Simulation And Analysis Of Smart Solar Tunnel Dryer

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Abstract- **The PV model of the solar cell is designed and developed using Matlab/Simulink. Simplified analytic formulae are derived that describes the four-parameter model. The characteristics of the PV model are obtained by simulation, which is useful for analysis and MPPT algorithmic simulations. This simulation consists of PV module comprising of cells in series and parallel alignment array of cells that are apt for testing on the MPPT based algorithms. This is applied for PV characteristics and MPPT tracking of applications using solar cells. Additional converter circuit is implemented for working of mechanical and electrical devices implemented within the main set-up. A boost converter used for this purpose. Additionally a field controlled dc motor is used for speed controlling.**

Index Terms: **Armature controlled DC motor, auxiliary heating coil, boost converter, controlled blowers, humidity sensor, solar collector, temperature sensor.**

I. INTRODUCTION

Renewable energy has become the need of the hour owing to its non-polluting, eco-friendly and sustainable characteristics. Solar energy is the most abundant and easy to harvest form of renewable energy. Solar panels are used in electrical devices working under solar power and the PV system model is the most suitable and efficient form of design in use. The characteristics obtained by PV analysis help to determine the output of the system under consideration. Various advanced tools and software have been developed for simulation purposes, with the help of component blocks, mainly electronic components.Matlab / Simulink software are mainly used for the implementation of simulation.SimPowerSystem tool is utilised for this modelling. The simulation result provides the relationship between the terminal voltage and current. The parameters of solar cell can change over time. Hence, certain relations between them have to be developed to analyse accurately. This paper consists of PV cell modelling for the solar panel and MPPT characteristics. Converter section is implemented to this to support the working of the Smart Solar Tunnel Dryer. This is an environment-friendly, innovative model of the conventional dryer developed to work using solar energy. The biggest advantage of the proposed model is that it is affordable on the long run, promotes sustainable development and is user-friendly, and thus can be adaptive in industrial as well as domestic applications, both in rural and urban areas. Since it does not depend on the availability of electric power supply, it is not affected by weak or absence of supply. Thus the Smart solar tunnel dryer would turn out to be a boon to the society, in agricultural and food industries.

II. MATHEMATICAL MODELLING

The mathematical modelling and study of PV module has been done in the past using characteristics relations connecting the parameters involved. These parameters are the output voltage and current. These studies are then applied for higher techniques involving Maximum Power Point Tracking (MPPT). Circuits are generated from the relations of the parameters. From the circuits, further equivalent circuits are developed for easy analysis. The equivalent circuit of a general PV Model that is commonly accepted consists of photocurrent, Diode, Parallel resistor for expressing leakage current and series resistor. The equivalent circuit of the PV cell is shown below in Fig. 1. The relationship between output current and terminal voltage of the solar cell is given as,

$$I = I_{Ph} - I_S \left[\exp\left(\frac{q\,(V+IRs)}{KTcA}\right) - 1\right] - \frac{V+IRs}{Rsh} \qquad (1)$$

where, I_{ph} : Photo current
I_s : Dark current or Cell saturation current
q : Electron charge = 1.6×10^{-19}C
K : Boltzmann's constant = 1.38×10^{-23}J/K
Tc : Cell temperature
A : Ideal factor

R_{sh} : Shunt resistance
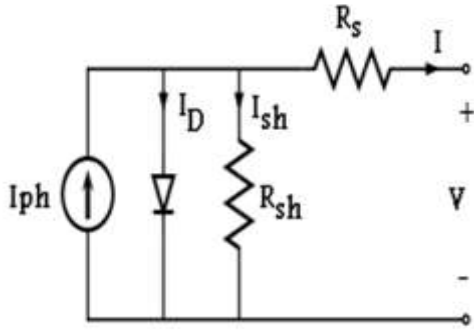R_s : series resistance

Fig. 1. Solar cell model

The photocurrent is a parameter that mainly depends on the intensity of solar energy and also the temperatureat which the cell is under working condition This can be described by the equation,

$$I_{ph} = [I_{sc} + K_1(T_c - T_{ref})] \, H \qquad (2)$$

where,I_{sc} : Cell short circuit current at 25^0C and $1kW/m^2$
K_1 : SC current temperature coefficient
T_{Ref} : Reference temperature
H : Solar insolation in kW/m^2

Cell saturation current is another parameter that also depends on the cell working temperature, and varies as the latter also varies. It is described the equation, given by

$$I_s = I_{Rs} \left(\frac{T_c}{T_{ref}}\right)^3 \exp\left[\frac{qE_g \ (T_c - T_{ref})}{T_{ref} \ T_c \ k \ A}\right] \qquad (3)$$

where, I_{Rs} : cell's reverse saturation current at reference temperature and the cell's incident solar radiation
E_g : band gap energy of the semiconductor used.
A : the ideal factor dependent on PV technology

A PV array can be described simply as an array of group of several PV cells. They are electrically connected by the help of parallel and series circuits. The equivalent circuit of a solar module is shown below in Fig. 2. In this figure, it can be understood that Np denotes the number of parallel circuits and Ns denotes the number of series circuits, that are connected as a group. This arrangement is provided so as to obtain the required current and voltage levels as specified.
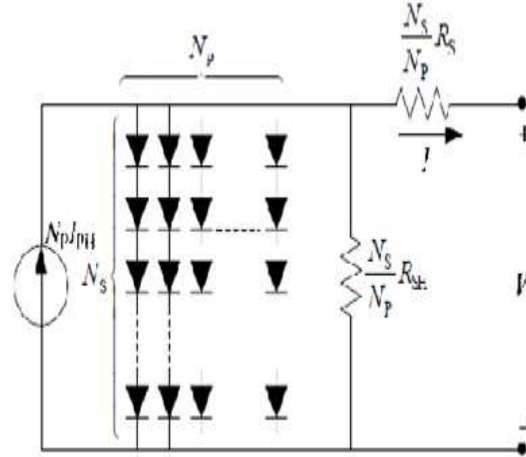

Fig. 2 Equivalent circuit of solar array

From this, the equation connecting the terminal voltage and current can be developed as,

$$I = N_p I_{ph} - N_p I_s \left[\exp\left(\frac{q(V + IRsm)}{NsKTcA}\right) - 1\right] \qquad (4)$$

Where , $R_{sm} = \frac{NsRs}{Np}$

The simpified circuit of the above circuit of array can be obtained by neglecting the shunt resistance.

III. SIMULATION OF PV MODEL USING MATLAB

The PV model built using matlab/Simulink according to the above equations. The unknown values of this model can be obtained from the known values. The proposed model is shown below.
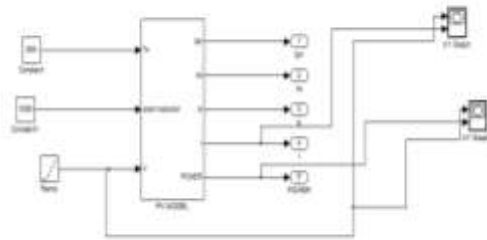

Fig.4PV simulation.

The specifications of the simulating model are given in the table. These are specifications used in this modeling.

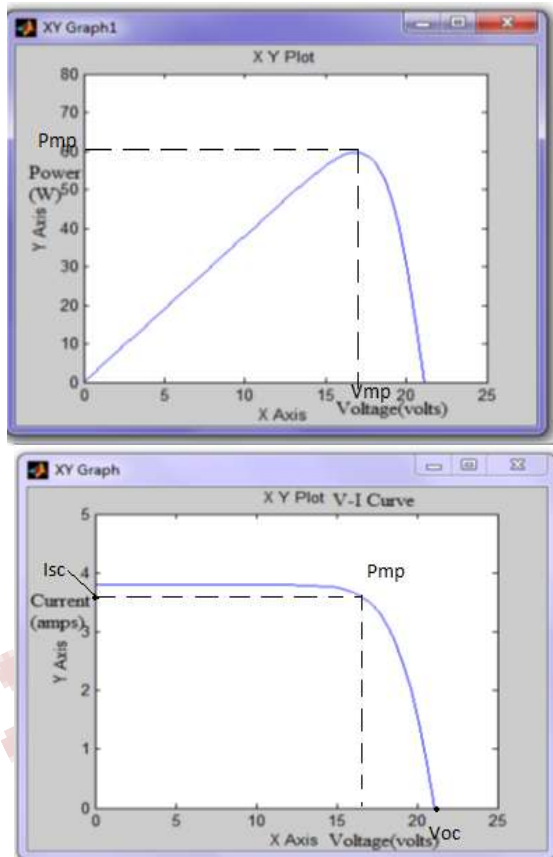| Characteristics	Specifications
Open circuit voltage	21.1 V
Short circuit current	3.8 A
Current at peak power	3.5 A
Voltage at peak power	17.1 V
Temperature coefficient of sc voltage	0.003A/^{0}C

Table 1. Specifications

Fig.6 I-V and P-V characteristics of PV model

The output current and power depends the cell temperature Tc and terminal voltage of the cell V. The open circuit voltage logarithmically depend the solar irradiance. Also short circuit current proportional to the intensity of solar irradiance.

IV. MPPT SIMULATION

MPPT (Maximum Power Point Tracking) is the algorithm used for extracting maximum power available from the PV module. The voltage at which the PV module can produce max power is called peak power voltage. The value of maximum power varies depending upon solar irradiation,ambient temperature and cell temperature. MPPT can optimize the power going to this circuit.

Solar cells have a complex relationship between temperature and total resistance that produces a non linear output efficiency which can be analysed based on the I-V curve. It is the purpose of the MPPT system to sample the output of the PV cells and apply the proper resistance/load to obtain maximum power for any given environmental condition. Commonly used MPPT algorithms are Perturbation and Observation (P&O), incremental conductance and fractional open circuit voltage. Here we use P&O algorithm.

This algorithm perturbs the operating voltage to ensure maximum power. While there are several advanced and more optimized variants of this algorithm, a basic P&O MPPT algorithm is shown below:
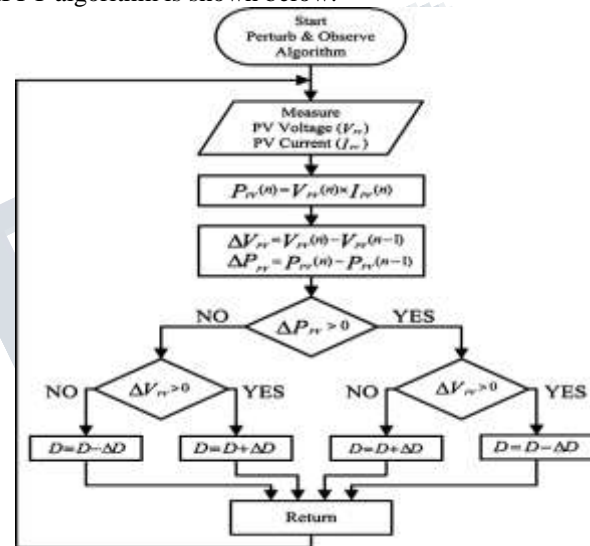
V. BOOST CONVERTER

A boost converter is a DC to DC step up converter. The output voltage of the boost converter is greater than the input voltage. Hence we call it as a step up converter. This name comes from analogous with the principle of step up transformer. The principle of operation of boost converter can be given as follows. Any sudden change in the input current to the circuit will be resisted by the inductor present in the input. Inductor acts as a storage of energy during the closed condition of the switch and discharges it during the open stage
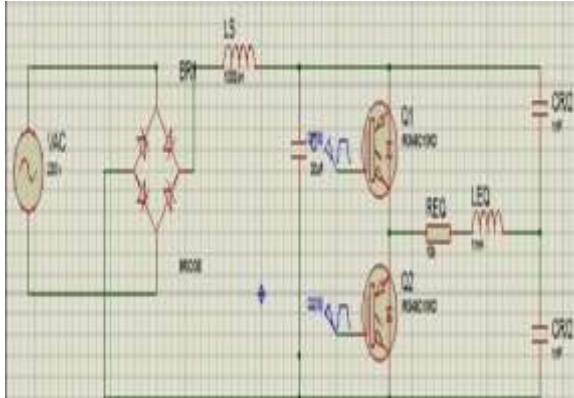
Fig 8. Boost converter simulation in diptrace

VI.   ARMATURE-CONTROLLED DC MOTOR SIMULATION

The armature-controlled DC Motor is used for monitoring and controlling the speed of the blower that is implemented in the Solar tunnel dryer. The speed of the DC motor is directly proportional to the armature and inversely proportional to the flux in
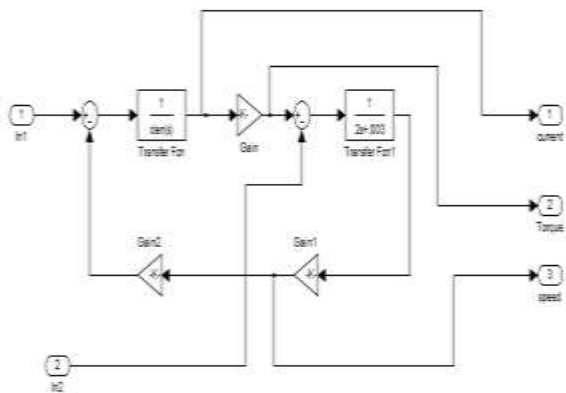

Fig. 9 Simulation of Armature-controlled DC motor speed control

field winding. Desired speed is obtained by varying the armature voltage. The transfer function of the armature-controlled DC motor is governed by 4 equations:

$$i_a Ra + La\frac{dia}{dt} + e_b = va \qquad (5)$$

$$T = K_t i_a \qquad (6)$$

$$Eb = K_b\frac{d\theta}{dt} \qquad (7)$$

$$J\,(d^2\theta\,/\,dt^2) + B\,(d\theta\,/\,dt) = T \qquad (8)$$

Where ,
i_a: Armature current
Ra : Armature resistance
La : Armature inductance
e_b : Back emf
va : Armature voltage
T : Torque

These standard equations are equated together so as to obtain the overall transfer function of the armature controlled DC motor. It can be described as follows:

$$\frac{\theta(s)}{Va(s)} = \frac{Kt}{(Ra+sLa)(Js^2+Bs)+Kb\,Kt\,s} \qquad (10)$$

The simulation of this model is obtained as in Fig. 9.

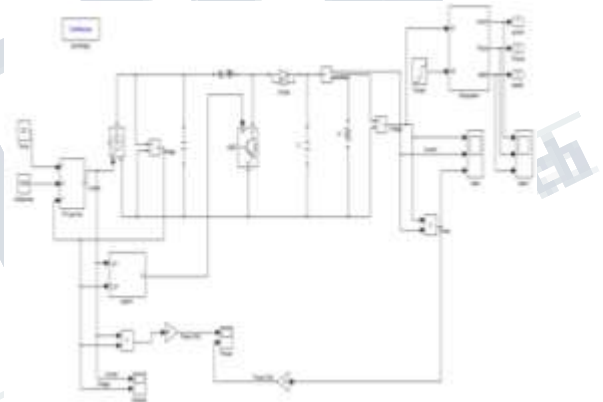## VII.   OVERALL SIMULATION OF SMART SOLAR TUNNEL DRYER

Fig. 10 Overall Simulation in Matlab/ Simulink

VIII.   CONCLUSION

The PV Model has been designed and developed. It is tested and compared with available module. The entire modelling and simulation was carried out using Matlab/Simulink. This simulation is applicable for analysis of the PV parameters and also for MPPT technologies. The final simulation also implements the speed control of DC motor using armature controlled method. This DC motor is used for driving and control function of the blower implemented in the solar tunnel dryer model.

REFERENCES

The overall simulation of the Smart solar tunnel dryer comprises of PV modelling, MPPT technology, Boost converter and armature controlled DC motor control. It is obtained as shown in Fig. 10.

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