Design of MPPT Based PV System Using DC-DC Converter

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Abstract: This paper aims to analyze the potentiality and cost-effectiveness of PV systems' application and ensure maximum power extraction from the solar panel. Solar panels have stationary parts with a durable lifetime along with the nature of modularity and shorter commissioning time compared to other available energy sources. To clinch the tracking of maximum power Mpp, Perturb, and Observe algorithm is preferred. Matching the load impedance with the PV panel is ensured by employing a Boost converter topology where the duty cycle is adjustable. The system was comprised of a solar module, DC-DC Boost converter, and a resistive load. The system was designed, and performances were evaluated through simulation using PSIM software. Later the parameters were verified by experimental conditions using a solar panel of the exact specifications, and some data were obtained close to the simulated data.

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1. INTRODUCTION

Expansion of the energy sector in Bangladesh following the country's socio-economic development and wide-ranging urbanization forced the government of Bangladesh to adopt the renewable energy policy in 2008 to ensure 10% of the total electrical energy generation from renewable energy resources [1]. Solar energy is the best alternative for Bangladesh as the average daily solar radiation is 4-6.5 kWh/m² [2]. MPPT and solar charge controller in this paper confirm the logical utilization of converting the available solar energy to the desired energy source. Furthermore, researchers also implemented the Fuzzy logic MPPT algorithm, a complex algorithm to track the maximum power from the connected solar panel from its smooth functioning. Also, the dc-dc converters used are the conventional ones. The load plays an important role here since the radiation of the sun generally varies during the day, also in different weather conditions. Some statistical studies are done in the recent research papers, how to store the power in the battery bank and the radiation changes in different country locations. The two problems in solar cell technology are low efficiency (i.e., 10 % to 20%) and nonlinear I-V characteristics. Many MPPT algorithms have been developed in recent studies that

extract maximum power from P-V cells in any environmental conditions to meet this drawback. In recent research studies on this topic, the fuzzy logic controller is very famous for applying the MPPT algorithm [3-4]. Amongst the dc-dc converters used for impedance matching, boost converter is utilized to boost up the extracted voltage from panel. However, the solar panel current is also an important term. Some research papers discussed the use of buck converter and its efficiency in this system. Boost converter is using in this research to show that it is also appropriate and efficient as well as buck converter [5]. Many software were used to design the system amongst which, PSIM design was a very new and improved design. Some of the works created a great scope to design an efficient and new form of MPPT based PV system.

2. PHOTOVOLTAIC AND PV ARRAY

Among the available DC sources, PV is a distinctly nonlinear energy source. Matching its operation to that of its equivalent electrical load is mandatory to ensure the extraction of maximum obtainable energy [6]. The elementary equivalent model of PV cell is presented in Figure 1. An ideal current source, an ideal diode, a series resistance R_S , and shunt resistance R_P are in parallel connection [7]. The TBP1240

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MPV module was used, and the specification of the panel is given in Table 1 and shown in Figure 2.

Figure 1. Solar cell equivalent cell.

Table 1. PV Module Specifications

Maximum Power, P _{max}	No. of cells	V _{max}	I _{max}	Open circuit voltage, V _{oc}	Short circuit current, I _{sc}
150W	72	34.5V	4.35A	43.5V	4.75A

Figure 2. Physical model of PV in PSIM with irradiance 1000W/m².

3. PERTURBATION AND OBSERVATION

Perturb and observe algorithm is implemented to detect the Peak Point in the MPPT system. When the steady-state is reached, the algorithm swings the operating point around the peak point and slightly reduces the PV efficiency, as shown in Figure 3. This is one of the simplest circuits used to track the maximum power point, requiring only two sensors [8]. It can be done by any microcontroller or any other digital signal processor. The algorithm is initiated by removing the power change resultant unsettling a low voltage from PV.

Figure 3. Perturb and observe technique.

4. BOOST CONVERTER

The boost converter is implemented for the step-up operation and load matching. The circuit of the DC-DC boost converter with a resistive load is simulated in PSIM, as shown in Figure 4, where MPPT is not applied in the simulation [9-10]. Faraday's law is applied to determine the following equation

$$V_s D T = (V_0 - V_s)(1 - D)T(1)$$

The transfer function of the DC voltage was calculated from equation (1). And the equation becomes as follows:

$$M_v = \frac{V_0}{V_s} = \frac{1}{1 - D} \quad (2)$$

As the name of the converter infers, the yield voltage is consistently greater than the input voltage. The Persistent Conduction Mode (CCM) of boost converter operation is for $L > L_b$ [3]. Where

$$L_b = (1 - D)^2 D R / 2f. \quad (3)$$

The boundary value of the inductor parameter is $L_b = 6.25 \mu H$ considering Duty Cycle $D = 0.5$, Load resistance $R = 10 \Omega$, and switching frequency $f = 100 \text{ kHz}$. The output RC circuit of the boost converter gets the discontinuous current. It is required to introduce a larger filter capacitor in the converter circuit to minimize the ripple of output voltage to an acceptable level [1]. Moreover, the filter capacitor ensures the supply of output DC when the diode is not in conduction mode. The base estimation of the filter capacitance that outcome in the voltage ripple is given by equation (4).

$$C_{min} = D V_0 / V_r R f. \quad (4)$$

At Duty Cycle, $D = 0.5$; $V_r / V_0 = 1\%$, Load resistance, $R = 10 \Omega$; and switching frequency, $f = 100 \text{ kHz}$; the minimum capacitance used in boost converter is $C_{min} = 50 \mu F$ [8-9]. Ratings of boost converter are shown in Table 2, respectively.

Table 2. Boost Converter Parameter Values.

Parameters	Value
Input voltage, V_{in}	34 to 38.5V
Duty cycle	0.5
Switching frequency, F_s	10 KHz
Load Resistance, R	120 ohms
Inductance, L	2.16mH
Capacitance, C	470.SuF
Input capacitance, C_{in}	60uF
Maximum output voltage, V_{out}	43.5V

4. DESIGN AND SIMULATION

The circuit design and simulation part is performed in POWERSIM 9.0.2. PSIM electronic circuit simulation software package was designed to perform fast simulation of power electronics and motor drives. Here the components from the PSIM library were used for simulation. Hence, the thesis work is basically based on the use of the solar panel, which generates power under specific conditions such as radiation, temperature, and inclination of the panel, etc. These parameters are very fragile and limit the success of this project to a certain extent [11].

Figure 4. Boost converter without MPPT.

Panel specification from solar module utility of PSIM is applied to design the physical model [10]. The change PV output with irradiance is displayed in Figure 5. When irradiance 1000W/m²,

the maximum power is 162.10W. PV basic physical model designed in PSIM is presented in Figure 6.

Figure 5. Variation PV output with varying irradiance levels during simulation with time.

Figure 6. A basic model of PV system in PSIM.

Figure 7. Simulation circuit of the system.

Figure 7 shows the simulation diagram of the total system and the obtained results. Figure 8. Shows input and output voltage curve. Figure 9 is the simulation result of the output voltage and current. Figure 10 is the simulation result of the output power

under a standard irradiance value of 1000W/m^2 . Figure 11 shows a small PV panel project to obtain some values under experimental conditions. Table 3 shows the comparison between simulated data and experimental data obtained.

Figure 8. Input and Output voltage.

Table 3. The power output of different irradiance values.

Irradiance (w/m^2)	Simulated output power (W)	Experimental output power (W)
1000	150.75	146.24
800	128.57	123.78
600	96.42	92.38

Figure 9. Output Voltage and Current.

Figure 10. Output power (Pout) with MPPT for irradiance 1000W/m^2 .

Figure 11. Solar panel with boost converter circuit in bread board.

5. CONCLUSION

Generation of maximum power of PV system was ensured by employing MPPT. The implementation of the proposed system was enlightened with the specification of waveforms showing the simulated output for distinctive radiation and temperature levels. The proposed system's main idea was to design MPPT based PV system with the boost converter as a power conditioning unit. The PSIM environment gives a real-time design system for the thesis. The solar module system is capable of tracking the maximum available power. To extract maximum power, it is desirable to use MPPT algorithm, therefore to develop different types of algorithms of MPPT, so that maximum power can be extracted from solar energy with good efficiency.

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