

# Controlling of Solar Powered S.E DC Motor using IMC Controller

SALIM\*, JYOTI OHRI  
 Department of Electrical Engineering  
 National Institute of Technology  
 Kurukshetra  
 INDIA

salimnitk@gmail.com ohrijyoti@rediffmail.com

**Abstract:** - Due to the economic challenges in surging oil costs and natural concern India is facing huge growth in renewable energy resources. By adopting artificial intelligence technique based input to the drive train mechanism, the effective utilization of the solar energy has been performed. The complete system has an array of solar panel, a boost converter, separately excited DC motor and Internal Model control (IMC) controller as a voltage regulator. IMC Controller have been designed to deal with the system nonlinearity and its associated uncertainty. Monitoring of system is based on LabVIEW virtual instruments.

**Key-Words:** - P&O MPPT, S.E DC Motor, IMC Controller.

## 1 Introduction

Clean green renewable source of energy has been expected to play more significant role in the global energy future. Geographically, India has ideal characteristics for solar energy. Solar radiation provides most promising and everlasting gist of sources which we have; tapping its better output using artificial intelligence may have best possible output from it. With the increase in adoption of LEDs, low voltage electronics and efficient DC motor technology, houses energy need fulfilled by using DC directly from solar panels. This can help reduce energy consumption by over 50 per cent. PV system referred to any array of cells having PV material that convert solar radiation into direct current. In this study, PV array has been designed to provide maximum output at the rated conditions of the DC motors when the PV array has full illumination.

MPPT technique has been used to get maximum power output from PV system by matching the load resistance and achieves maximum power. Article shows that the solar energy is used to feed the DC motor which is operated using IMC controller instead of conventional controller to have better speed accuracy. The proposed system provides an effective MPPT controller for solar panel and Fuzzy based PID controller to control the speed of separately excited DC motor. Actual work has been shown in below figure.

## 2 Modeling of a Photovoltaic Cell:

For better results optimize the performance of the photovoltaic (PV) module, we have to analyse the behaviour of its I-V characteristic by simulation of the equivalent circuit of solar cell shown in Figure 2 [2].

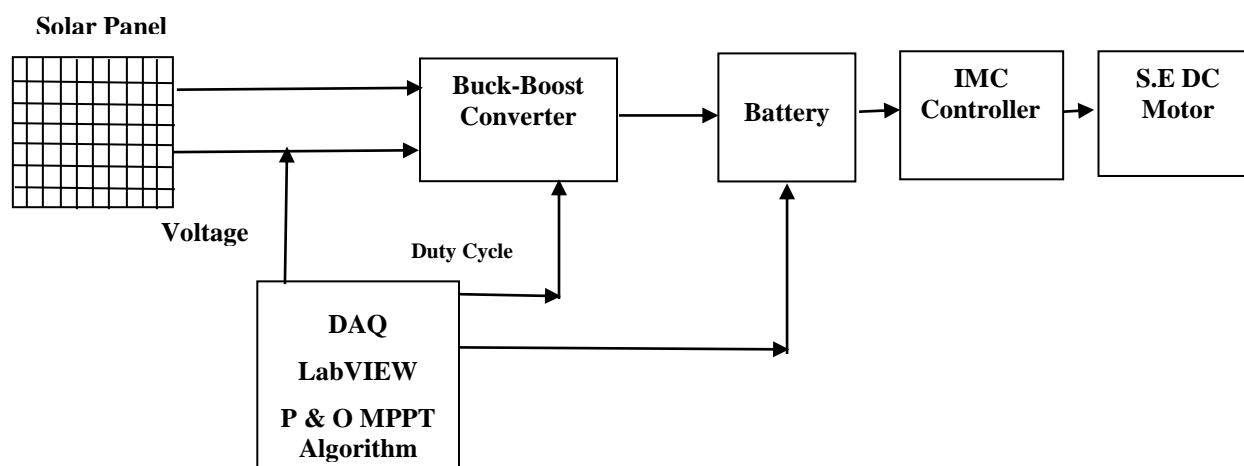


Figure 1: Block diagram for proposed work.

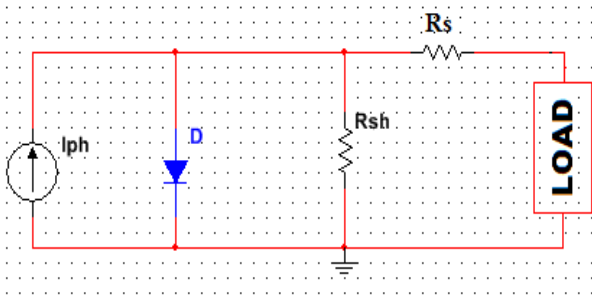


Figure 2: One diode circuit model of PV cell.

One diode model has been illustrated for the modelling of PV panel due to its simplicity and precision in mathematical calculation. The voltage versus current characteristic equation of a solar cell has been provided as follow:

Photo Current  $I_{ph}$ :

$$I_{ph} = [I_{sc} + K_i(T - 298)] \times \frac{G}{1000} \quad (1)$$

Here

- $I_{ph}$  : Photo current (A)
- $I_{sc}$  : Short circuit current (A)
- $K_i$  : Short circuit current constant of cell at 25 °C and 1000 W/m<sup>2</sup>
- T : Operating temperature (K)
- G : Solar irradiation (W/m<sup>2</sup>)
- $I_{rs}$  : Model reverse saturation current:

$$I_{rs} = \frac{I_{sc}}{[\exp(\frac{q \times V_{oc}}{N_s \times k \times n \times T}) - 1]} \quad (2)$$

Here, q: Electron charge, =  $1.6 \times 10^{-19}C$ ;  $V_{oc}$ : Open circuit voltage (V);  $N_s$ : Number of cells connected in series; n: the ideality factor of the diode; k: Boltzmann's constant, =  $1.3805 \times 10^{-23} J/K$ .

The module saturation current  $I_0$  depends on cell temperature, which has been given by:

$$I_0 = I_{rs} \left[ \frac{T}{T_r} \right]^3 \exp \left[ \frac{q \times E_{g0}}{n \times k} \left( \frac{1}{T} - \frac{1}{T_r} \right) \right] \quad (3)$$

Here,  $T_r$ : nominal temperature = 298.15 K;  $E_{g0}$ : band gap energy of the semiconductor, = 1.1 eV the current output of PV module:  $I =$

$$N_p \times I_{ph} - N_p \times I_0 \times \left[ \exp \left( \frac{V + I \times R_s}{\frac{N_s}{n \times V_t}} \right) - 1 \right] - I_{sh} \quad (4)$$

With  $V_t = \frac{k \times T}{q}$  and  $I_{sh} = \frac{V \times \frac{N_p}{N_s} + I \times R_s}{R_{sh}}$

Here:  $N_p$ : number of PV modules connected in parallel;  $R_s$ : series resistance ( $\Omega$ );  $R_{sh}$ : shunt resistance ( $\Omega$ );  $V_t$ : diode thermal voltage (V).

$$V = N_s \times \left[ n \times V_t \times \log \left\{ \frac{I + I_{sh} - N_p \times I_{ph}}{N_p \times I_0} + 1 \right\} - \frac{I \times R_s}{N_p} \right] \quad (5)$$

### 3 Mathematical Model of S.E DC Motor:

DC motor has lots of desirable properties like reliability, durability, low cost, and low operation voltage, positive conversion coefficients between electrical and mechanical components. A differential equation for the equivalent circuit has been derived using Kirchoff's voltage law around the electrical loop [1] [10]. The control equivalent circuit of the DC motor using the armature voltage control method has been shown in Figure 3.

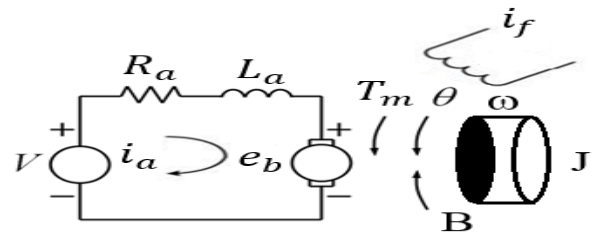


Figure 3: Equivalent circuit of DC motor.

- $R_a$  : Armature resistance
- $L_a$  : Armature inductance
- $i_a$  : Armature current
- $i_f$  : Field current
- V : Input voltage
- $e_b$  : Back electromotive force (EMF)
- $T_m$  : Motor torque
- $\omega$  : Angular velocity of rotor
- J : Rotating inertial measurement of motor bearing
- B : Damping coefficient

The transfer function [11] of DC motor speed with respect to the input voltage can be written as follows,

$$G(s) = \frac{\Omega(s)}{V(s)} = \frac{K_T}{(L_a s + R_a)(J s + B) + K_b K_T} \quad (6)$$

$$= \frac{0.028}{(4.47296 \times 10^{-6})s^2 + 3.1820410^{-5}s + 0.00078994}$$

### 4 IMC Controller Design

Internal model control principle (IMC) simply states that control can be achieved only if the control system encapsulates, either implicitly or explicitly, some representation of the process to be controlled [9] [6].

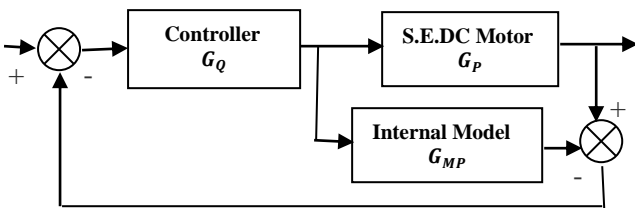


Figure 4: Structure of IMC.

The following steps are used in the IMC-based PID control system design

1. Find the IMC controller transfer function, \$G\_Q(s)\$ which includes a filter, \$G\_f(s)\$ to make \$G\_Q(s)\$ semi proper or to give it derivative action (order of the numerator of \$q(s)\$ is one order greater than the denominator of \$G\_Q(s)\$). Notice that this is a major difference from the IMC procedure. Here, in the IMC-based procedure, we may allow \$G\_Q(s)\$ to be improper, in order to find an equivalent PID controller.
2. Find the equivalent standard feedback controller using the transformation

$$G_C(s) = \frac{G_Q(s)}{1 - G_{MP}(s)G_Q(s)} \tag{7}$$

Write this in the form of a ratio between two polynomials.

3. Show this in PID form and find \$K\_C, \tau\_I, \tau\_D\$. Sometimes this procedure results in a PID controller cascaded with a lag term \$\tau\_f\$

$$G_C(s) = K_C \left[ \frac{\tau_I \tau_D s^2 + \tau_I s + 1}{\tau_I s} \right] \left[ \frac{1}{\tau_f s + 1} \right] \tag{8}$$

Perform closed-loop simulations for both the perfect model case and cases with model mismatch. Choose the desired value for \$\lambda\$ as a trade-off between performance and robustness.

### 5 Simulation Results:

LabVIEW block diagram model of the PV panel has been shown in Figure 7. PV panels are connected in series/parallel. Current (I) versus voltage (V) curves of the PV panel is depicted under different temperature level in Figure. Power (P) versus voltage (V) curves of the PV panel is depicted under different temperature level in Figure. Figure shows Power versus Voltage and Current versus Voltage curves of the PV array under different irradiance level.

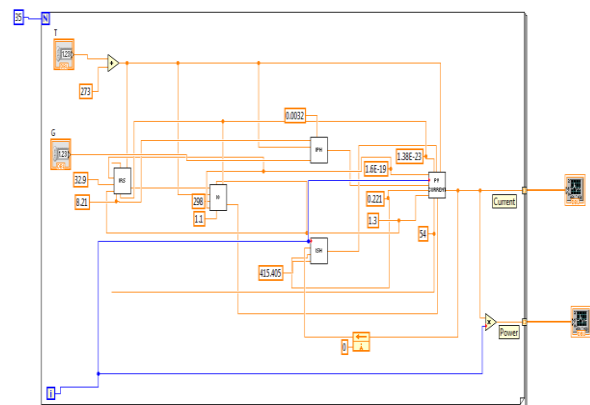


Figure 5: Block Diagram view of Solar PV module.

#### Impact of Temperature on I-V and P-V Characteristic of a Solar Panel

Temperature affects the voltage of solar cell and small effect on saturation current of solar cell because it has negative (-) temperature coefficient (for silicon \$-2.3\text{mV}/^\circ\text{C}\$), Figure 8 showing the I-V curve and P-V curve for different temperature variation.

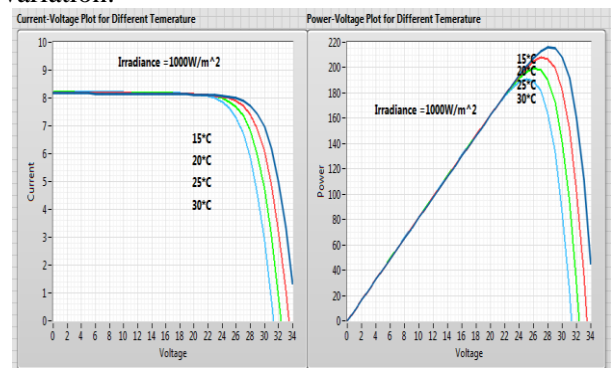


Figure 6: I-V and P-V curve under different temperature level.

As the temperature increases voltage decrease and maximum power decrease for a fixed irradiance level of \$1000\text{W}/\text{m}^2\$.

### Impact of Solar Irradiation on P-V and I-V Characteristic of a Solar Panel

Solar constant is 1361 W/m<sup>2</sup>, average annual solar radiation arriving at the top of the Earth's atmosphere. Sun's rays are attenuated by clouds and other atmosphere elements, leaving maximum normal surface irradiance at approximately 1000 W/m<sup>2</sup> at sea level on a clear day. If the solar irradiance is decreases due to rainy clouds, the earth movement or any other reason will reduce the output current of the solar panel because of the is directly proportional to the sun irradiance while the variation on voltage is much smaller as shown in Figure 9.

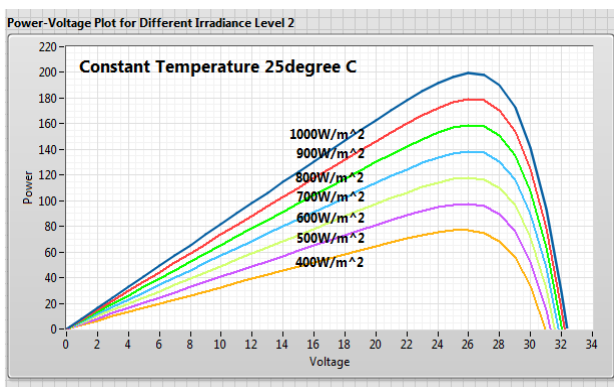


Figure 7: P-V curve under different irradiance level.

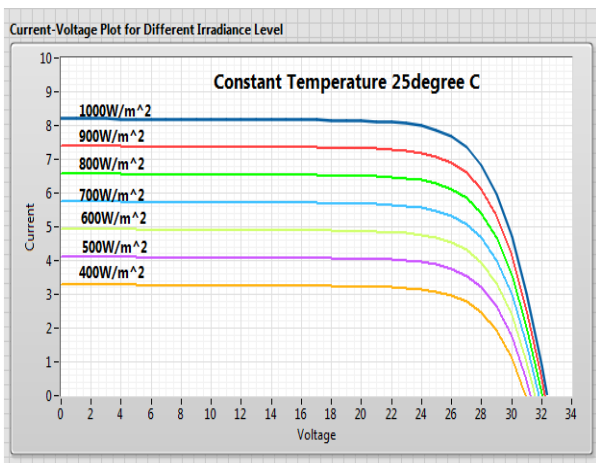


Figure 8: I-V curve under different irradiance level.

### P&O based MPPT algorithm

Perturb and Observe based MPPT algorithm in math script (LabVIEW) is shown in Figure 10. It provides variable duty cycle for buck and boost converter or fixed dc voltage for DC motor [4].

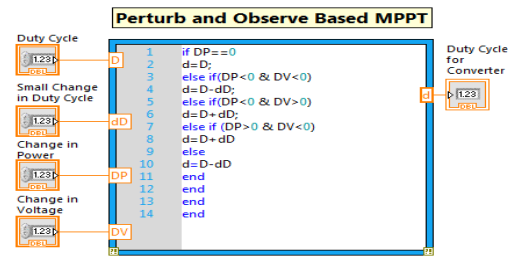


Figure 9: P&O algorithm based MPPT program.

Here A is the present duty cycle for Boost and Buck converter, B is the small change. DP and DV are the change in power and change in voltage respectively. Variations in duty cycle are shown in Figure 11.

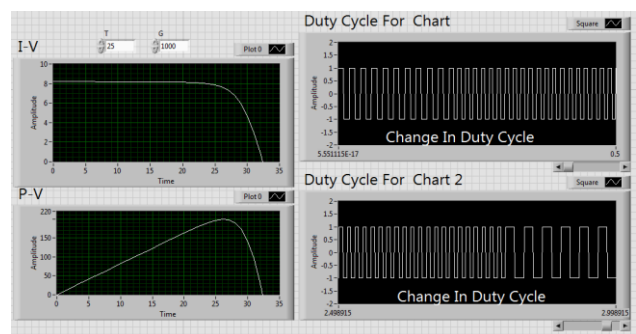


Figure 10: I-V and P-V Characteristics of PV module and Variable duty cycle based on MPPT.

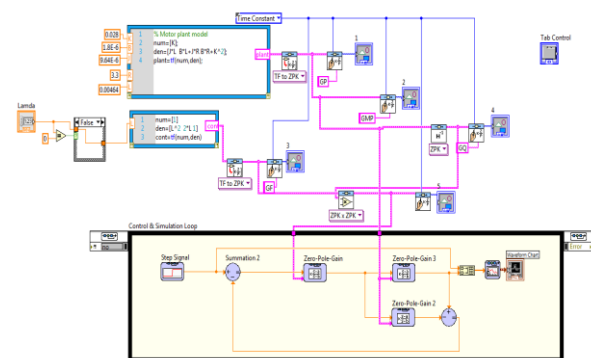


Figure 11: Block diagram representation of IMC method.

Unit step response of IMC for speed control of separately excited DC motor for different values of lambda (λ) are shown in

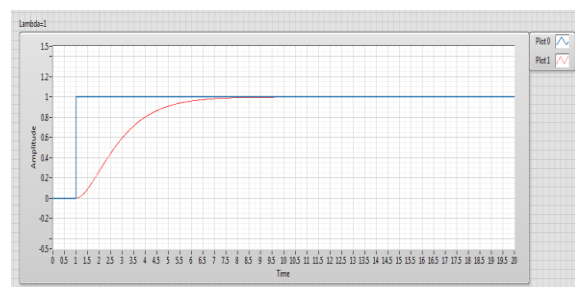
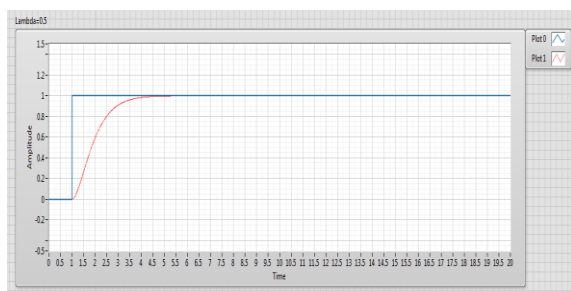
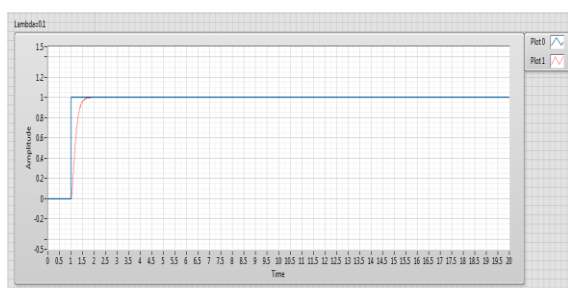


Figure 12: Unit step response of IMC (λ = 1).

Figure 13: Unit step response of IMC ( $\lambda = 0.5$ ).Fig.14: Unit step response of IMC ( $\lambda = 0.1$ ).

## 5 Conclusion

In this work, a simple but efficient solar energy based DC motor control system is presented. It provides theoretical studies of photovoltaics' (PV) and its modeling techniques in LabVIEW software. We have focused on the development of a stand-alone PV system. The individual system performance of PV system is studied through simulation for solar insolation and temperature. The duty cycle of boost converter is decided by P&O algorithm. In this study P&O based MPPT and IMC controller is used for optimum output from solar panel and DC motor. Low value of lambda results in better performance in IMC controller. Temperature and irradiance effect on solar output is simulated, shows that as temperature increases panel output decreases. Physical implementation of the system remains for future research.

### References:

- [1] M. M. Saied, "The Available Matching of Solar Arrays to dc Motors Having Both Constant and Series-Excited Field Components" IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 17, NO. 3, pp. 301-305, 2002.
- [2] M. Kolhe, J. C. Joshi, and D. P. Kothari, "Performance Analysis of a Directly Coupled Photovoltaic Water-Pumping System", IEEE Transactions on Energy Conversion, Vol. 19, No. 3, pp. 184-192, 2004.
- [3] H. Patel, V. Agarwal, "MATLAB-based modelling to study the effects of partial shading on PV array characteristics", IEEE Transactions on Energy Conversion 23 (2008) 302-310.
- [4] M. Azab, "A New Maximum Power Point Tracking for Photovoltaic Systems," in WASET.ORG, vol. 34, 2008, pp. 571-574.

- [5] N. Amin, L. Z. Yi and K. Sopian, "Microcontroller based smart charge controller for stand-alone solar photovoltaic power systems," Photovoltaic Specialists Conference (PVSC), 2009 34th IEEE, Philadelphia, PA, 2009, pp. 001094-001097.
- [6] Brian R Copeland, "Using the Lab-VIEW PID Control Toolkit with the LabVIEW Control Design and Simulation Module", Sep 2009.
- [7] Tat Luat Nguyen, Kay-Soon Low, "A Global Maximum Power Point Tracking Scheme Employing DIRECT Search Algorithm for Photovoltaic Systems," IEEE Transactions on Industrial Electronics, vol. 57, no. 10, pp. 3456-3467, Oct. 2010.
- [8] M. A. Elgendy, B. Zahawi and D. J. Atkinson, "Comparison of Directly Connected and Constant Voltage Controlled Photovoltaic Pumping Systems", IEEE Transactions on Sustainable Energy, Vol. 1, No. 3, pp. 184-192, 2010.
- [9] K.P Ramachandran "Control Engineering" Wiley Precise Textbook", 2011.
- [10] G. N. Reddy, D. G. Shekhar, S. Choudhari, and M. Ademola, "A Statistical Analysis Package for DC-DC Boost-Converter Design" IEEE, 2011.