of the PV system is insufficient, the utility grid can provide backup energy from conventional sources. Solar PV modules geneate DC electricity. The grid-tied solar inverter converts the DC electricity generated by solar PV modules into AC and feeds into the grid. The kilowatt meter measures the electricity drawn from the grid. So it saves energy and traffic [5, 3].

2.1 Grid Connected without Battery Backup System

The systems without battery up are more common and consist of two main components: solar PV array and grid tied inverter. The controller to extract maximum DC power from PV array is in-built in a inverter. This type of system is easy to install, efficient and cost effective, it has no means of supplying AC power when the grid is not available. Removing the battery subsystem not only represents a considerable cost and size reduction of the whole system but also increases its reliability while a PV cell lasts more than 20 years, a battery operates for almost 5 years and needs periodic maintenance [2, 5].

3. Experimental Procedure

Metering parameters are voltage, current and power. Metering panel measures the panel’s output power, output voltage, output current and grid input power, voltage, current. And also conditioner’s output voltage, power, current can be expressed. The measured output data are in actual condition case on sunny and cloudy condition.

4. Performance of Grid Connected PV System in Factory

In super mega factory, on-grid (4 kW) photovoltaic without battery up system is installed. There are sixteen numbers of poly crystalline PV modules (245 W), 4 kW delta power conditioner and metering panel in this system.

Eight modules are connected in series to form a string. The power output of one module is 245 W. For a string, output power extracted 1,960 W. Two strings are connected in parallel so output power is 3,920 W which is close to 4 kW. Output voltage of a string is 296 V.

The output voltage and current of PV array first passes through the metering panel and also the incoming grid line also does and input voltage and current of grid line are also measured. After passing through the metering panel, the output of PV and incoming grid line combines in power conditioner, within the grid input voltage (180~250 V) and the input DC voltage (80~450 V) the conditioner synchronizes the output parameters. Time taken for synchronizing is 90 s to match the voltage and current of the grid line and PV output. After condition, the conditioner sent the voltage and current to the load as shown in Fig. 1. The power system of factory is three-phase for heavy machinery such as punching and drilling and single phase for lightning and others electrical appliances like air-condition.

5. Sample Record Data Parameter

The installed capacity of the system is 4 kW, the output kilowatt is utilized to the small load sides. As using the solar energy, it depends on the solar insolation and weather condition. But the output power cannot get maximum always. There may be fluctuation of output power according to weather condition such as rainy, winter and summer. The summer can get the best output power of PV system.

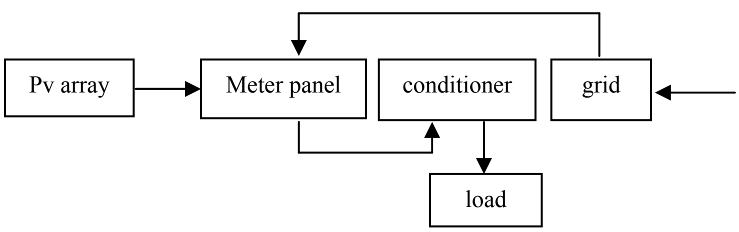

Fig. 1 Block diagram of grid connected system.

The collected sample data are compared between sunny and cloudy days in winter season. In Fig. 2, the output current results are described. As differing in condition, the output results are apparently unstable.

On sunny day, the output current steadily increases but on cloudy day, output one fluctuates. On the cloudy weather condition the amount of output current gets less shown in Fig. 2. So the weather condition is important.

On sunny day, the output voltage is nearly 240 V stable, whereas on cloudy day, firstly the output increases and then it dramatically decreases as shown in Fig. 3.

As the output of voltage and current vary according to weather condition, the output power also is shown in Fig. 4. On the cloudy day the output power is the worst, the power reaches 400 W even on the noon.

On the sunny day, even though the output voltage, current and power increase, they are not in full capacity because it concerns with right position of PV array and right azimuth angle. If the panels are not in suitable position to be perpendicular with the route of solar rays, the output power cannot be obtained. Therefore, collector' azimuth angle is important.

5.1 Approaching of Theoretical Way

According to collected output data, to get the good output result, reconfiguration is needed for this system. To get better output power, the good weather condition, the right direction of the solar panel and right azimuth angle of collector are basically needed. With approaching theoretical ways, the required equations are used to get the maximum power and these equations are mentioned below. The direction of the panel is in south, azimuth angle is taken as 18 degree. Latitude of Myanmar is 16.8 degree. Different azimuth angles produce different solutions.

The following equations are used to get the rated output power.

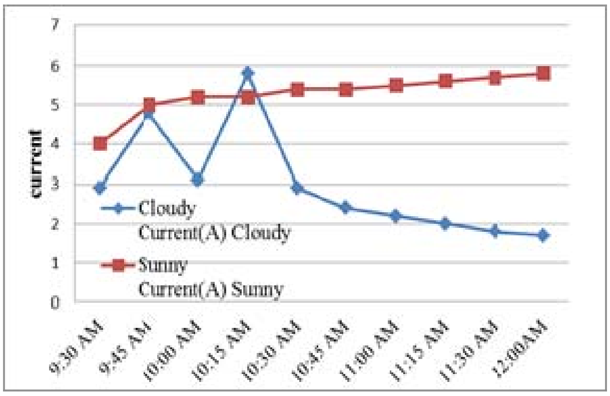

Fig. 2 Comparison of PV current in weather condition.

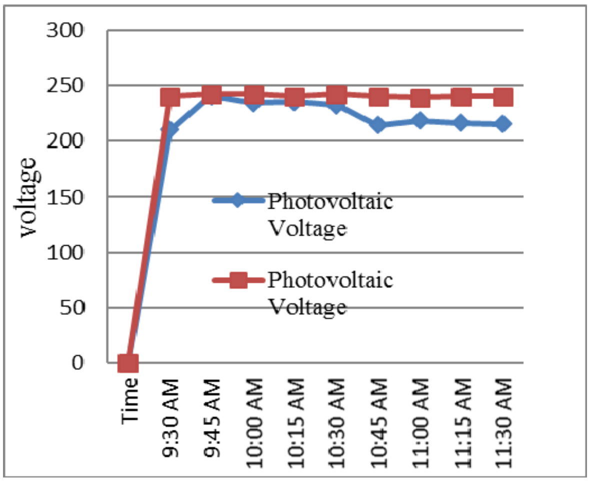

Fig. 3 Comparison of PV output voltage.

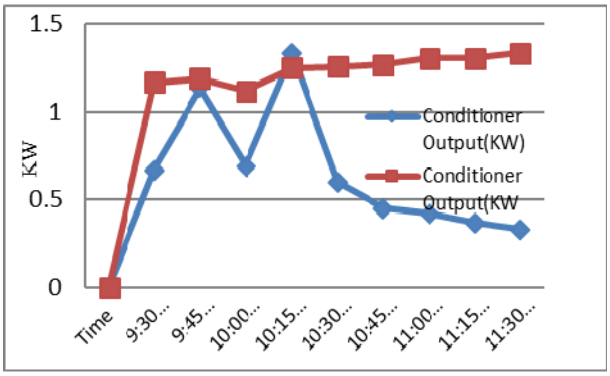

Fig. 4 Comparison of output (kW).

$$\Delta = 23.45 \sin\frac{360\times(n-1)}{365} \quad (1)$$

n = day number, δ = solar declination

$$\beta = \sin^{-1}[\cos(L)\times\cos\delta\times\cos(H)+\sin(L)\times\sin(\delta)]$$

β = solar altitude angle, H = hour angle, L = latitude (2)

$$M = \frac{1}{\sin(\beta)} \quad (3)$$

m = air mass

$$A = 1160 + 75 \sin\left[\frac{360\times(n-275)}{365}\right] \quad (4)$$

A = apparent extraterrestrial

$$k = 0.0174 + 0.03 \sin\left[\frac{360\times(n-100)}{365}\right] \quad (5)$$

k = atmospheric optical depth

$$C = 0.095 + 0.04 \sin\left[\frac{360\times(n-100)}{365}\right] \quad (6)$$

C = sky diffuse factor

$$\phi_s = \sin^{-1}\left(\frac{\cos\delta \times \sin H}{\cos\beta}\right) \quad (7)$$

ϕ_s = solar azimuth angle

$$I_b = Ae^{-km} \quad (8)$$

$$\cos\theta = [\cos\beta \times \cos(\phi s - \phi c) \times \sin\Sigma \times \sin\beta \times \cos\Sigma]$$

ϕc=collector azimuth angle (9)

$$I_{bc} = I_b \times \cos\theta \quad (10)$$

I_{dc} = diffuse insolation on collector

I_{bc} = reflected insolation on collector

$$I_{dc} = Ae^{-km} \times (C) \times \frac{(1-\cos\Sigma)}{2} \quad (11)$$

I_{dc} = diffuse insolation on collector

$$I_{rc} = \rho \times I_b \left[(\sin\beta + C) \times \left(\frac{1-\cos\Sigma}{2}\right)\right] \quad (12)$$

I_{rc} = reflected insolation on collector

$$I_c = I_{bc} + I_{dc} + I_{rc} \quad (13)$$

I_c = insolation on collector [4]

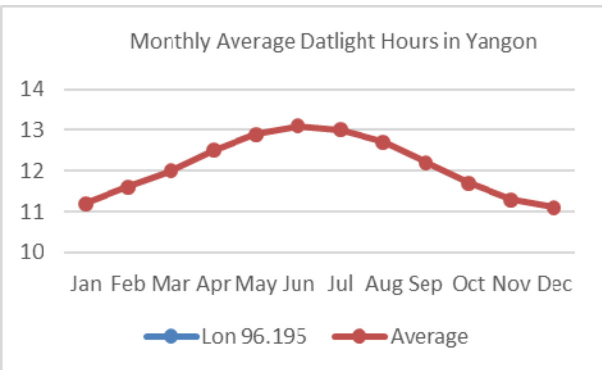

Fig. 5 Monthly average datlight hours in Yangon [6].

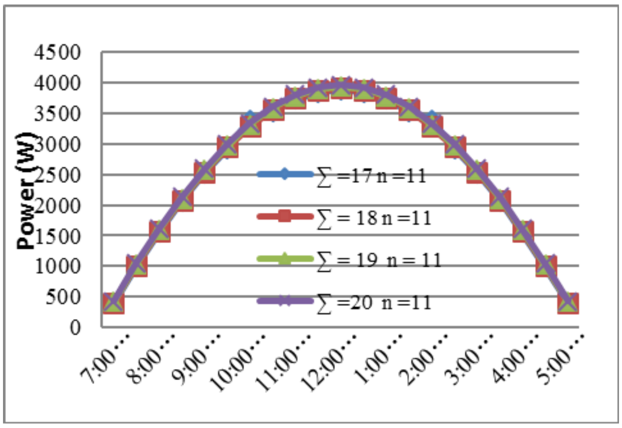

Fig. 6 Different collector angles and different output power.

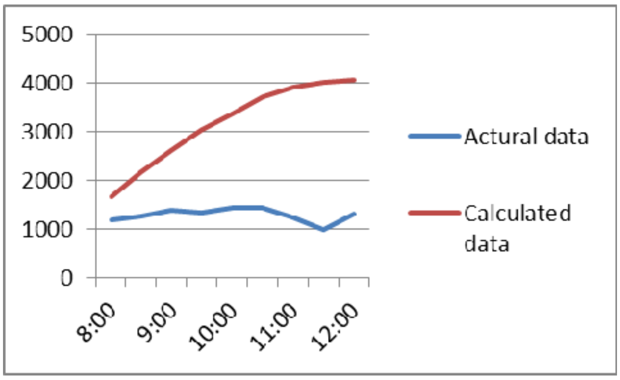

Fig. 7 Comparison of output power calculated data and collected data.

Output Power = solar area × solar efficiency × No. of solar modules × I_c

Fig. 6 shows how different real and calculated power, calculated data increase steadily to hit their peak but the real output is not over 1.5 kW. It depends on whether condition, position of panel.

6. Conclusion

The use of grid-connected PV systems gets not only beneficial for residential housing, but also contributes to the revitalization of the communities and industries, as well as improving the overall well-being of the country. In super mega factory, 4 kW grid connected photovoltaic system is installed. So performance of the grid connected PV system is learned and the output voltages, current of PV and power conditioner are recorded. But the output powers are unstable and do not hit the peak. It concerns with weather condition.

Fig. 4 shows the sunny and cloudy condition. The outpour powers fluctuate. In sunny day, power increases dramatically whereas in the cloudy, power goes gradually. Another point is the position and collector tilt angle. If they are wrong, the maximum output power cannot be got. If theoretical equation is used, the output power is calculated. The collector tile angle is 18° and position is south direction. So Figs. 6 and 7 show the result of the output power . The maximum power can be achieved. But if the collector tilt angles change the output power varies in Figs. 5 and 6. If the correct position and angle are changed in this grid connected, the maximum output power can be obtained but the weather condition cannot guess.

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