Performance analysis of 120kW PV System under Partial Shading Condition

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ABSTRACT

Now-a-days renewable energy is growing like anything and is the prime source of power generation and generating a wide path of research for all kind of researchers like students, faculty, industrials etc. Solar energy is a renewable energy which is used to convert sunlight to electrical energy by using solar panels which is made of either a series or parallel combination of solar cells. Based on the requirements of power generation, the solar panels can be connected either series or parallel to meet the design specifications. The process of converting sunlight into electrical energy is known as "photovoltaic effect". The draw back in the method of generating electricity from solar energy is not 100% efficient due to the conservational factors as well as faults in the solar panels which affects the system output efficiency. The faults like partial shading, cell cracks, connection failures etc will generally occurs in PV system. Partial shading fault is occurred in the panel due to the passing clouds, nearby buildings, bird droppings and fallen leaves. Partial shading fault makes the PV array efficiency low. Due to the partial shading in addition to mismatch losses and hotspot problems, it affects the output power of PV system leading to safety and reliability issues. Bypass diode will give better solution to the effect of partial-shading. In this paper a 120kW PV system si developed to analyse the efficiency of the system under partial shading condition by using MATLAB/SIMULINK.

Keywords: PV panels, PV array, partial shading, efficiency, solar energy

I. INTRODUCTION

Wind, hydro and solar are renewable energy resources. These sources are free of pollution, available easily and unlimited. So, these energies are mostly used instead of using non-renewable energy resources like natural gas and oil. Among all the renewable energies, solar system is used mostly because of its cleanliness and cost [1]. So, the usage of solar system has improved from the last several years. Over all world-wide the photovoltaic system is installed with the capacity of 75Gw in the year of 2016 which is almost a 50% growth from the year of 2015 which installed with the capacity around 50Gw [2].

The goal of using renewable energy sources (RES) is modern energy production. For example, RES has many benefits, such as availability, eco-friendliness and low maintenance. Among the renewable energy options, the photovoltaic (PV) components are world's most esteemed systems as they have a extensive lifetime (usually in excess of 20 years), and other advantages [3].Solar energy is developing rapidly in several countries all over the world, with PV generation exhibiting the highest growth in dynamics relative to other forms of RES [4].

In a solar photovoltaic system the quantity of solar cells to construct a solar panel is linked in series or parallel and then the panels are linked in a sequence to build PV array. The panels which converts solar energy into electrical energy are connected in series to form a string to achieve required voltage and power output. Generally more than 1000 PV panels are employed to provide megawatts of electrical power production [5].Photovoltaic (PV) energy storage technology has been increasingly being used to reduce dependence on mineral-based resources. The electrical properties of a PV system are greatly affected by partial shading scenarios (PSS) [6].

In general PV system consists of a pair of strategies such as PV array, AC or DC converter, energy storage devices and load. DC electricity is produced directly without discharge and ecological collision by using solar array and then the obtained DC electricity is converted into AC electricity by connecting the DC-DC converter, inverter to the array. The electricity has to be adjusted for computing tools and electronics such as laptops, heating and lighting control and uninterruptible power supply (UPS) etc. To regulate the output power of PV array a low cost high efficacy of DC-DC converter by voltage fed back is generally considered for the system [7].

Photovoltaic cells are very low utilization costs, limited maintenance requirements, reliable, noise less operation and easy to install. In early time, solar system is used as power supplies for some particular applications like satellite communication. The function of photovoltaic source has been widened in some commercial fields and all domestic with the power electronic device development [6]. It has been used in many electrical power applications, regardless of low efficiency and initially high cost, photovoltaic system has small cost of maintenance and operation as it is a fixed source of energy fabricated from semiconductor equipment [8].

The conditions of partial shading impact the maximum power generation capability. In this the designed PV system is simulated by using a two diode PV model to evaluate the output and performance characteristics [1].

This paper discusses about the construction of a stand-alone system with 2kw capacity to feed various domestic loads. To track the maximum power from photovoltaic array a push-pull inverter has been designed, implemented and tested [9].

This paper proposes the snubber circuit operation at high switching frequency and a simple stand-alone integrated PV battery scheme is planned for rural application. It shows that the proposed system has a better life span than conventional PV systems [10].

A comprehensive study in the design and performance analysis of the various inverters and converters has been discussed in this paper. PV array is modelled at various irradiance and temperature to analyse device behaviour [11].

II. DESIGNING OF A PV ARRAY:

A Photo-Voltaic cell's electrical analogue model consists of a current source and a parallel connected diode. The PV cell purposes as a highly nonlinear basis of current, and its voltage output is controlled.

It is known from the characteristics of the PV-cell voltage versus power that the produced power reaches its limit under an accurate charge [3]. Modules consist of many solar cells that are arranged in series and parallel to increase module current and voltage levels. The single-diode model is shown in Fig.1 can represent a PV-array. A computational equation representing the PV cell's output current is given as follows:

$$I = I_{ph} - I_D - I_{sh} = I_{ph} - I_o \left[\exp\left(\frac{(q(V+IR_s))}{A*K*T}\right) - 1\right] - \frac{V+IR_s}{R_{sh}} \quad \text{...... [1]}$$

Where, I, V= PV array current and voltage

I_{ph}= current of the PV array

A= Diode ideality factor

I_o= Diode Reverse saturation current

R_s, R_{sh}= Series and parallel resistance

T= Cell temperature

q= Charge of electron ($q=1.602*10^{-19}$ (C)

K= Boltzmann constant ($K=1.38*10^{-23}$ (J/K)

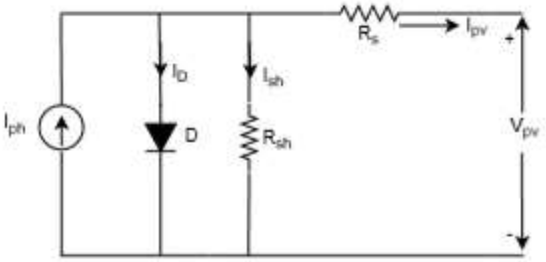

Fig 1. The equivalent circuit of PV array

Equation (1) Consists of five undefined variables (I_{ph}, I_o, A, R_s, R_{sh}), which depend on the PV array temperature and sun irradiance. Additionally, one can set I=0 for the open-circuit voltage V_{OC}, indicating no output current, while the short-circuit current is achieved when the V=0. In addition, concentrated power can occur by multiplying the operating voltage V_{MPP} and current I_{MPP}.

When there is a change in the load associated to the panel, then it results in the variations of voltage and current values. Instrument temperature, irradiation, and interior features impact the module's P-V functionality. Irradiation on a battery consumes strong impacts on battery charging haulers [1]. So the current created by the module changes reliant on the module's irradiation. When light concentration rises, the respective temperature of module is changes. Thus the current produced by the module predisposed also by temperature.

Designed parameters of a PV Array (Znshine PV-Tech ZXP6 – 72-300p):

Parameters	Values
Open circuit voltage, V_{oc} (V)	44.95V
Short circuit current, I_{sc} (A)	8.64A
Voltage at maximum power, V_{Mpp} (V)	36.95V
Current at maximum power, I_{Mpp} (A)	8.12A
Maximum power, P_{Mpp} (W)	300.034W
Open circuit voltage coefficient V_{oc}, K_v (V/◦C)	0.36901
Short circuit current coefficient I_{sc}, K_i (A/◦C)	0.06
Number of cells connected in series, N_s	72
Number of parallel strings	10
Series connected modules per string	10

Table 1.Parameter specification

III. STAND-ALONE PV SYSTEM

Distributed energy technologies such as stand-alone photovoltaic (PV) systems have been widely used for the electrical equipment in recent years due to the growing international consumption of electricity as well as the worry about the environmental issues of generating greenhouse gases. Due to the rapid growth of direct current (DC) grids and portable electronics, such as their existing alignment with primary sources, standalone photovoltaic system with storing energy for DC applications is introduced [12].

By using PV technologies Stand-alone electricity generation systems have emerged as a significant and favoured way of harnessing photovoltaic energy because of its multi-dimensional benefits such as independent of energy, stability, absence of electric bills, simpler and appropriate deployment, continuing storage and power backup whenever and wherever you need it [13].

The common alignment of standalone photovoltaic system is shown in Fig 2. A standalone solar-based system comprises a photovoltaic panel array for capturing solar energy, a charging controller as a control panel, a batteries as a storage device and a DC / AC conversion inverter for AC charges Due to the fast, simpler, uncomplicated and problems-free design of stand-alone PV systems, they are quickly spread around the world.

Normal conditions along with faults and partial shading result in a decrease in a photovoltaic (PV) array's overall available capacity. For strengthened system efficiency and performance, partial shading and faults must therefore be identified in a PV array [14].

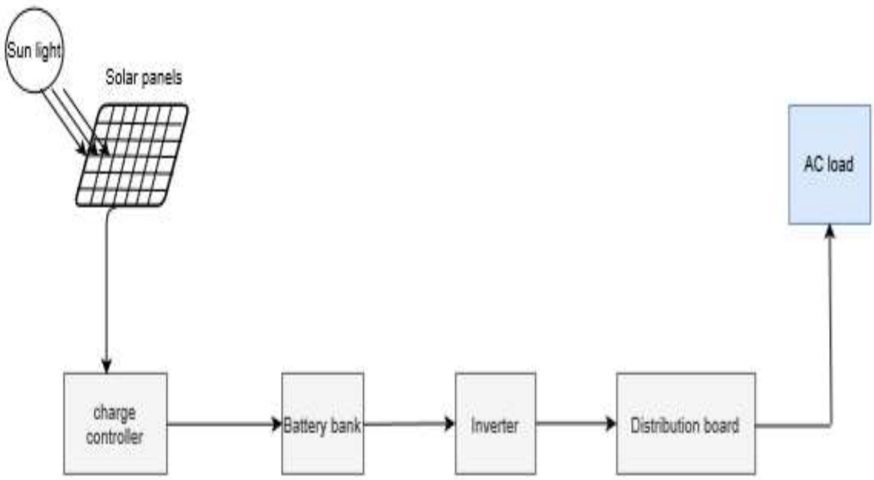

Fig 2. Common alignment of stand-alone photovoltaic system

Under varying climatic conditions, stand-alone photovoltaic (PV) systems must be built to produce full charge power. Because of the erratic nature of the solar irradiation, the PV output capacity involves major variations in the power supplied to the load. Since no grid connections are made, major network autonomy problems are important and need to be addressed to certify non-stop process of the load [15].

The most worrying problem surrounding their use is their reliance on environmental conditions. It needs not only night time backup energy equipment but also special arrangements to capture the full available electricity.

Since decades, standalone photovoltaic energy systems have been used for isolated electrification and rural irrigation, largely because these systems do not need costly deployment equipment [16].

IV. PARTIAL SHADING

Shading plays a key role in the operation of photovoltaic (PV) systems, particularly when one of the modules or cells in the string is subjected to lower rates of irradiance lead to partial shading (PS). It occurs due to numerous issues such as passing clouds, deposition of dirt, shade of trees or neighbouring constructions, fall of birds etc. [1]. The modules or cells engross the power produced by the unshaded areas as a result of this effect, thus creating hotspots that can irrevocably affect the system. To alleviate this difficult, bypass diodes are frequently coupled in parallel with modules in order to reduce the inverse voltage and consequently the power loss [17].

Partial shading is a critical problem since shaded cells may become reverse biased and start consuming power in its place of producing power resultant in a loss of entire output power and power damages in distinct shaded cells will result in native heating and temperature changes distressing surrounding cells [1]. It happens on a solar panel on only a portion of the surface of the panel is entirely illuminated. The effectiveness of partial shading over solar panels reduces the efficiency. The partial shading contributes to an unreliable and specific irradiance of the same string performance and Specific power has been generated in each cell [5].

Compared to uniform shading event, the result of partial shading on a few cells is additional harmful to the operation of the solar panel. As an implication the action of the PV systems is brutally pretentious by the array characteristics deterioration. The reverse bias on the solar cell will exceed its breakdown voltage under extreme situations of shading. The cell is absolutely damaged in these cases, cracks form and there could be an open circuit at the serial outlet where there is cell connection.

The hot-spot is a natural phenomenon that occurs when shaded on one of the panel lines. The shaded solar cells consume a large amount of electrical energy that is produced by many other photovoltaic cells that receive the highest irradiation and transform it in to electricity [15].However, the increase in the rate of irradiation and shadows in the combined solar cell spectrum enables the shaded cell to disperse the power generated by other cells that would drastically reduce maximum power [1].

The P-V curve is more complex during partial shading conditions and correct adjustment is very demanding [18].The significant increase of our research is to cover the complex behaviour of PV power specifications under both normal and inconsistent weather patterns, without immersion in the external and interior investigation of solar cell features. The temperature was set at 25^0c and the shading pattern irradiance rates on the PV array are shown in table 2.

Condition	**Irradiance (Wb/m^2)**			
	PV Array 1	**PV Array 2**	**PV Array 3**	**PV array 4**
1	1000	1000	1000	1000
2	1000	800	800	800
3	1000	600	600	600
4	1000	400	400	400
5	1000	300	300	300
6	1000	200	200	200
7	1000	100	100	100
8	1000	0	0	0

Table 2. Shading pattern

V. SIMULATION MODEL AND DESCRIPTION

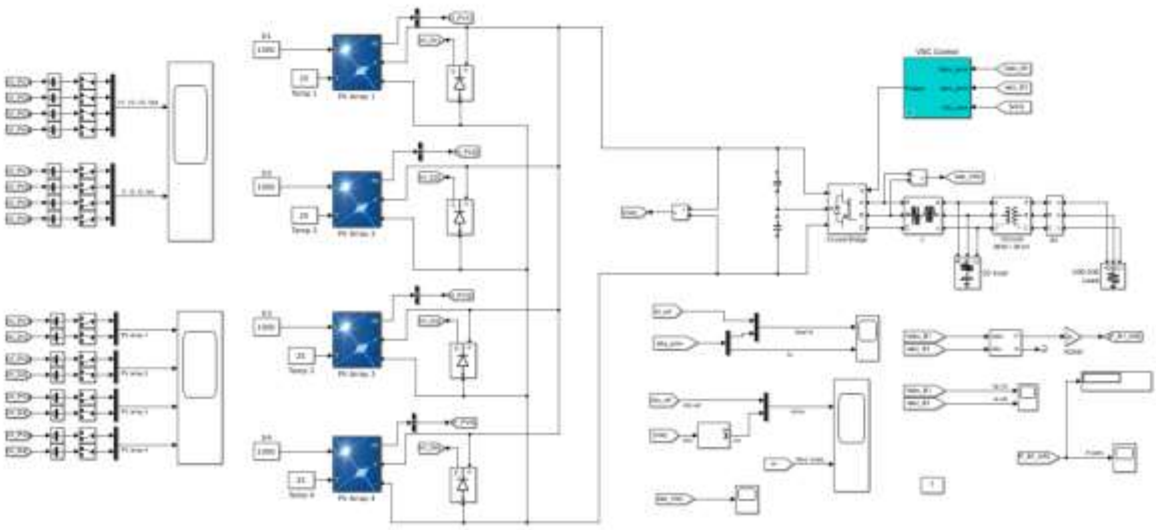

Fig 3. Matlab/Simulink of the proposed PV system

Description:

The proposed 120kW solar system consists of four30kW parallel linked PV arrays. The output of the parallel connected PV arrays is given to the voltage source converter, and the output of the VSC is then given to the 120kW load via the coupling transformer. The voltage source converter transforms the connecting voltage from 500V DC to 260V AC and preserves the unit power factor. Two control loops are used by the VSC system: an exterior control loop that controls the dc Output voltage and an interior control loop that controls the i_d and i_q currents. Whereas i_d current reference is an external controller's DC voltage output, i_q current reference is fixed to zero to preserve unity power factor. The current controller's Vd and Vq voltage outputs are converted to three modulating signals which the PWM generator uses. A 10KVAR condenser bank is connected to filter the VSC-produced harmonics, and a 3-phase coupling transformer 100KVA 260V/25KV is used to attach the converter to the charge.

Efficiency:

Due to natural conditions, the efficiency of the solar panel is reduced. Therefore, it is very important to take care of parameters such as dust, humidity, irradiance, and temperature. Device efficiency can be measured using equ (4).

Efficiency (η) $= \frac{V_{oc}*I_{sc}*FF}{P_{in}}$ …….. (2)

Where FF is Fill Factor = $\frac{P_{out}}{V_{oc}*I_{sc}}$ …….. (3)

By substituting equ (3) in equ (2)

$$\eta = \frac{P_{out}}{P_{in}} \quad …….. (4)$$

VI. RESULTS AND DISCUSSION

The designed circuit of a single step load associated PV system/stand-alone PV system is exposed in fig 3. A PV array is connected to a load via a three-phase voltage source converter and distribution transformer. The PV array used for the proposed system comprises of 10 strings with 10 series connected modules in each string. The partial shading condition applied to the designed system by varying irradiance value of PV arrays. In this paper we are calculating efficiencies by applying different shading conditions which is shown in table 2. The obtained values are shown in the table 3.

Condition	Irradiance (Wb/m^2)				Output Power (P_{out}-kW)	Efficiency (%)
	PV Array 1	PV Array 2	PV Array 3	PV Array 4		
1	1000	1000	1000	1000	90.86	76.55
2	1000	800	800	800	86.68	73.28
3	1000	600	600	600	78.64	66.95
4	1000	400	400	400	61.64	51.53
5	1000	300	300	300	46.22	39.98
6	1000	200	200	200	30.21	27.29
7	1000	100	100	100	18.03	16.94
8	1000	0	0	0	7.46	6.69

Table 3. Output power and efficiency under different shading conditions

The graphs obtained by simulating the designed circuit under different shading conditions are shown below:-

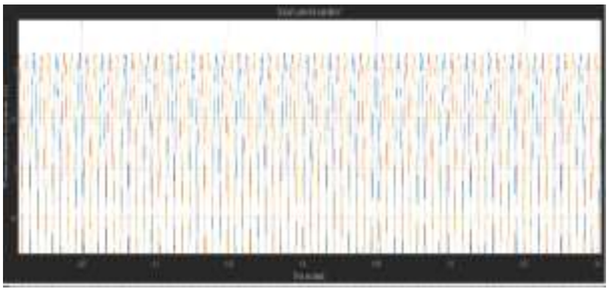

Fig.4 (a) Output current

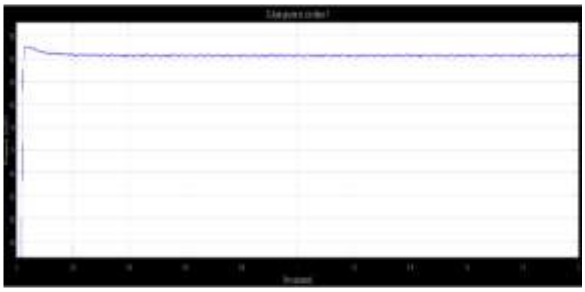

Fig.4 (c) Output power

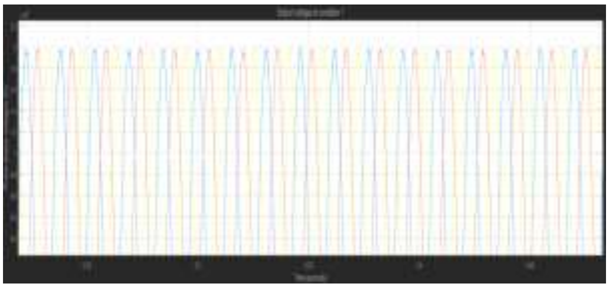

Fig.4 (b) Output voltage

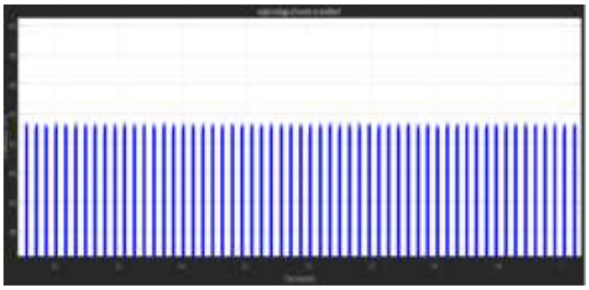

Fig.4 (d) Inverter output voltage

Figs 4(a), 4(b), 4(c) and 4(d) are the output current, voltage, power and Inverter output voltages at condition1.

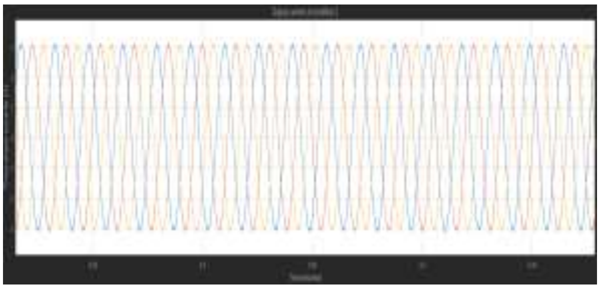

Fig.5 (a) Output current

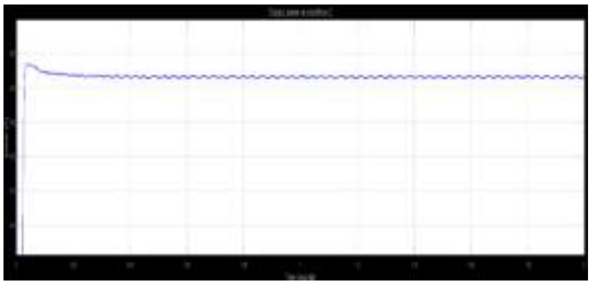

Fig.5 (c) Output power

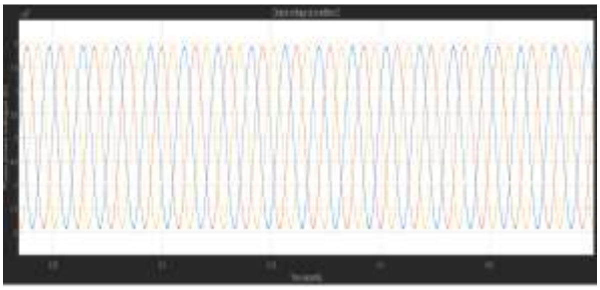

Fig.5 (b) Output voltage

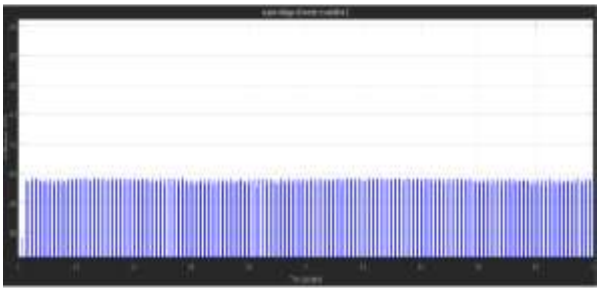

Fig.5 (d) Inverter output voltage

Figs 5(a), 5(b), 5(c) and 5(d) are the output current, voltage, power and Inverter output voltages at condition2.

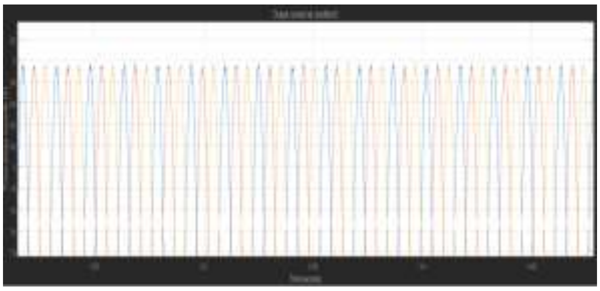

Fig.6 (a) Output current

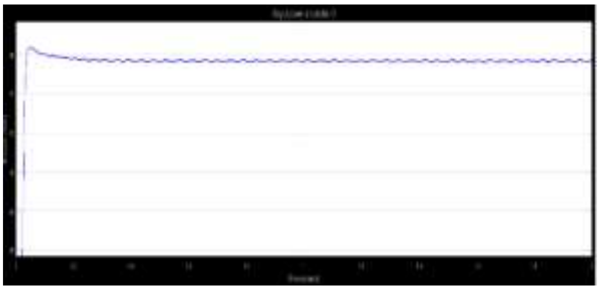

Fig.6 (c) Output power

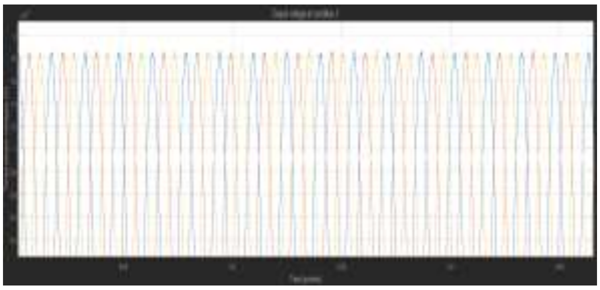

Fig.6 (b) Output voltage

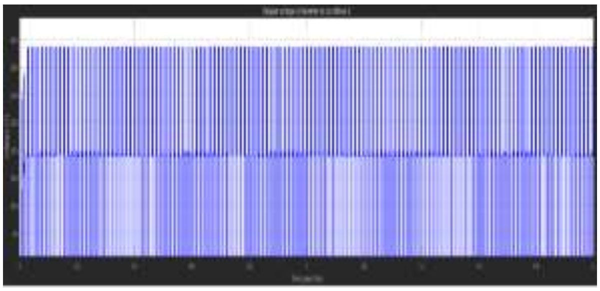

Fig.6 (d) Inverter output voltage

Figs 6(a), 6(b), 6(c) and 6(d) are the output current, voltage, power and Inverter output voltages at condition3.

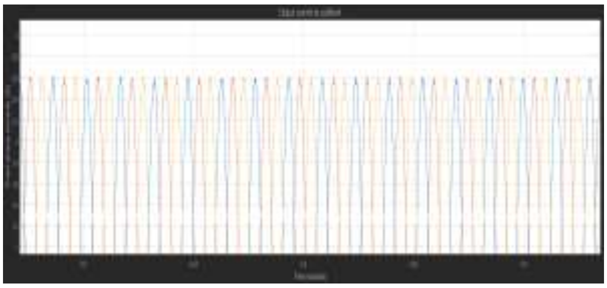

Fig.7 (a) Output current

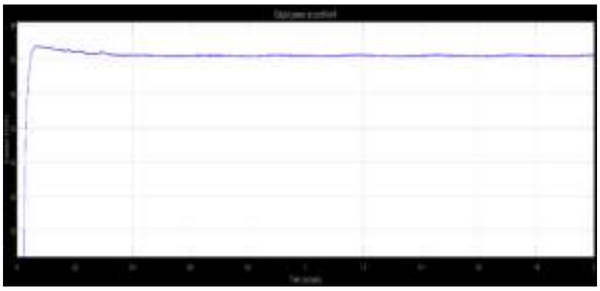

Fig.7 (c) Output power

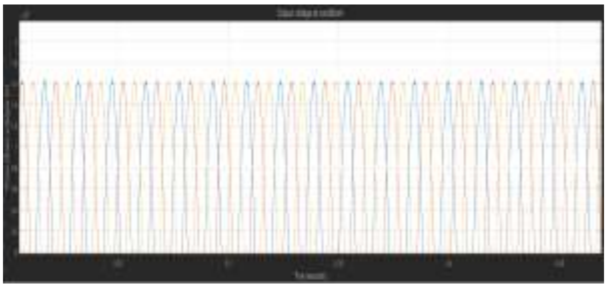

Fig.7 (b) Output voltage

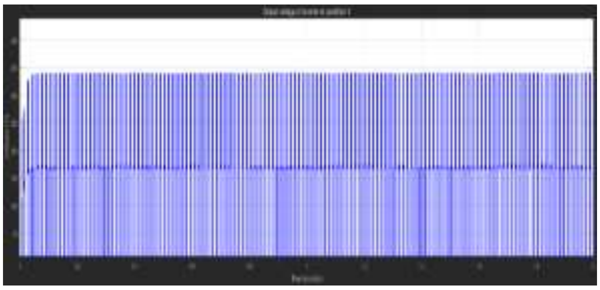

Fig.7 (d) Inverter output voltage

Figs 7(a), 7(b), 7(c) and 7(d) are the output current, voltage, power and Inverter output voltages at condition4.

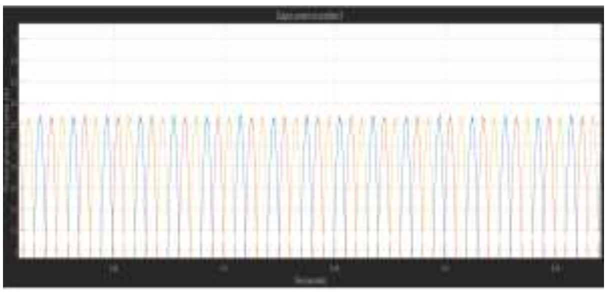

Fig.8 (a) Output current

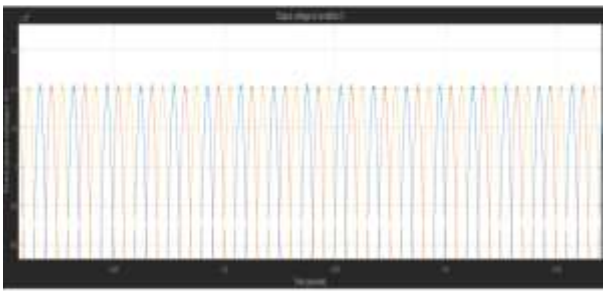

Fig.8 (b) Output voltage

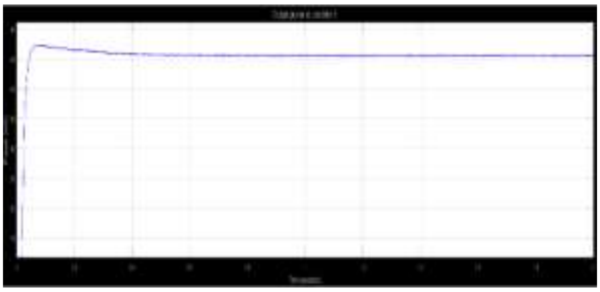

Fig.8 (c) Output power

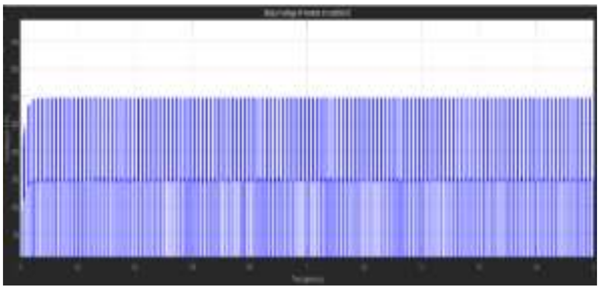

Fig.8 (d) Inverter output voltage

Figs 8(a), 8(b), 8(c) and 8(d) are the output current, voltage, power and Inverter output voltages at condition5.

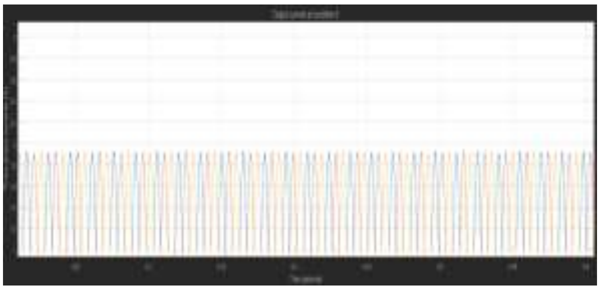

Fig.9 (a) Output current

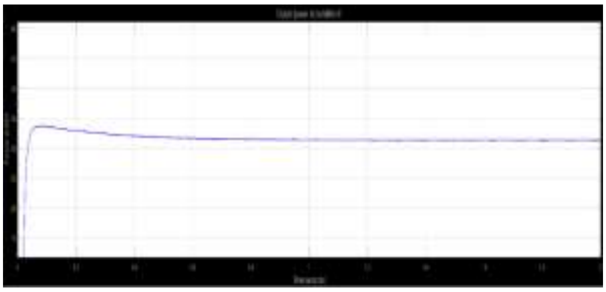

Fig.9 (c) Output power

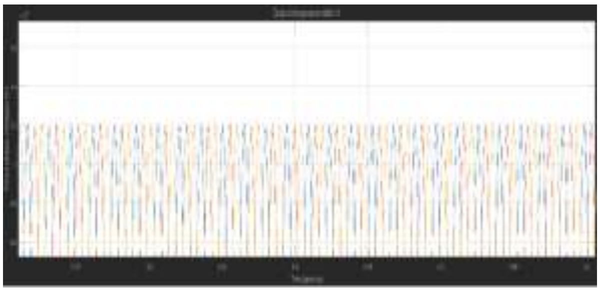

Fig.9 (b) Output voltage

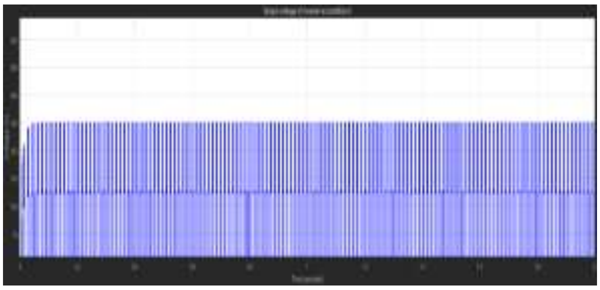

Fig.9 (d) Inverter output voltage

Figs 9(a), 9(b), 9(c) and 9(d) are the output current, voltage, power and Inverter output voltages at condition6.

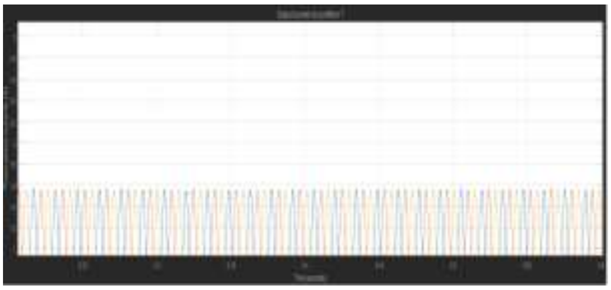

Fig.10 (a) Output current

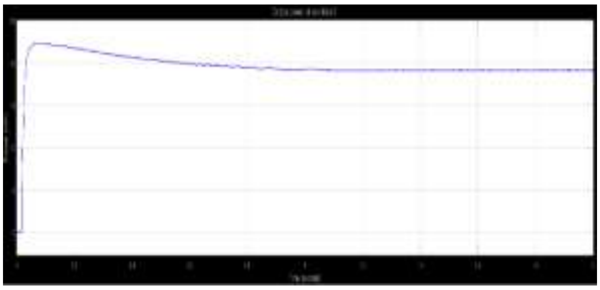

Fig.10 (c) Output power

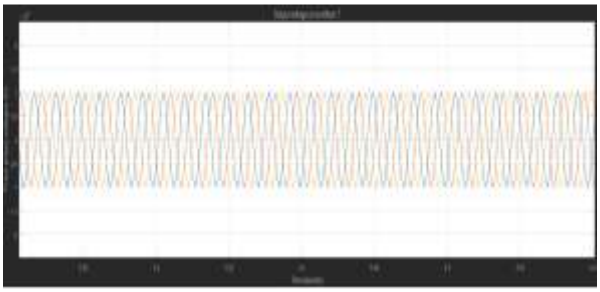

Fig.10 (b) Output voltage

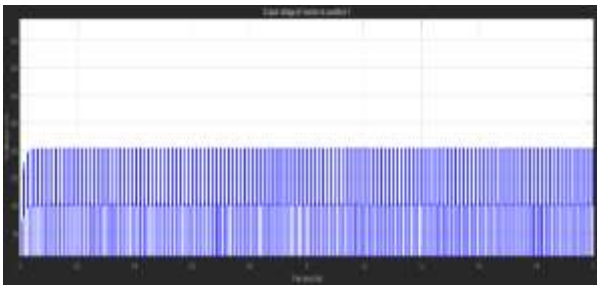

Fig.10 (d) Inverter output voltage

Figs 10(a), 10(b), 10(c) and 10(d) are the output current, voltage, power and Inverter output voltages at condition7.

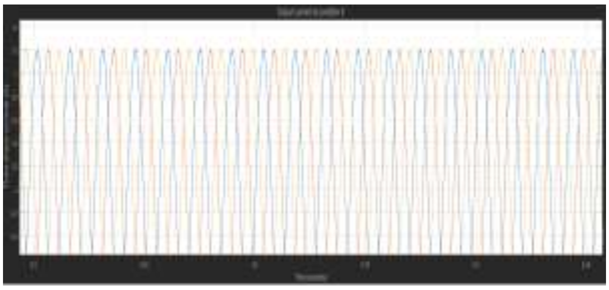

Fig.11 (a) Output current

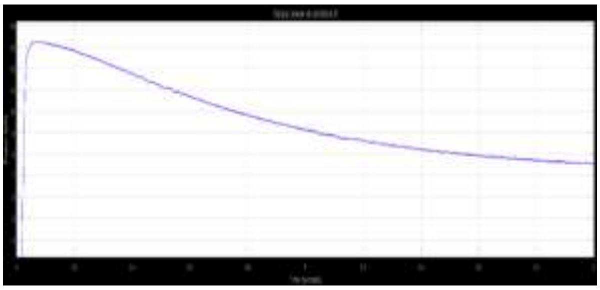

Fig.11 (c) Output power

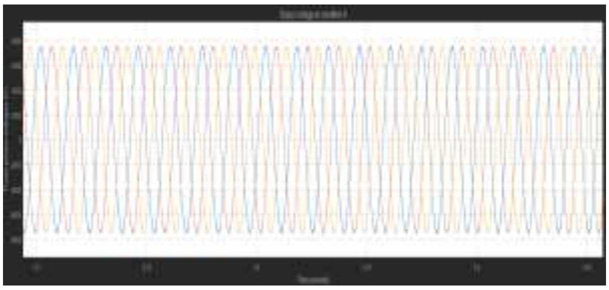

Fig.11 (b) Output voltage

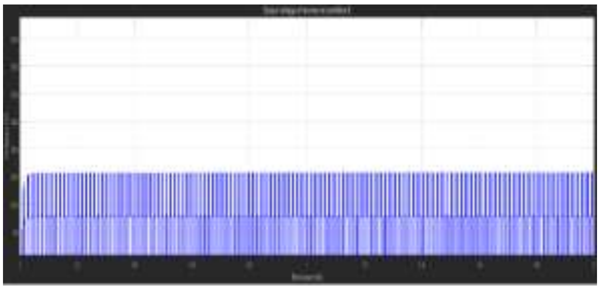

Fig.11 (d) Inverter output voltage

Figs 11(a), 11(b), 11(c) and 11(d) are the output current, voltage, power and Inverter output voltages at condition8.

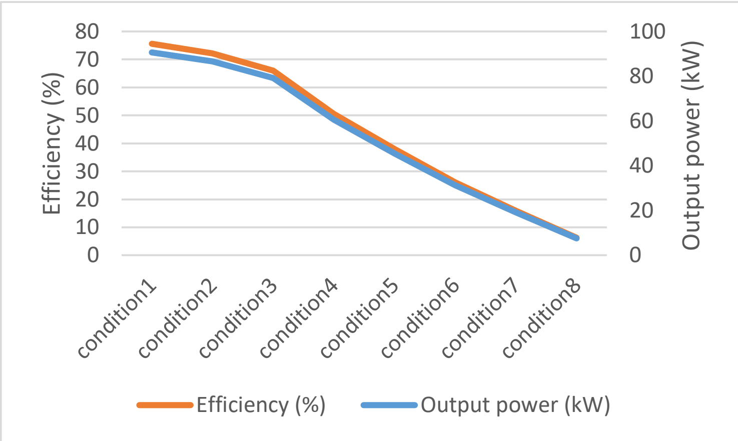

Fig 12. Output power at load Vs Efficiency

Fig (12) shows that the graph obtained by using output power and efficiency of designed model at different shading conditions which shown in the table 3.

VII. CONCLUSION

In this paper, MATLAB/SIMULINK was used to model and simulate a single power electronic interface using a voltage source inverter for a 120kw load connected PV system to measure maximum power output and system performance. This paper describes how the output power and efficiency reduced with respect to irradiance levels under partial conditions. The partial condition effect is to given high priority while developing and designing the PV system. Analysis of the results with MATLAB will provide the feasible solution to implement the system practically. Energy is transformed from the sun into electricity and how it is delivered to the consumers. The energy is provided by the solar panel, which transforms it into electrical energy, although this is DC in nature and thus needs to be transferred to the ac using an inverter afterwards. To raise the voltage level of the load, a transformer is used and thus power is supplied to the load. Several safety and power improvement equipment are used to strengthen the system performance. For that the experiments were carried out by applying different shading conditions on a 120kw PV system. Finally it is concluded that the proposed system in this paper shows that the output power is directly proportional to the efficiency and is reduced in case of partial shading. And is to be considered highly while installing PV panles.

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