Development of 1000W, 230volt Solar Photovoltaic Power Electronic Conversion System

Deepali Sharma, Uphar Tandon, Nitin Saxena

ABSTRACT: This paper defines a Mathematical Modelling of the system having PV cell, Chopper and Inverter in order to estimate the electrical behaviour of the cell with respect to changes on environment parameter of temperature and irradiance and thereby an accurate Electrical model was implemented on MATLAB script file and accepts irradiance and temperature as variable parameter and outputs I-V characteristics. Therefore Particular number of modules and boost chopper with single phase series inverter was used to achieve 1000 watt with 230.

KEYWORDS: Boost Chopper, Distributed Generators, Photovoltaic module, Series inverter MATLAB.

I. INTRODUCTION

Renewable energy resources will be an increasingly important part of power generation in the new millennium. Besides assisting in the reduction of the emission of green house gases, they add the much needed flexibility to the energy resource mix by decreasing the dependence on fossil fuels. In other hand, deregulation of the electric utility industry is providing an opportunity for higher penetration and use of distributed resources (DR). Distributed resources are generation sources that can be located at or near loads. Distributed resources can provide benefits that bulk power generation cannot. PV systems are ideally suited for distributed resource applications. The ever increasing energy demand, along with the necessity of cost reduction and the reliability requirements, are driving the modern power systems towards distributed generation (DG) as an alternative to the expansion of the current energy distribution systems. In particular, small DG systems, typically with power levels ranging from 1KW to 10MW, located near the loads are gaining popularity due to their higher operating efficiencies. Fuel cells (FCs), photovoltaic cells (PVs), Batteries, micro-turbines, etc. are now days the most available DGs for generation of power mostly in peak times or in rural areas. Photovoltaic (PV) systems produce DC electricity when sunlight shines on the PV array, without any emissions then that power increased to a useful amount through a Boost chopper that controls the DC Voltage across the capacitor to achieve the maximum power from the PV based on the load or ambient condition changes after that DC power is converted to AC power with an inverter and can be used to power local loads or fed back to the utility.

II. PV Generator

A photovoltaic PV generator is the whole assembly of solar cells, connections, protective parts, supports etc. In the present modelling, the focus is only on cell/module/array. Solar cells consist of a p-n junction fabricated in a thin wafer or layer of semiconductor (usually silicon). In the dark, the I-V output characteristic of a solar cell has an exponential characteristic similar to that of a diode. When solar energy (photons) hits the solar cell, with energy greater than band gap energy of the semiconductor, electrons are knocked loose from the atoms in the material, creating electron-hole pairs These carriers are swept apart under the influence of the internal electric fields of the PN junction and create a current proportional to the incident radiation. When the cell is short circuited, this current flow in the external circuit; when open circuited this current is shunted internally by the intrinsic p-n junction diode. The characteristics of this diode therefore set the open circuit voltage characteristics of the cell

III. MODELLING OF THE SOLAR CELL BOOST CHOPPER AND INVERTER:

A. PV module

Thus the simplest equivalent circuit of a solar cell is a current source in parallel with a diode. The output of the current source is directly proportional to the light falling on the cell (photocurrent I_{ph}). During darkness, the solar cell is not an active device; it works as a diode, i.e. a PN junction. It produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generates a current I_D, called diode (*D*) current or dark current. The diode determines the I-V characteristics of the cell.

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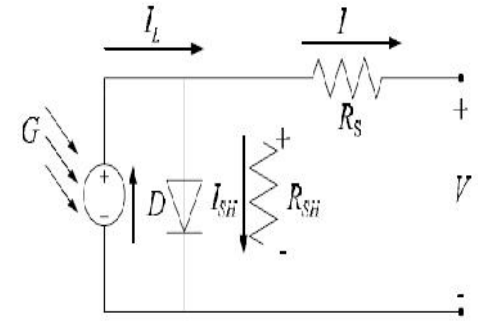

Fig.1. Circuit diagram of the PV model

Increasing sophistication, accuracy and complexity can be introduced to the model by adding in turn:

- Temperature dependence of the diode saturation current I_0.
- Temperature dependence of the photo current I_L.
- Series resistance *Rs* which gives a more accurate shape between the maximum power point and the open circuit voltage. This represents the internal losses due to the current flow.
- Shunt resistance R_{sh}, in parallel with the diode, this corresponds to the leakage current to the ground and it is commonly neglected
- Either allowing the diode quality factor *n* to become a variable parameter (instead of being fixed at either1 or 2) or introducing two parallel diodes with independently set saturation currents. In an ideal cell $R_s = R_{sh} = 0$, which is a relatively common assumption. For this paper, a model of moderate complexity was used. The net current of the cell is the difference of the photocurrent, I_L and the normal diode curent I_0:

$$I = I_L - I_o\left(e^{\frac{q(V+IRs)}{nkT}} - 1\right) \quad (1)$$

$$I_o[e^{\frac{q(V+IRs)}{nkT}} - 1] = I_L - I$$

$$e^{\left(\frac{q(V+IRs)}{nkT}\right)} = \frac{Il-I}{Io} + 1$$

$$q\frac{(V+IRs)}{nkT} = \log\left\{\left(\frac{Il-I}{Io}\right) + 1\right\}$$

$$V = \frac{nkT}{q}\log\left(\frac{Il-I+Io}{Io}\right) - IRs \quad (2)$$

B. Current-Voltage I-V Curve for a solar Cell

A typical I-V characteristic of the solar cell for a certain ambient irradiation *G* and a certain fixed cell temperature *T* is shown.

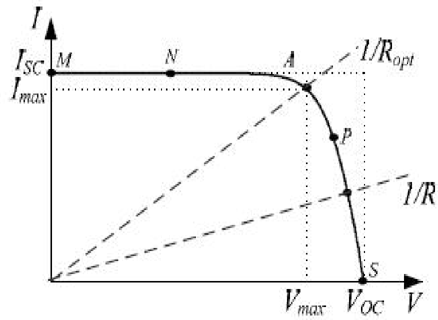

Fig 2. A typical current voltage I-V curve for a solar cell.

It should be pointed out that the power delivered to the load depends on the value of the resistance only However, if the load *R* is small, the cell operates in the region *M-N* of the curve (Fig 2), where the cell behave as a constant current source, almost equal to the short circuit current. On the other hand, if the load *R* is large, the cell operates on the regions *P-S* of the curve, the cell behaves more as a constant voltage source, almost equal to the open-circuit voltage. A real solar cell can be characterized by the following fundamental parameters, which are also sketched in Fig. 2.

- Short circuit current: $I_{sh} = I_{ph}$. It is the greatest value of the current generated by a cell. It is produce by the short circuit conditions: $V = 0$.
- Open circuit voltage correspond to the voltage drop across the diode (p-n junction), when it is transverse by the photocurrent I_{ph} (namely $I_L = I_{ph}$), namely when the generated currents is $I = 0$. It reflects the voltage of the cell in the night and it can be mathematically expressed as:

$$Vpv = \frac{AKTc}{e}\left(\frac{Iph+Io-Ic}{Io}\right) - RsIc \quad (2)$$

Where

A=Constant value for curve fitting

e=electron charge $1.602 \times 10^{-19}\,C$

k=Boltzmann constant $1.38 \times 10^{-23}\,J/K$

I_c=output current of PV cell

I_{ph}=Photocurrent (1A)

I_0=Diode reverse saturation current(0.2mA)

R_s=Series resistance of PV cell(1Ω)

V_{ph}=output voltage of PV cell

T_c=PV cell reference temperature25

- Maximum power point is the operating point *A* (V_{max}, I_{max}) in Fig 2, at which the power dissipated in the resistive load is maximum: $P_{max} = V_{max}I_{max}$. The open circuit voltage increases logarithmically with the ambient irradiation, while the short circuit current is a linear function of the ambient irradiation. The dominant effect with increasing cell's temperature is the linear decrease of the open circuit voltage, the cell being thus less efficient. The short circuit current slightly increases with the cell temperature.

C. Boost Chopper

A chopper is a static device which is used to obtain a variable dc voltage from a constant dc voltage source. A chopper is also known as dc-to-dc converter. The thyristor offers greater efficiency, faster response, lower maintenance, smaller size. Choppers are widely used in trolley cars, battery operated vehicles, traction motor control, control of large number of dc motors, etc. They are also used in regenerative braking of dc motors to return energy back to supply and also as dc voltage regulators. There are different configurations of chopper and boost chopper was chosen in this paper.

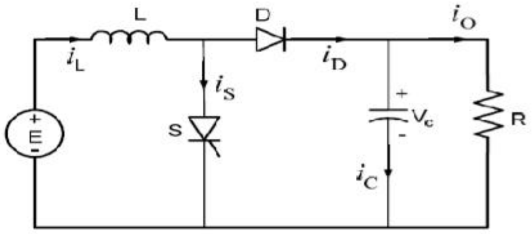

Fig 3: Boost Chopper

In the continuous current mode of chopper where the inductor current flows continuous

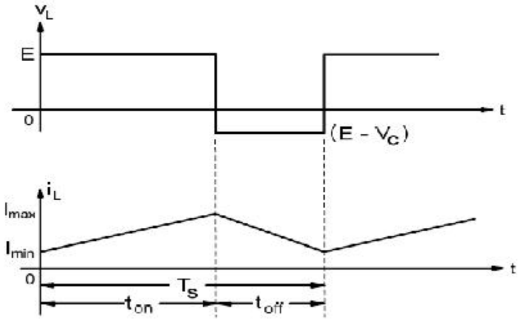

Fig 4: Steady-state waveforms of the boost chopper

During the time the switch thyristor S switch closed, the inductor current increases linearly

$$\frac{dI_L}{dt} = \frac{E}{L}$$

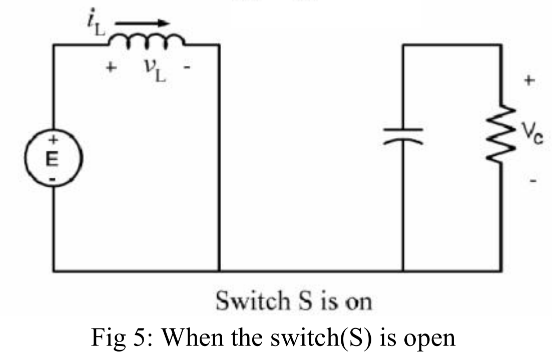

Fig 5: When the switch(S) is open

The inductor current decreases linearly and reaches to its minimum level Imin.

$$\frac{dI_L}{dt} = \frac{E - Vc}{L}$$

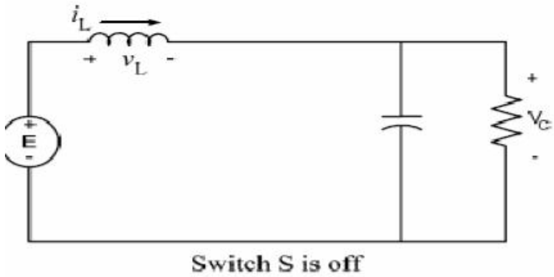

Fig 6: When the switch (S) is close

Now from Eqn (1) we can write

$$I_{max} - I_{min} = \frac{E}{L}T_{on}$$

$$\frac{E}{L}T_{on} = -\frac{E - V_c}{L}T_{off}$$

$$E\,T_{on} = -(E - V_c)T_{off}$$

$$V_c T_{off} = E(T_{off} + T_{on}$$

Express Ton as a fraction of the total period Ts.

$$T_{on} = KT_s$$

Therefore,

$$T_{off} = (1 - KT_s)$$

$$V_c T_{off} = E(T_{off} + T_{on})$$

$$V_c(1 - KT_s) = ET_s$$

$$V_c = \frac{E}{1 - K} \quad (3)$$

D. Single Phase Series Inverter:

Inverters in which commutating components are permanently connected in series with the load are called series inveter. The series circuit so formed must be underdamped as the current attains zero value due to the nature of the series circuit, series inverters are also classified as self commutated inverters or load commutated inverters. These inverters operate at high frequencies (200Hz to 100 KHz).the size of commutating components is, therefore, small. These inverters are used extensively in induction heating; fluorescent lighting etc.The PV generator output is converted to AC system through a single phase line commutated inverter in which the relation between DC voltage and AC line voltage is given by

$$V_s = \left(\frac{3\sqrt{2}V_{inv}}{\pi}\right)cos\beta$$

$$V_{inv} = \left(\frac{V_s \times \pi}{3\sqrt{2} \times cos\beta}\right) \quad (4)$$

Where
V_{inv} = output voltage of inverter
V_s= input voltage to inverter
β=firing angle(51°)
And inverter current equation is given by

$$I_{inv} = -\frac{V_C}{R} + \frac{V_C}{R}\left(2 - e^{-Rt_1/L}\right)e^{-Rt_2/L} \quad (5)$$

Where V_c= chopper output
t_1, t_2= operating time

IV. DESIGNING OF THE MODEL

The influence of the ambient irradiation *G* and the cell temperature *T* on the cell characteristics can be obtained from the model equations. The PV cell photocurrent *IL*(A) is directly proportional to solar irradiance *G*(W/m2). When the solar cell is short circuited, negligible current flows in the diode. Solar intensities are commonly normalized with respect to full solar radiation at sea level with average humidity and aerosol particulate concentration (1 Sun = 1000Watt/m2). Though somewhat contrary to intuition, PV cell performance does not degrade significantly between full sun and cloudy conditions. The power output decreases nearly lineally with incident solar energy, but efficiency is nearly flat over the region of concern. The relationship between the photo-current and temperature is linear and is deduced by noting the change of photo-current with the change of temperature (eqn.2). When the cell is not illuminated, the relationship between the cell's terminal voltage and current is given by the Shockley equation. When the cell is open circuited and illuminated, the photo-current flows entirely in the diode. The I-V curve is offset from the origin by the photo current. The value of the saturation current I_0 at 25°C is calculated. Then further the chopper output voltage (eqn.3) represents inductor L in series with the photovoltaic output voltage and depends on the duty cycle .As the voltage across the load exceeds the source voltage the circuit act as a boost chopper and the energy stored in array released to the load.

The PV generator output is converted to the AC system(eqn.4) through single phase line commutated inverter.

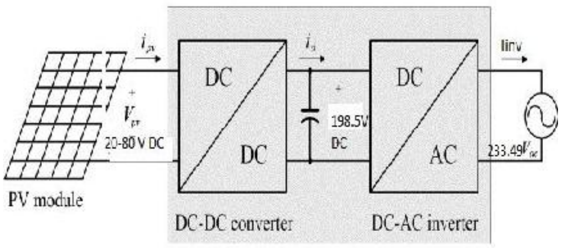

Fig.7: Equivalent circuit of the Model with calculated parameters

V. ALGORITHM

1) Execute eqn.2 where variable input parameter I_{ph}=1000mA, T_c=25□ to obtained output currnt of the cell.
2) Plot I-V curve for eqn.2
3) Select value of V& I of a cell at which maximum power is obtained.
4) Choose combination of cells required in a module.
5) Choose combination of number of modules in a panel so as to obtain the desired results.
6) Execute eqn.3 by considering the output voltage of cell as input to the chopper.
7) Execute eqn.4 considering output voltage of boost chopper as input to inverter.
8) Thus output voltage of inverter is obtained corresponding to input.
9) Execute eqn.5 to obtain inverter current.

Thus Electrical model was implemented using a MATLAB program. The model parameters are evaluated during execution using the equations listed on the previous section.

Table1: Technical Specifications

Number of cells in module	72(18*4)
Number of module	88(22*4)
Radiation level	1000mA
Ambient Temperature	25°C
Output voltage @PV	.2006V DC
Output current @PV	866.8669mA
Frequency	50Hz
Output voltage @chopper	198.5446V
Boost chopper parameter	L=0.07H R=35.80Ω
Duty cycle(K)	0.6
Output voltage @inverter	233.4961V AC
Output current @ inverter	5.55Amp
Maximum power	1101.535 W

VI. RESULTS OF MATLAB MODEL

The output of the MATLAB function is shown.

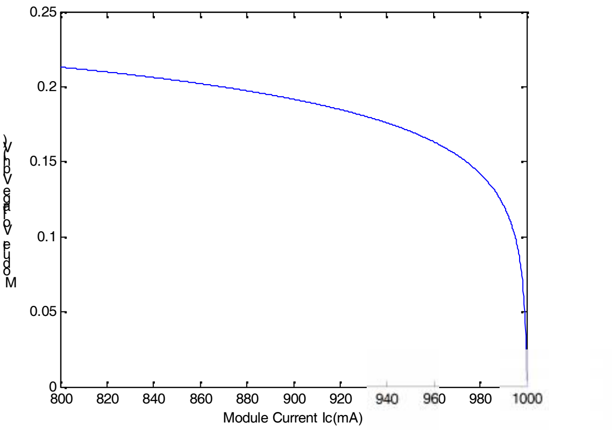

Fig 8: Matlab Model I-V curve for $(I_{ph} = 1000\,mA, T = 25$□$)$

A number of discrete values of voltage and current are obtained from the pv curve the value of voltage and current i.e. at a point where maximum power was obtained is chosen and the further those values used to obtain the inverter current waveform

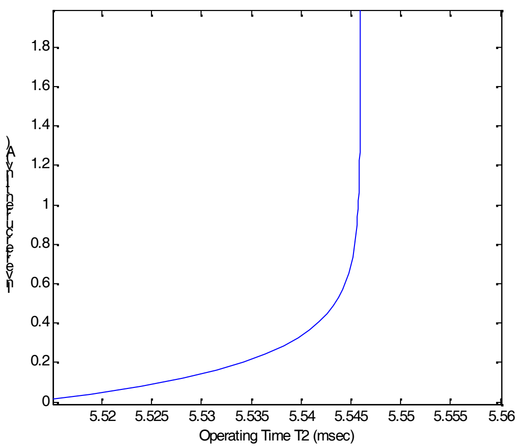

Fig 9: Inverter current versus time curve for various value of time

VII. CONCLUSION

An accurate electrical model is presented and demonstrated in MATLAB for a typical 1000watt solar panel. Given solar isolation and temperature, the model calculates the current for the given voltage. After being pass through a chopper and inverter 1000 watt and 230 volt is obtained. Hence the model development shows the effect of isolation, temperature ideality factor, series resistance and duty cycle on the results.

This paper is the basic to develop a complete solar photovoltaic power electronic conversion system in MATLAB, further by using different configurations of inverter better results could be obtain.

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