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Performance Investigation of Solar Photovoltaic System for Mobile Communication Tower Power Feeding Application

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ABSTRACT- In emerging nations like India, the use of energy is rising quickly over time. The moment is opportune to rely increasingly on renewable energy sources, such as solar photovoltaic, to satisfy the demand. Mobile communication towers are one of the industries with the highest power consumption rates, and a lot of these towers are situated rather distant from the power grid. This research develops the performance investigation of solar photovoltaic system for mobile communication tower power feeding application. In order to power the mobile tower, a 6 kW_P solar photovoltaic system with 250W_P polycrystalline solar panels is designed. Multiple low dc voltage ports are needed, and isolated output dc ports at 48 V dc are made using an isolated dc-dc converter. The amount of battery bank needed is determined via mathematical modelling depending on the backup time. On the 1-dimensional platform, real-time inputs like solar radiation and panel temperature are taken into account and simulated. Results are monitored both at the panel level and at the system level using an isolated dc-dc converter for panel level monitoring. Theoretical findings are used to validate the simulation results.

Keywords: Solar PV, isolated dc-dc converter, maximum power point tracking, battery back-up, mobile communication tower.

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1. INTRODUCTION

In developing countries like India, the use of electricity or total energy per person is rapidly increasing. Because using fossil fuels increases greenhouse gas output, humanity's reliance on them to meet its electrical demands is growing. Global warming needs to be curbed since the world has already crossed a dangerous threshold [1-2]. Now is the perfect time to transition to some alternative energy sources because fossil fuels like coal, natural gas, and oil may soon become extinct. Experts are already putting up significant effort to replace fossil fuels with renewable energy sources [3-4]. Alternative energy sources shouldn't emit substances that cause global warming since the environment is increasingly polluted. The best method of producing electricity is solar photovoltaic (PV) technology, and India has the greatest geographic potential for solar energy [5-7].

A solar PV panel's performance is influenced by input factors including sun irradiation and panel temperature. Due to the dynamic nature of the input parameters, the performance of the solar PV panel/ PV system is dynamic in nature. The PV panels' voltage and current will keep varying. Power electronic converters are required to transform fluctuating DC voltage into constant DC voltage since the usable form of DC electricity should have a constant magnitude [8]. It makes use of a closed-loop dc-dc converter with a PWM control scheme. According to the application, bucking and boosting operations must be performed, and a new power converter must be employed for the same. A maximum power point tracking (MPPT) system with a dc-dc converter must be installed in order to collect the most power possible from the PV panel at any available temperature and irradiation. There are several MPPT strategies, such as perturb and observation (PO), incremental conductance (IC), constant voltage (CV), and hill climbing (HC) [9-11]. These methods include continually modifying the gate pulse width to balance the dc link voltage of dc-dc converters.

Since integrated circuits are extremely sensitive to voltage variations, telecommunication towers and the integrated circuits attached to them are powered by 48 V dc. Traditionally, a diesel generator with battery backup or a rectifier and filters are used to transfer power from the grid to the communications tower [12-14]. Since rectifiers are non-linear loads and grid voltage variations may affect the functioning of telecommunication systems, they will function as harmonic sources to the grid if they are converting ac power to dc power. An isolation should

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be established between the grid and the communication system since the grid voltage will be higher than the operating voltage of the telecommunication system and its related integrated circuits. The traditional power supply method will cost close to 25% of the total network running costs if it is adopted. The power needed for mobile communication towers spans from 1 kW to 8 kW, however the largest power need for towers is below 3.5 kW [14].

The voltage regulation in the communication towers is one of major problem as the system operates at lower voltages [15]. In order to mitigate the voltage regulation issue, even more power electronic converters are required. The typical range of voltage regulation if 5% [16-17]. An off-grid solar PV system with several dc output ports is shown in this paper. The recommended method may improve power quality, save operational expenses, and increase dependability by increasing battery backup capacity. The recommended dc-dc converter can be utilised with several ports of constant dc output voltage and a single variable dc voltage input. The same dc-dc converter is used to carry out the MPPT simultaneously. The recommended remedy can be used as a substitute for remote locations' access to grid connections.

The article is further structured so that *chapter 2* discusses the proposed system's specifics, including a block diagram, PV array calculations, battery calculations, and dc-dc converter specifics. *Chapter 3* includes mathematical modelling of solar PV panels and PV arrays. *Chapter 4* presents the system simulation findings, while *Chapter 5* presents the finalized lines and validation.

2. PROPOSED SOLAR PV SYSTEM

The proposed 6 kW_P off-grid solar PV system has several dc outputs ports, and 48 V dc may be accessible at each port. *Figure 1* depicts the suggested system's schematic diagram.

2.1 Solar PV Array Calculations

24 solar panels are connected in parallel to create a solar PV array, and 250 WP solar PV panels are taken into consideration. In order to offer an ac source of supply at the transformer terminals and to maintain the output voltage at 48 V dc, a transformer is taken into consideration, and a switch will be maintained on switching at a high frequency.

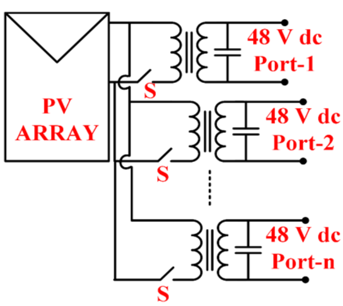

Figure 1: Schematic diagram of the proposed PV system

To build the system, a SUNPOWER SPR-250NX-BLK-D solar PV panel was used; *Table 1* lists the solar PV panel's specifications.

Table 1: Solar PV panel specifications

S. No.	Parameter	Value
1.	Maximum power	250 W
2.	Cells per module	72
3.	Open circuit voltage V_{OC}	50.93 V
4.	Voltage at maximum power point V_{mp}	42.8 V
5.	Short circuit current I_{SC}	6.2 A
6.	Current at maximum power point I_{mp}	5.84 A
7.	Temperature coefficient of V_{OC} (%/deg.C)	-0.29103
8.	Temperature coefficient of I_{SC} (%/deg.C)	0.013306
9.	Light generated current I_L	6.2081
10.	Diode saturation current I_O	13.617 pA
11.	Diode ideality factor	1.0263
12.	Shunt resistance R_{Sh}	448.6949 Ω
13.	Series resistance R_{Se}	0.37759 Ω

2.2 DC-DC Converter

In order to run several integrated circuits, an isolated dc-dc converter with numerous output ports is constructed. The maximum PV output voltage is 42.8 V since all of the panels are linked in parallel, which is the voltage at which each panel is operating at its maximum power. Due to the nature of the inputs to the PV panel, the output voltage will continue to change. When the MPPT approach is used, the output voltage ranges from 38 to 42.8V with a load. The transformer's turns ratio, or the ratio of secondary turns to primary turns, is regarded to be 1.5 when it comes to isolated dc-dc converters. If the minimum PV voltage at any irradiation and temperature may not fall below 32 volts, the ratio of output voltage to the minimum input voltage is (48/32) is taken as transformation ratio. For the PV voltages above 32 V the gate pulse width can be controlled in order to control the voltage at output terminals. The circuit diagram of basic isolated converter is shown in *figure 2*.

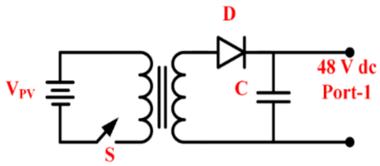

Figure 2: Isolated dc-dc converter

The diode's function is to limit the reverse currents from the output to the PV, and the capacitor is retained to reduce and stabilize output voltage profile changes. Perturb and observation MPPT method is used to extract the maximum power and sampling time is considered as 20 μS.

3. BATTERY BANK CALCULATIONS

Let say, the average full bright sunny hours per day is 5.0 in the southern part of the India.

Therefore, in one full sunny day, the average electrical energy generated by the 6 kW_P PV plant with MPPT is given by = Plant peak capacity (kW_P) x Average full bright sunny hours per day

$$= 6\ kW_P \times 5.0 = 30\ kWh \text{ or Units}$$

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The total energy consumed by the mobile communication tower per day is

= Total load x 24 hours = 1 kW x 24 = 24 kWh

Because the energy produced daily is 25% greater than the energy used daily, it is possible to compensate for any days when appropriate irradiation is not available by producing extra power on a bright, sunny day.

As the mobile communication tower is required to operate as of now and owing to severe weather or continuous rain even three to four days of good irradiation may not be available during monsoon season, consider the battery backup necessary is for five continuous days. As a result, the battery's stored energy should be used by the system.

Therefore, total energy needs to be stored in the battery bank is given by

= Total energy consumed by the system per day x number of days the back-up required

= 24 kWh x 5 days = 120 kWh

As the system is operating at 48V dc, the battery voltage is chosen as 48 V for the convenient operation.

Therefore, at 48V, the 'Ah' capacity required to store the 120 kWh energy is given by

$$= \frac{total\ energy\ needs\ to\ be\ stored}{battery\ operating\ voltage} = \frac{120\ kWh}{48V} = 2500\ \text{Ah}$$

Consider, the depth of discharge (DOD) of battery as 80%, that means only 80% of the stored energy can be delivered to the system load. Therefore, the net 'Ah' capacity required is

$$= \frac{2500\ Ah}{0.8} = 3125\ \text{Ah}$$

Consider 48V, 250 Ah lithium batteries, the number of batteries required to be connected in parallel to store the total required energy is given by

$$= \frac{3125Ah}{250Ah} = 12.5$$

The total number of batteries that must be linked in parallel is 12.5, and the closest positive integer above that is 13, thus take 13 batteries into consideration.

Therefore, to have a 5 days back-up for the proposed system 13 numbers of 48V, 250 Ah batteries are required.

4. SIMULATED RESULTS

On a MATLAB/SIMULINK environment, the proposed 6 kW_P solar PV system with numerous dc output ports is simulated. The 250 W_P solar PV panel of choice is simulated under various temperature and irradiance conditions. The first experiment maintains the panel temperature at 25°C while varying the irradiation in small increments. The resulting I-V and PV characteristics are displayed in *figure 3 (a)*. In the second experiment, the panel temperature is gradually changed while the solar irradiation is maintained constant at 1000 W/m2. The resulting I-V and P-V characteristics are displayed in *figure 3 (b).*

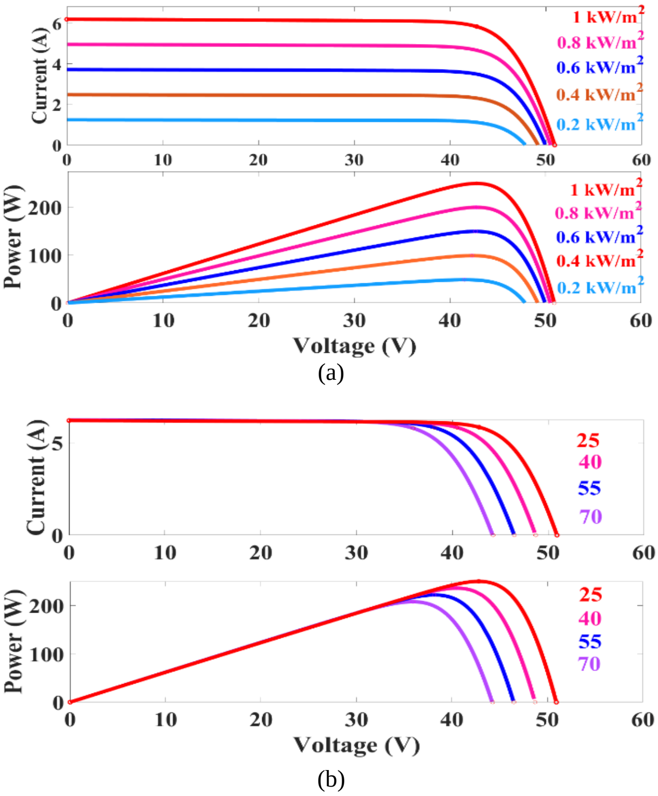

Figure 3: I-V and P-V characteristics (a) with variable irradiance and constant panel temperature, (b) with variable panel temperature and constant irradiance

The solar irradiance directly affects the panel's output current, however a rise in panel temperature causes a little increase in the output current profile. As panel temperature rises, the output power decreases because the drop in voltage profile is greater than the increase in current profile. Isolated boost converters are utilized to execute MPPT and stabilize the output voltage at 48V dc while connecting all 24 panels in parallel. The output voltage at each port is illustrated in *figure 5*, where 48V is maintained constant.

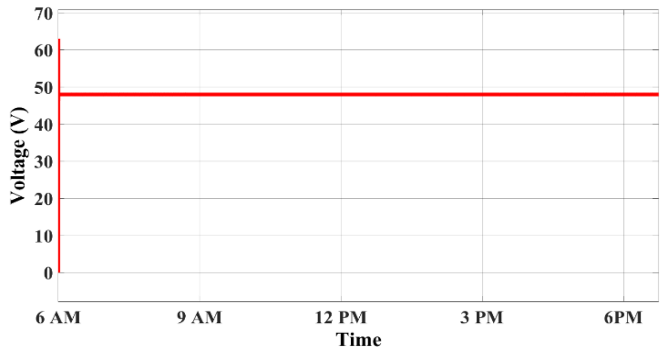

Figure 5: Voltage profile at each output port

Figure 6 displays the output current from each panel, which is nearly proportional to the irradiation. The PV system receives

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inputs in the form of the panel temperature and solar irradiation in real time. The real time data considered is of Bhopal for 17th march 2022. The closed loop operation of dc-dc converter is effectively worked, so that irrespective of small variations in the real time inputs out voltage is maintained constant.

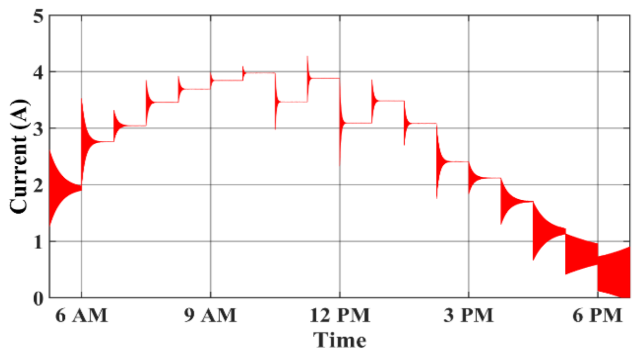

Figure 6: Current profile from each solar PV panel

Figure 7 displays the total current from the 6 kW_P solar PV system. It is clear that the present profile reaches its peak around midday, but proper irradiation was unavailable after 1 PM due to cloudiness. Along with changing proportionately with the input solar irradiation, the overall output current also does.

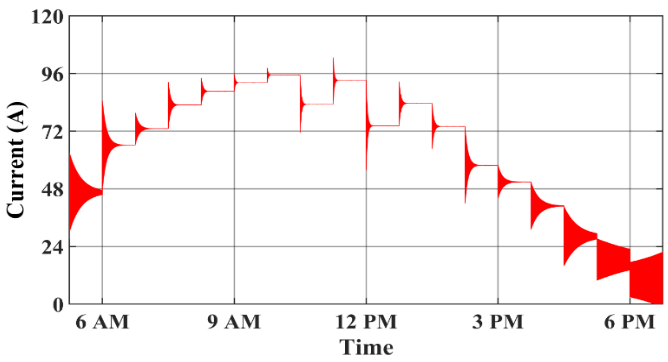

Figure 7: System output current profile at 48V

The 6 kW_P solar PV system's peak power output throughout the day for the 17th march 2022 is around 4.6 kW, and the PV system rating may be determined based on the power requirements of mobile communication towers. In accordance with the required voltage, the voltage level may also be changed. The overall output power profile for the throughout day is shown in *figure 8*.

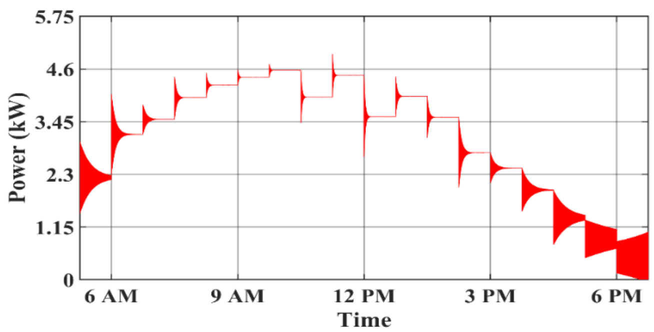

Figure 8: Overall output power profile

5. CONCLUSION

The mobile communication towers are being powered from grid or diesel generator sets through the required converters. A 6 kW_P solar photovoltaic system has been presented in this paper with multiple dc output ports for mobile communication tower power feeding application. At each dc output port 48 V constant voltage is maintained and 24 numbers of 250W_P polycrystalline solar PV panels are used and connected all in parallel. An isolated output ports are developed to have a flexibility to use for power feeding of various integrated circuits. The performance investigation of the proposed system is done with variable inputs, that is panel temperature and solar irradiations are kept inconstant, in fact real-time inputs are given to the system. Mathematical modelling is developed for the battery back-up calculation. The proposed system is simulated on SIMULINK platform and the obtained simulated results are validated with the theorical findings and they are close knit.

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