PV Powered Water Pumping System Using PMDC Motor

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Abstract — Sun’s radiation that is harnessed by humans for practical ends is the solar energy but the conversion of sun’s heat and radiations into electricity is the pre-eminent use of solar energy made by the humans. The proposed study is about the simulation of “PV Powered Water Pumping System Using PMDC Motor”. This project makes an active effort towards operating the solar panel at maximum power point by the use of an intermediate buck-boost dc-dc power converter known. The dynamic performance of the entire system is analyzed by developing mathematical models of sub-systems and is simulated.

Index Terms—Permanent Magnetic DC, direct current, Alternating current

I. INTRODUCTION

1. Solar Energy: The solar energy falling on the Earth’s continents is more than 200 times the total annual commercial energy currently being used by humans. Solar energy systems can be divided into two major categories namely [1],
   - Solar thermal systems
   - Photo-voltaic systems

2. Buck-Boost Converter: The switch is closed for the time DT and open for (1-D) T. The output voltage has the opposite polarity from the source voltage. [2].

3. PMDC Motor: A PM DC motor provided by permanent magnets instead of salient pole wound field structure in PMDC motor, a fixed magnetic field generated by the permanent magnets interacts with the field induced by the currents in the rotor windings, thus creating a torque. Since flux remains constant, the only way to control its speed is to vary the armature voltage with the help of an armature rheostat [3].

Advantages: The efficiency of the PMDC motors is generally higher than that of the wound field motors. In many cases a PMDC motor is smaller in size than a wound field dc motor of equal power rating.

II. Modelling of System Components

1. PV Array:

   The equivalent circuit of general model is shown fig.

   Considering the 100% solar radiation the photon current becomes 14.4 A. The PV generator used in this study consists of 18 parallel strings, 324 cells in series per string, such that the overall volt-ampere characteristic is given by [4],

   \[ V_{PV} = 23.68 \ln \left( \frac{l_{PV} - l_{PV} + 0.009}{0.009} \right) - 0.9l_{PV} \]
3: PMDC Motor

The photocurrent, which is proportional to the insolation.

2: Buck-Boost Converter:

Equations from the circuit for two different switching conditions with R Load,

\[
\frac{dI_a}{dt} = \frac{V_{IN} \cdot S - V_0 (1-S)}{L} - \frac{V_0}{R \cdot C} \cdot \frac{I_a (1-S)}{C}
\]

Fig 7: Buck-boost converter

Standard values has been given as input to get the below result [2],

For, \( C = 80 \mu F, L = 20 \mu H, R = 5 \Omega, V_{IN} = 24 \text{ V, } f = 10^5 \text{Hz} \)

Fig 8: voltage and current of buck-boost converter

\[
\begin{array}{|c|c|c|}
\hline
\text{Sl.no} & \text{Theoretical output} & \text{Simulated output} \\
\hline
1 & V_0(AVG) & -16 \text{ V} & -16 \text{ V} \\
2 & I_a(AVG) & 5.33 \text{ A} & 5.3 \text{ A} \\
\hline
\end{array}
\]

Voltage and currents are the functions of time.

By changing the duty ratio the output voltage of the buck-boost converter can be controlled.

11: Equivalent circuit combined system

The combined equations are,

\[
\begin{align*}
\frac{dI_a}{dt} &= \frac{V_{IN} \cdot S - V_0 (1-S)}{L} - \frac{V_0}{R \cdot C} \cdot \frac{I_a (1-S)}{C} \\
\frac{dV_0}{dt} &= \frac{-[I_a + I_a (1-S)]}{C} \\
\frac{dI_a}{dt} &= \frac{(V_0 - E_b - R I_a)}{L}, \ E_b = K \cdot \omega \\
\frac{d\omega}{dt} &= \frac{1}{J} (T - T_L), \ T = K \cdot I_a
\end{align*}
\]

iii. Combining the individual sub-systems

1: Combination of Buck-Boost Converter and PMDC Motor: The output of the buck-boost converter is given as input to the PMDC motor i.e. the buck-boost converter and PMDC motor are combined to get a single system.
Initially, the armature current rises drastically and attains the steady state. The voltage is negative polarity. The torque is high initially, attains the steady. The speed is low and later, it increases & reaches steady state. The inductor current of buck-boost converter increases initially, and attains steady state.

2: Combination of PV Array, Buck-Boost Converter and PMDC Motor: The output of the PV array is fed to buck-boost converter, and the output of this converter is given as input to the PMDC motor.

![Fig 12: Armature current v/s time](image)

![Fig 13: Voltage v/s Time](image)

![Fig 14: Torque v/s Time](image)

![Fig 15: Speed v/s Time](image)

When switch is ON:

\[ V_C = 23.68 \times \ln \left( \frac{I_{pv}}{I_{ph} - I_{pv} + 0.09} \right) - 0.9 \times I_{pv} \]

\[ \frac{dV_C}{dt} = \frac{-I_a}{C_s}, \quad \frac{di_L}{dt} = \frac{(V_C - E_b - R I_a)}{L} \]

\[ \frac{d\omega}{dt} = \frac{1}{J}(T - T_L), \quad T = K \times I_a, \quad E_b = K \times \omega \]

When switch is OFF:

\[ \frac{dV_C}{dt} = \frac{l_{pv}}{C_s}, \quad \frac{di_L}{dt} = \frac{V_o}{L} \]

\[ \frac{dV_o}{dt} = \frac{l_a}{C_s} - \frac{l_{pv}}{C_s}, \quad \frac{di_L}{dt} = \frac{(V_o - E_b - R I_a)}{L} \]

\[ \frac{d\omega}{dt} = \frac{1}{J}(T - T_L), \quad T = K \times I_a, \quad E_b = K \times \omega \]

![Fig 16: Equivalent circuit of whole system.](image)

![Fig 17: PV o/p voltage for 100% insolation](image)

![Fig 18: Inductor current](image)

![Fig 19: Armature current](image)

![Fig 20: Speed v/s Time](image)

### Conclusion

The equations of the system are written as,
Characteristics of each sub-system are analyse, each sub system is modelled by its differential equations. These differential equations are solved by applying Euler’s implicit method [5], and the “C” code [6] is written to solve these equations. And response curves are obtained with the help of GNU plot. It can be concluded that, the modelling and simulation of “PV Powered Water Pumping System by PMDC Motor” can be achieved by combining each sub system, and i.e. PMDC motor can be driven by solar PV array efficiently.

REFERENCES
[2.] Power Electronics, by Daniel Hart.

[5.] Applied Numerical Methods with MATLAB for Engineers & Scientists, by Steven C. Chapra.

APPENDIX
D-Duty ratio, T-Time period, \( V_{PW} \)=output voltage of PV array, \( I_{PH} \)= photo current=14.4 A for 100% solar insolation, \( I_{PV} \) = output current of PV array, \( I_L \)= Inductor current \( V_{IN} \)= Input voltage, \( V_0 \)= Output voltage, 
\( S \) = State of the switch, \( S=1 \) switch is closed \( S=0 \) switch is open, \( V \) - Input voltage to the PMDC motor, \( I_a \) - Armature current, \( E_b \) - Back E.M.F, \( \omega \) - Speed of the motor, \( T \) - Torque of PMDC motor, \( T_L \) - Load torque, \( J \) - Inertia, \( K=0.0143 \), \( J=0.0022 \) kgm\(^2\), \( L=0.00521 \), \( R=0.7 \) ohm, \( T_c=0 \) [7], \( I_C \) - Capacitor current.