International Journal on Future Revolution in Computer Science & Communication Engineering
Volume: 4 Issue: 1

ISSN: 2454-4248
57 – 60

Comperative study of current drawn by DC Motor used in Sun Tracking structure operated by 24Volt PV solar cells/24V-DC battery

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Abstract— This paper introduces an approach to Model a DC Motor directly connected to 24 Volt PV cells supply used for solar tracking PV system and also represent the comparative analysis of the transient performances of series wound dc motor with a 24 Volt PV cells supply and a 24 Volt DC supply Using SIMULINK.The analysis carried-out and the results obtained can be very useful in the study of the SWDCs dynamics, controllability, observability, and stability. It's also plays an important role in designing the solar tracking system. A commonly used solar array model is linear and combination of a simple current source and resistances.

Keywords— - *D.C. motor, transient, stability, SIMULINK, modeling, photo voltaic system.*

NOMENCLATURE.

I_{ds}	Diode saturation current.
I_{ph}	Photon current.
T_{actual}	Actual Temperature in K.
T	Nominal Temperature in K.
G_0	Solar radiation on the solar cell in W/m^2.
G	Nominal solar radiation in W/m^2.
K_c	Current/temperature coefficient.
I_{dst}	Temperature dependent diode saturation current.

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I. INTRODUCTION

Extracting useable electricity from the sun was made possible by the discovery of the photoelectric mechanism via a semiconductor device which converts photon energy into electrical energy. The amount of installed megawatts of solar arrays rapidly grows; while the panel price decreases Solar energy is the least polluting and the most inexhaustible of all known energy sources. Solar cell produces the solar power changes according to change in solar radiation and temperature [1].As irradiation and temperature level changes rapidly; the voltage produced fluctuates and become inconstant. There are three ways to increase the efficiency of a solar photovoltaic system [2].The first is to increase the efficiency of the solar cell. The second is to increase the efficiency of a PV system is to employ a solar panel tracking system. In this process we are normally used series wound DC motor (SWDC). Their torque/speed characteristics can be varied over a wide range, while the machine maintains its efficiency without sacrificing its speed as in the case of induction motors [7].

II. PHOTOVOLTAIC CELL MODEL.

This section starts with the modeling concepts of single diode PV cell without emphasis given on physics of how to pv cell transforms the solar photon into electrical power. The standard PV cell equivalent circuit diagram shown in Fig.1, diode is connected in parallel to current source, the photon energy incident on the PV cell generate current. This current is directly proportional to the amount of photon energy incident on PV cell. A more accurate model can be represented by inclusion of the following.

- Internal losses represented by series resistance R_s.
- Considering leakage current represented by R_{sh}.
- Effect of temperature on diode saturation currentI_{ds}.
- Temperature dependence of the photon current, I_{ph}.
- Diode quality factor β.

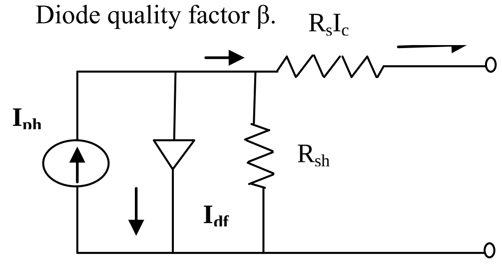

Figure 1: Equivalent circuit of a PV cell

Applying KCL to the model circuit:

$$I_{ph} - I_{ds} - \frac{V_d}{R_s} - I_c = 0 \quad (1)$$

$$I_c = I_{ph} - I_{df} \quad (2)$$

Diode forward biased current.

$$I_{df} = I_{ds}[\exp\left(\frac{qV}{\beta kT}\right) - 1] \quad (3)$$

Now considering effect of R_s and R_{sh} of each PV cell thus the above equation is expressed as:

$$I_c = I_{ph}N_p - I_{ds}N_p[\exp\left(\frac{qV + I_cR_s}{\beta V_t}\right) - 1] - \frac{V + I_cR_s}{R_{sh}} \quad (4)$$

Where V_t= kT, N_p= Number of PV cells connected in parallel.

I_{ph}photon current also depends on temperature, now considering the effect of temperature.

$$I_{ph}(T) = \left[I_{ph}(T_0) + K_I\Delta T\right]\frac{G_0}{G} \quad (5)$$

$\Delta T = T_0 - T.$

The temperature dependence of diode saturation current I_{dst} can be expressed as:

$$I_{dst} = I_{ds}\left(\frac{T}{T_0}\right)^3 \exp\left[\frac{qE_g}{\beta k}\left(\frac{1}{T} - \frac{1}{T_0}\right)\right] \quad (6)$$

III. Series wound dc motor mathematical model.

In a series wound dc motor the armature current flowing is same as the field current due to connection of field winding in series with armature winding. Normally, to derive a SWDC motor, we apply input voltage V_{in} to the motor, making it to rotate at an angular velocity of w_m rad/sec.

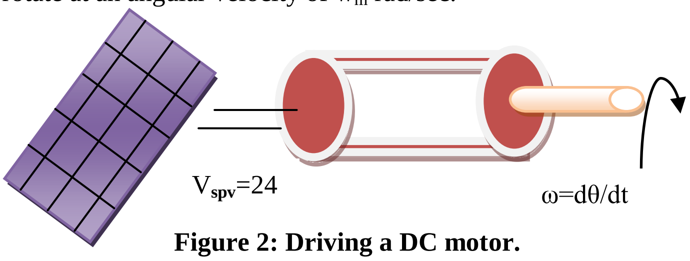

Figure 2: Driving a DC motor.

A mathematical model is a theoretical way of describing how a system behave i.e. indicating how a system behaves at specific time, its behavior depends on the kind of input to a system and system parameters.

With the help of mechanical model we can describe the relationship between various torques and resulting motion. Torque equations are:

$$\frac{d^2\theta}{dt^2} = \frac{1}{J}\left(k_t i - \kappa\frac{d\theta}{dt}\right) \quad (7)$$

Where: T = torque (Nm), J = Moment of Inertia(Kg.m^2/s^2), κ = Damping coefficient of the mechanical system (Nms), K_t = Electromotive force constant (Nm/A).

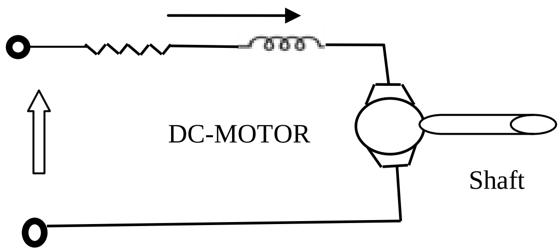

Figure 3: Equivalent Circuit model.

From figure: 3. Equivalent Electrical Circuit model,

$$\frac{di}{dt} = \frac{1}{L}\left(-iR + V_{in} - K_e\frac{d\theta}{dt}\right) \quad (8)$$

Now the dynamic equations of motor for transient behavior analysis [8]:

$$\dot{i}_a = \frac{V_a}{(L_a + L_f)} - \frac{(R_a + R_f)}{(L_a + L_f)}i_a - \frac{K_b w_m}{(L_a + L_f)}i_a \quad (9)$$

$$\dot{w}_m = \frac{1}{J}(T_e - \kappa w_m - T_l) \quad (10)$$

The speed of series D.C. motors is inversely proportional to load,at zero armature current the speed of SWDC motor will theoretically become infinity [4].

IV. SPECIFICATION

Table 1: Specifications of Series wound DC motor.

R_a	1 Ohm
L_a	0.05 H
R_f	0.0260 Ohm
L_f	0.160 H
J	0.01 Kg-m^2/s^2
B	1.74e-4 Nms^2
T_L	2.4930 Nm
K_b	0.01 Nm/A^2
V_a=V_f	24 Volt

Table 2: Specifications of Solar Photovoltaic Modules

Configuration	Single Glass Laminated Type With 72 Cells (12 × 6) In Series
Overall Size	1595 (±3) × 790 (± 2) × 50 (±1) MM
Weight	15 Kg. (Typical)
Module Frame	Anodized Aluminum
Typical Electrical Characteristics of L24150 type module (170 Wp)	
Open Circuit Voltage (V_{oc})	42.0 V
Short Circuit Current (I_{sc})	4.86 A
Operating Voltage	35 V
Max Power Output	170.0 W±3%

V. STATE SPACE REPRESENTATION FOR TRANSIENT PERFORMANCE.

With the help of linear differential equations we can represent the state space of an n^{th} order system [6] is;

$$Y = CX + DU \quad (11)$$

$$\dot{X} = AX + BU \quad (12)$$

Using load torque (T_l) as input and electromechanical speed (ω_m) as output, the state space representations of the SPV supply Series Wound DC model are realized as shown below. Where: X =State variable vector, U = Input vector, A = Coefficient matrix or System matrix, B = Input or Control or Driving matrix, Y = Output vector, C = Output matrix, D = Transmission matrix.

Stability Studies:

A system is said to be stable if the real parts of the eigen-values are all negative. For a system represented in state space, the eigenvalues are determined in MATLAB® as eig(A). The eigenvalues are determined for the SP-SWDC Models as shown below.

SP_Series D.C. Motor eig(A)=1.0e+003 *[-1.0000, -1.0000, -0.0002]

It can be seen that all the eigenvalues have negative real parts; this systems is, therefore, stable.

VI. SIMULATION RESULTS AND DISCUSSION

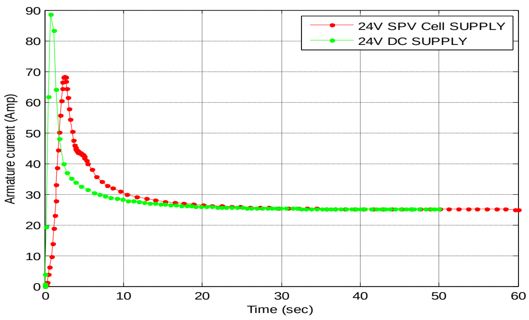

Figure 4: Armature current Vs time (sec).

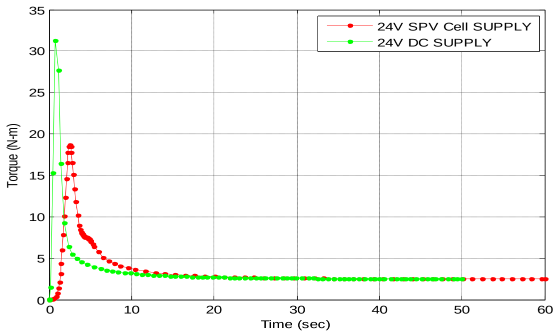

Figure 5: Electromagnetic Torque Vs time (sec).

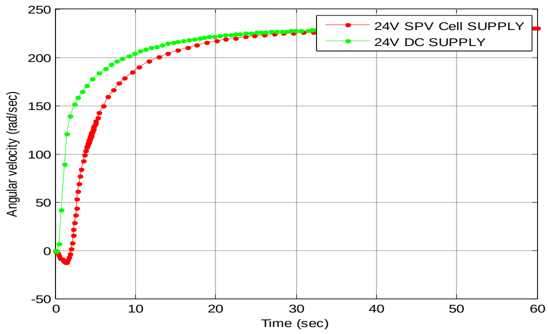

Figure 6: Angular velocity Vs time (sec).

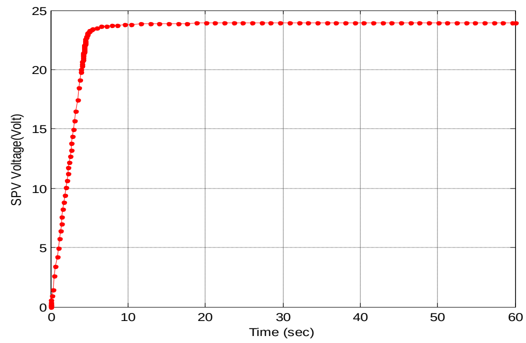

Figure 7: SPV Voltage Vs time (sec)

Simulation results shows that variation in the characteristics of SWDC Motor with respect to time operated by 24Volt PV solar cells/DC battery is due to variation in PV voltage as shown in figure 7. While designing the tracking system, dc motor should be connected to PV solar cells rather than battery for the safe operation of tracking system, gives the better results and also economical point of view.

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