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Advanced Closed Loop Control of PMDC Motor Drive using Boost Converter Fed from a Photo Voltaic Panel

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Abstract

The objective of the proposed system is to drive a Maximum Power Point Tracking (MPPT) algorithm based solar powered Permanent Magnet Direct Current (PMDC) motor that utilizes P & O (Perturb and Observe) method. Cost free source which is solar energy is captured and by P&O method of maximum power point tracking, the PMDC motor is able to drive. The output of solar panel is stepped up to desirable level using boost converter. Closed loop controlling of PMDC motor is done by using PI controller. PI controller will impart a constant output to motor. The programming part is done in PIC microcontroller. Simulation is done using MATLAB/Simulink and the PMDC motor characteristics are analyzed and studied. Taking into account the high power bearing capability of PMDC motor, it has got wide scope in agricultural fields. In PMDC, speed and armature current is taken as reference to the PI-controller considering some values of speed as reference. The output signal of the PI-controller is connected to another switch. A diode is connected parallel to the MOSFET to get a constant voltage. With the help of the boost converter it is proved that the boosting of voltage at required level can be done to drive a PMDC Motor such that boost converter forms a good interface between the photo voltaic panel and load. Speed of PMDC motor is controlled by proportional plus integral controller has controlled effectively. The hardware implementation of the proposed system is the future step in the work.

Keywords: Boost Converter, Buck Converter, Maximum Power Point Tracking, Photovoltaic Panel, PMDC Motor

1. Introduction

With the rising demand for energy, fossil energy reserves are depleting at an alarming rate. Shortage of energy and the requirement for sustainable energy systems have forced the search for energy supplies based mainly on renewable energy resources.

In the proposed approach, the PMDC motor is driven using solar energy generated from photo voltaic panel. Since solar energy acts as the main source of power, it can be operated in standalone as well as grid connected modes of operation. Therefore the problem of insufficient supply from the grid can be eliminated. To get maximum power from Photo Voltaic (PV) panel, P and O MPPT technique is used. This approach uses different types of dc-to-dc converters to obtain the sufficient voltage required to drive the PMDC motor.

The proposed system is made up of photovoltaic panels to absorb the sunlight. To adjust the speed of induction motor, the power electronic devices are used. The machine can be related to black box, that only needs the input supplier (PV) and the Output (Motor). To maximize the availability of electrical power inside the photovoltaic cell, MPPT algorithm is used. The proposed block diagram as shown in Figure 1.

2. Previous Methods

The three phase induction motor needs more power to drive, and converting dc to ac current inverter is needed. In conversion process of dc to ac more losses will be occurring. To overcome these losses, inverter is removed and three phase induction motor is to be replaced with

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permanent magnet direct current (PMDC) motor. PMDC motors are sufficient for pumping application[1].

Brush less direct current motor has low efficiency as compared to the permanent magnet direct motor. PMDC motors have the capability of bearing high power, and they won't produce much heat. BLDC motors have problems due to heating. If overheating occurs, then BLDC motor magnets and insulation will be damaged. To overcome these losses PMDC motor is used[2].

3. Proposed Methodology

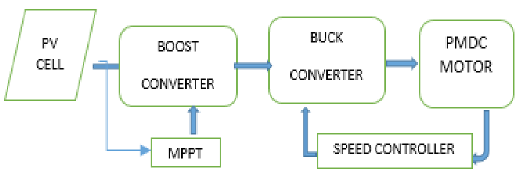

Figure 1. Proposed system's block diagram.

3.1 PV Panel

Photo voltaic cell converts solar energy into electrical energy. This energy depends upon the solar irradiance and temperature of the photo voltaic panel. Based on irradiance and temperature the VI-characteristics of the photo voltaic panel varies.

The following equations will be used for PV panel[1].

$$\mathbf{I(V)} = \frac{I_X}{\mathbf{1} - \exp\left(\frac{-\mathbf{1}}{b}\right)} \cdot \left[\mathbf{1} - \exp\left(\frac{V}{b \times V_x} - \frac{\mathbf{1}}{b}\right)\right] \quad (1)$$

Here I_x is the short circuit current under Standard Test Conditions (STC), V_x is the open circuit voltage under STC, and b is the characteristic constant of the panel

$$\mathbf{P}\ (\mathbf{V}) = V \times I(V) = \frac{\mathbf{V} \cdot \mathbf{I_X}}{\mathbf{1} - \exp\left(\frac{-\mathbf{1}}{\mathbf{b}}\right)} \cdot \left[\mathbf{1} - \exp\left(\frac{V}{\mathbf{b} * V_x} - \frac{\mathbf{1}}{b}\right)\right] \quad (2)$$

The I-V characteristics of the photo voltaic panel as shown in Figure 2 and Figure 3.

$$b_{((n+1))} = \left((V_{op} / V_X - 1\right) / \left(\ln[1 / V_{op} I_{sc}]\right) * \left(P_{\max} - P_{\max} \times \exp((-1)/b(n))]\right) \quad (3)$$

Here $_{\mathbf{Vop}}$ is the voltage at maximum power which is extracted from photo voltaic panel and $\mathbf{P}_{\mathbf{max}}$ is the maximum power point at the panel under standard test conditions.

3.2 Maximum Power Point Tracking

A maximum power point tracker (MPPT) is a device that looks for the maximum power point of a source and keeps on operating in that point. The MPPT tries to match the power source to impedance that demands the maximum power out of it. Photo voltaic panel does not always produce constant power because of variation of temperature and irradiance. So, MPPT is used in the PV panel to produce constant power. Different techniques are available in MPPT. The proposed approach uses perturb and observe method. This is made real time application by implementing inside a microcontroller. MPPT depends on the duty ratio. To carry out this P&O the facility ought to be read at a time K, soon after this voltage is usually improved. Subsequently, the facility over time k+1 is usually read, when this specific strength is usually incrementing we increment the duty ratio and by means of end result this voltage inside SOLAR FARM. In the event which the strength inside K+1 is leaner compared to inside K time period we decrement the duty ratio and by means of end result this voltage[3-6]. This system is usually running inside restrictions in the MPP. The protocol in the P&O is usually displayed inside Figure 4.

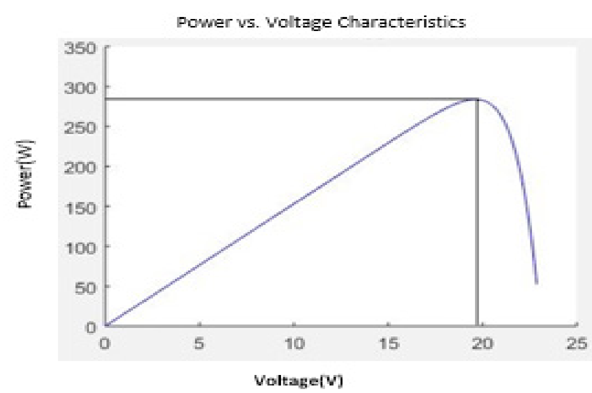

Figure 2. I-V Characteristics of the photo voltaic panel.

3.3 DC-to-DC Converter

Dc-to-dc converter is a switching device in which one voltage level is converted to another voltage level. It consists of inductor, capacitor and diodes to step down and step up the voltage and current. In these converter inductor and capacitor are designed for required load. This approach Boost converter (step up converter) and Buck converter (step down converter) Topology is used. In boost converter the switching time of the Mosfet is varying by duty ratio

(D). For this project Boost converter and buck converter is implemented. In Boost converter is designed for step up the voltage to drive the PMDC motor.

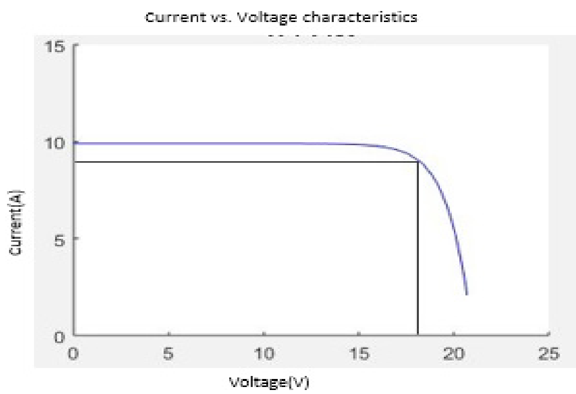

Figure 3. I-V Characteristics of the photo voltaic panel.

3.3.1 Boost Converter

Boost converter is a one of the switching device. Boost converter is mainly used to boost up the voltage. Boost converter is an electronic switch that works based on duty ratio. Here boost converter is designed based upon the required voltage of the load[7]. For designing of the boost converter following equations are used. The basic Boost converter circuit as shown in Figure 5.

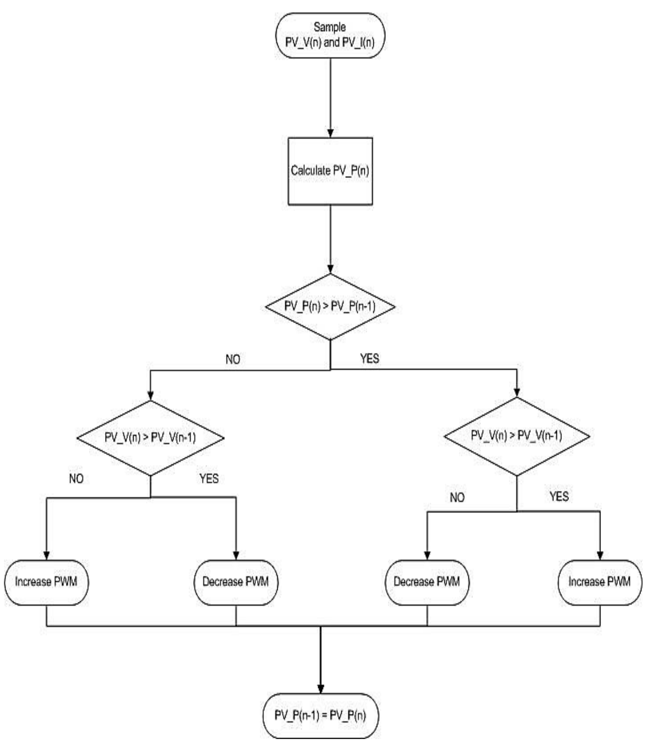

Figure 4. The perturbation and Observation Algorithm.

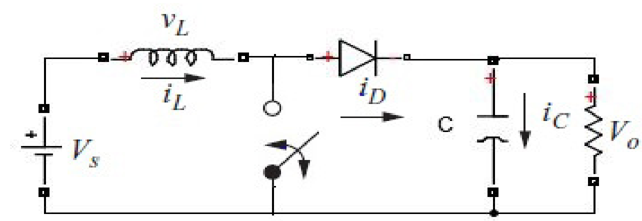

Figure 5. Circuit diagram of Boost converter.

The duty ratio of Boost converter depends on input and output. Duty ratio of Boost converter is expressed in the equation followed

$$D = 1 - (V_s/V_0) \quad (4)$$

Here V_s = Supply Voltage,

V_o = Output Voltage,

For boosting the output voltage of Boost converter Inductor (L) and Capacitor (C) value has to be determined. For designing inductor and capacitor values the following equations are utilized.

For Inductance, $$L = \left(\frac{V_s * D}{\Delta I * L * f}\right) \quad (5)$$

For capacitance, $$C = \frac{D}{R * \frac{\Delta V_o}{V_o} * f} \quad (6)$$

Where, f = Switching frequency

$\frac{\Delta V_o}{V_o}$ = Output voltage Ripple

R = Resistance

With the help of above equations the boost converter is designed based upon the load.

3.3.2 Buck Converter

Buck converter is also a switching device. Normally buck converter is mainly used to get reduced voltage. In buck converter is working on electronic switch based in duty ratio. In this project buck is using for switching application. For controlling the speed for the motor proportional and integral controller is used. The output signal of the PI-controller is connected to the converter switch[8-10].

3.4 PMDC Motor

Permanent Magnet Direct Current (PMDC) motors are preferred when there is an application which requires high torque with good efficiency. PMDC motors require less maintenance and construction is simple. Hence

PMDC motor is used for pumping and industrial purposes. PMDC is a high speed motor.

3.5 Closed Loop Controller

A closed-loop simulation for clockwise rotation of the electric motor is usually done by applying PI controller[11]. This simulation is executed using MATLAB software program. This closed-loop circuit with PI controller is shown in Figure 6 respectively. The resultant PI valuations are carried out in

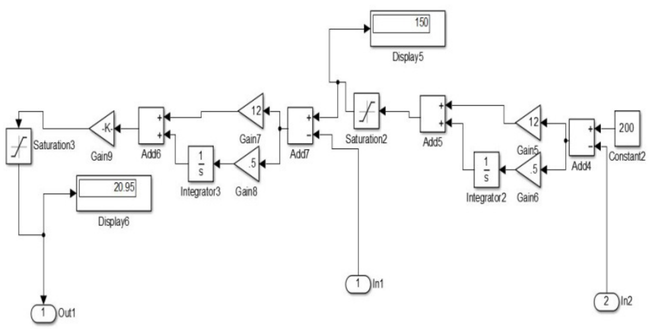

Figure 6. PI Controller.

Simulink models. The simulation circuit is as shown in Figure 6. The parameters of the PI-controller values as shown in Table 1[12].

Table 1. Values for Kp and Ki

Parameter	Value
Proportional constant(Kp)	12
Integral constant(Ki)	0.5

The output of the Boost converter is given to the permanent magnet dc motor. The output of the PMDC motor is as shown in Figure 7. In PMDC, speed and armature current is taken as reference to the PI-controller considering some values of speed as reference. The output signal of the PI-controller is connected to another switch. A diode is connected parallel to the Mosfet to get constant voltage.

4. Simulation and Experimental Results

In this project simulations are done in Matlab 2015a/ Simulink software is used. In this project simulation components are working by itself and each component diagram and result in presented in this project. Complete simulation diagram is as shown in Figure 8 and 9. The output of the system is as shown in Figure 10.

4.1 Photo Voltaic Module

From photo voltaic panel to get different voltage and current due to varying the irradiance and temperature. To get maximum power MPPT is using. The output voltage of the photo voltaic panel is given to the Boost converter. For this project to get high current solar panels are connected in parallel to get required current of the system[13]. The Photovoltaic module parameters as shown in Table 2.

Table 2. Parameters of Photo voltaic module

Parameter	Value
Voltage at Pmax(V_{mpp})	16.5V
Current at Pmax(I_{mpp})	4.13A
Short circuit current(I_{sc})	5.1A
Open circuit voltage(V_{oc})	23.1V
Maximum power(P_{max})	68W

4.2 Boost Converter

Using Boost converter based on input voltage of the photovoltaic panel with MPPT used to get the desired output. In designed Boost converter is boosting the photo voltaic panel output voltage into 48 volts[14-16]. In designed boost converter parameters as shown table. In designed boost converter output as shown in figure 8. The Boost converter parameters as shown in Table 3. The Simulation of the Boost converter is as shown in Figure 7.

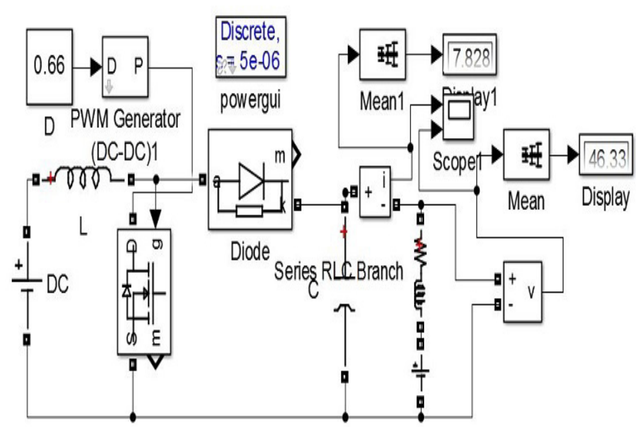

Figure 7. Simulation of Boost converter.

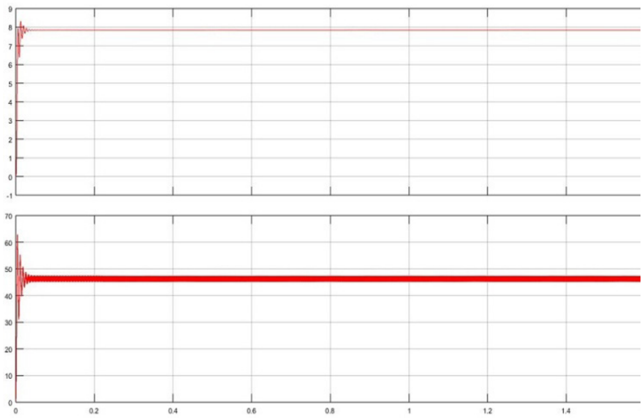

Figure 8. Boost converter output.

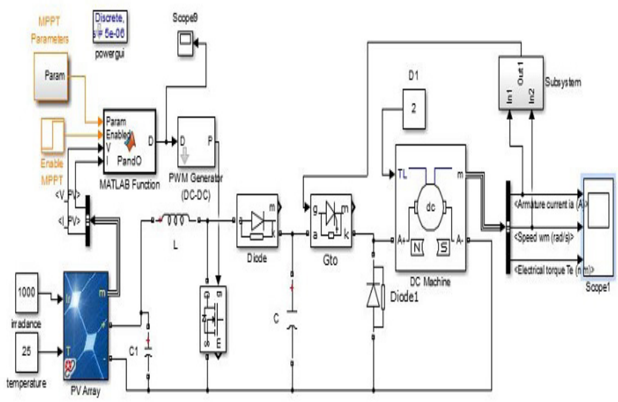

Figure 9. Simulation of proposed system in MATLAB/ SIMULINK.

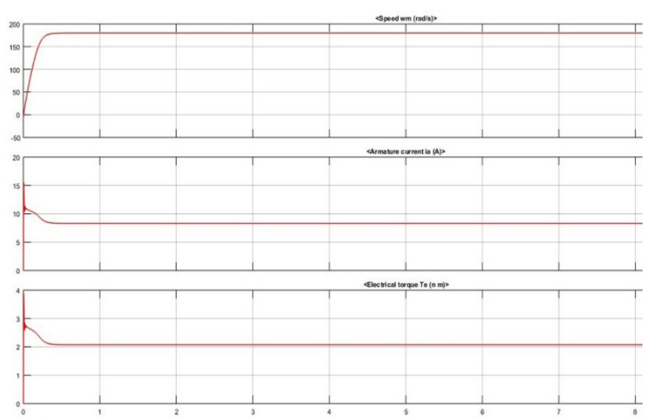

Figure 10. Motor Characteristics with PI controller.

Table 3. Boost converter parameters

Parameter	Value
Inductor(L)	0.845mH
Capacitor(C)	0.229mF

5. Conclusions

With simulation it is proved that the PMDC motor has to be driven with help of photo voltaic panel. Usage of perturb and observe MPPT technique is an effective way to extract maximum power by a panel. With the help of the boost converter it is proved that the boosting of voltage at required level can be done to drive a PMDC Motor. Boost converter forms a good interface between the photo voltaic panel and load. Speed of PMDC motor is controlled by proportional plus integral controller has controlled effectively. The next step is the hardware implementation of the proposed system.

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