NCPE 2016, KLESCET, Belagavi
International Journal of Technology and Science, ISSN (Online) 2350-1111, (Print) 2350-1103 Volume 3, Issue 2, 2016 pp. 27-30

PV Powered Water Pumping System Using PMDC Motor

Sacheen Aski[1], Teja B Barker[2], Mallanagouda[3] N B,. Naveen N D[4]
[1, 2, 3, 4] BVBCET, Dept. of Electricals & Electronics Engineering, Hubballi - 580031, India
Email:[1]sachinaski1995@gmail.com, [2]teju95900@gmail.com

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].

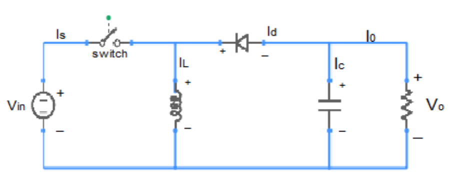

Fig 1: Buck-Boost Converter

3. PMDC Motor: A PMDC 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.

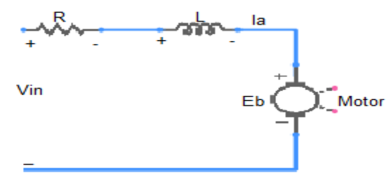

Fig 2: PMDC motor

4. Overview of the whole water pumping systems: DC motor transforms electrical energy into mechanical energy.

The water pumping can be done using various electric motors. One of the most suitable motors is PMDC motor. This system mainly consists of PV array, DC-DC converter and PMDC motor connected to a water pump

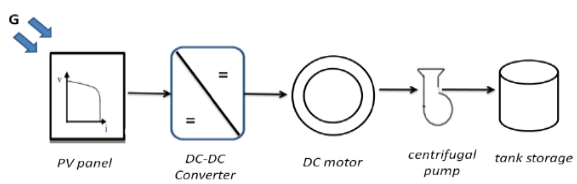

Fig 3: System model

II. Modelling of System Components

1: PV Array:

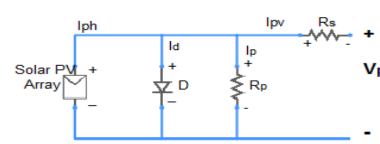

Fig 4: Equivalent circuit of a solar cell

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],

$$V_{PV} = 23.68 * \ln\left\{\frac{I_{PH} - I_{PV} + 0.009}{0.009}\right\} - 0.9 I_{PV}$$

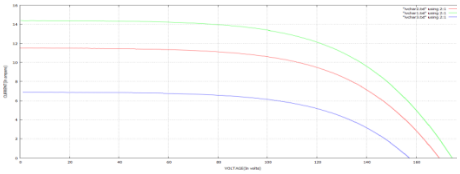

Fig 5: I-V Characteristics of PV array

---- 100% insolation---- 80% insolation

---- 50% insolation

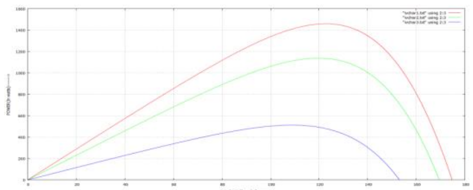

Fig 6: P-V Characteristics of PV array

---- 100% insolation---- 80% insolation

---- 50% insolation

The photocurrent, which is proportional to the insolation.

2: Buck-Boost Converter:

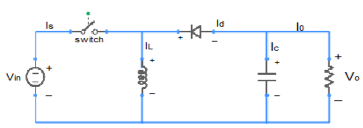

Fig 7: Buck-boost converter

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

- $\frac{dI_L}{dt} = \frac{V_{IN}*S-V_O(1-S)}{L}$
- $\frac{dV_O}{dt} = \frac{-V_O}{R*C} - \frac{I_L(1-S)}{C}$

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

For, C = 80μF, L = 20μH, R = 5Ω, V_{IN} = 24 V, f = $10^5 Hz$

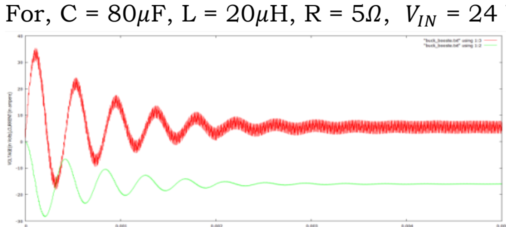

Fig 8: voltage and current of buck-boost converter

---- Voltage ---- Current

Sl.no		Theoretical output	Simulated output
1	$V_{O(AVG)}$	-16 V	-16 V
2	$I_{L(AVG)}$	5.33 A	5.3 A

Voltage and currents are the functions of time. By changing the duty ratio the output voltage of the buck-boost converter can be controlled.

3: PMDC Motor

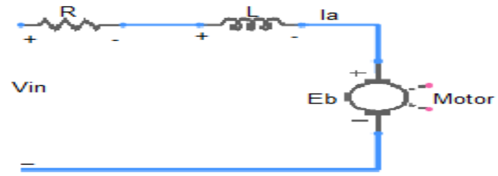

Fig 9: Equivalent circuit PMDC motor

Equations of PMDC motor are,

$$V = RI_a + L\frac{dI_a}{dt} + E_b, \quad E_b = K*\omega$$

$$T = K*I_a, \quad J*\frac{d\omega}{dt} = (T - T_L)$$

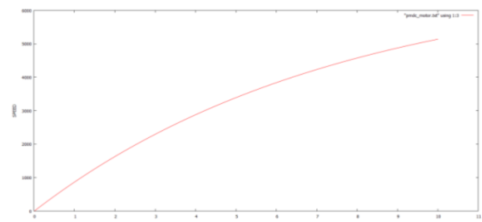

Fig 10: Speed v/s Time

Initially, the speed is low and later it reaches steady state.

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.

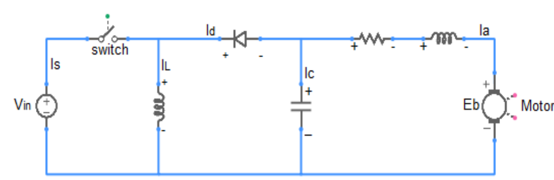

Fig 11: Equivalent circuit combined system

The combined equations are,

$$\frac{dI_L}{dt} = \frac{V_{IN}*S-V_O(1-S)}{L}, \quad \frac{dV_O}{dt} = \frac{-[I_a+I_C(1-S)]}{C}$$

$$\frac{dI_a}{dt} = \frac{(V_O-E_b-RI_a)}{L}, \quad E_b = K*\omega$$

$$\frac{d\omega}{dt} = \frac{1}{J}(T-T_L), \quad T = K*I_a$$

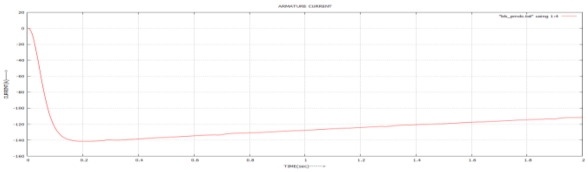

Fig 12: Armature current v/s time

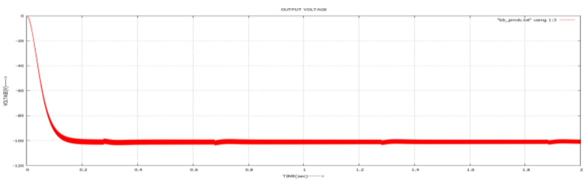

Fig 13: Voltage v/s Time

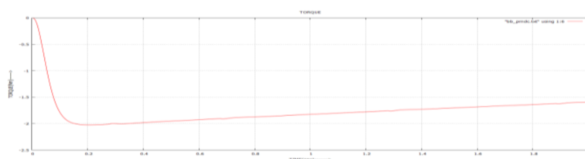

Fig 14: Torque v/s Time

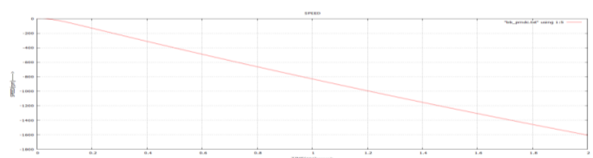

Fig 15: Speed v/s Time

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.

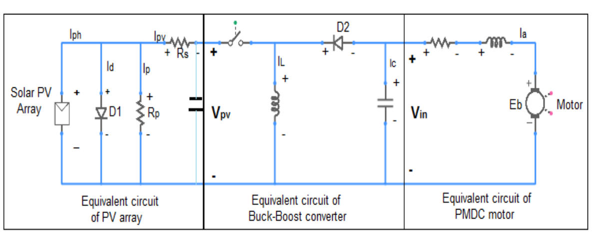

Fig 16: Equivalent circuit of whole system.

The equations of the system are written as,

When switch is ON:

$$\frac{dV_c}{dt} = \frac{(Ipv - I_L)}{C_s}, \qquad \frac{di_l}{dt} = \frac{V_c}{L}$$

$$V_C = 23.68 * \ln\left(\frac{Iph - Ipv + 0.09}{0.09}\right) - 0.9 * I_{pv}$$

$$\frac{dV_O}{dt} = \frac{-I_a}{C}, \quad \frac{dI_a}{dt} = \frac{(V_O - E_b - RI_a)}{L}$$

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

When switch is OFF:

$$\frac{dV_c}{dt} = \frac{Ipv}{C_s}, \qquad \frac{dI_L}{dt} = \frac{V_O}{L}$$

$$V_C = 23.68 * \ln\left(\frac{Iph - Ipv + 0.09}{0.09}\right) - 0.9 * I_{pv}$$

$$\frac{dV_O}{dt} = \frac{I_a}{C} - \frac{I_L}{C}, \quad \frac{dI_a}{dt} = \frac{(V_O - E_b - RI_a)}{L}$$

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

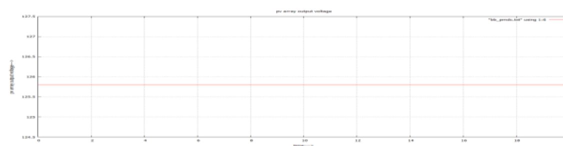

Fig 17: PV o/p voltage for 100% insolation

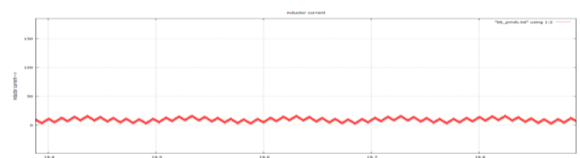

Fig 18: Inductor current

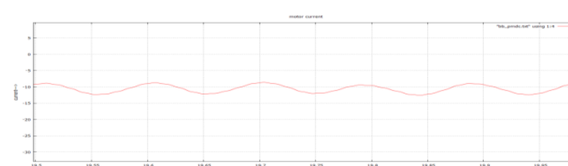

Fig 19: Armature current

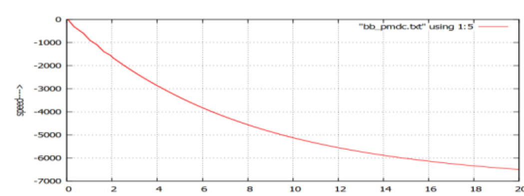

Fig 20: Speed v/s Time

CONCLUSION

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

[1.] Non-conventional Energy Resources, by B.H.Khan.
[2.] Power Electronics, by Daniel Hart.
[3.] Principles of Electric Machines & Power Electronics, by P.C. Sen.
[4.] Performance analysis of PV powered dc motor driving a three phase self-excited induction generator, by S.M.Alghuwainem, EEE Dept. King Sound University Riyad, Saudi Arabia.
[5.] Applied Numerical Methods with MATLAB for Engineers & Scientists, by Steven C. Chapra.
[6.] Systematic Approach to Data Structures Using C, by A.M. Padma Reddy.
[7.] Dynamic performance of a permanent magnet dc motor, powered by a PV array for water pumping, by C.L.Puttaswamy, B.Singh, B.P.Singh, EEE Dept.IIT Delhi.

APPENDIX

D-Duty ratio, T-Time period, V_{PV}=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_O = 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, ω - Speed of the motor, T - Torque of PMDC motor, T_L- Load torque, J – Inertia, K=0.0143, J=0.0022 kgm², L=0.00521, R=0.7 ohm, T_L=0 [7], I_C- Capacitor current.