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Developing an Equivalent Circuit Model Based M-File for Solar Photovoltaic Applications

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ABSTRACT: Energy is one of the most fundamental parts of our universe. Sources for power generation range from conventional ones such as coal, lignite, natural gas, oil, hydro and nuclear power to other viable non-conventional sources such as wind, solar, tidal, biomass and thermal. The total demand in our country is around 2015 is 9,00,000 MW and the total power generated in India is 2,72,502.95 MW. Through that the renewable source can be used to faced the demand. In our country the renewable source can available in the wide area, but our country is not shows much interest on that. The process of generating power and energy in non conventional source is causing the great pollution and environmental problems in this world. The sources that we tap for getting the energy that we need are called the non renewable energy sources. These non renewable energy sources are those natural resources that we tap to generate electricity and energy and ones that cannot be replenished or recycled. Solar is the one in which we can consume huge power in India. The generation of power in solar is depend upon the climate. The average power generation in natural resources is 35776.96MW.The main aim of this paper is to develop a equivalent circuit model based M-File using MATLAB software for solar photovoltaic applications. Simulation results shows the effectiveness of the developed m file coding for the variations in temperature, irradiance, etc in achieving the maximum power output from the solar panel at all the times.

KEYWORDS: Photovoltaic, p-n junction diode, PV module characteristics.

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I. INTRODUCTION

The Sun is a nuclear reactor, 150 million km away. Only a small fraction of light energy and heat energy (1 part in 10^10) reaches the Earth, but it is a huge amount to the Earth. The sun is probably the most important source of renewable energy available today. Traditionally, the sun has provided energy for practically all living creatures on earth, through the process of photosynthesis, in which plants absorb solar radiation and convert it into stored energy for growth and development. The solar panels are only a part of a complete PV solar system. Solar modules are the heart of the system and are usually called the power generators. One must have also mounting structures to which PV modules are fixed and directed towards the sun. For PV systems that have to operate at night or during the period of bad weather the storage of energy is required, the batteries for electricity storage are needed. The output of a PV module depends on sunlight intensity and cell temperature; therefore components that condition the DC (direct current) output and deliver it to batteries, grid, and/or load are required for a smooth operation of the PV system. These components are referred to as charge regulators. For applications requiring AC (alternating current) the DC/AC inverters are implemented in PV systems. These additional components form that part of a PV system that is called balance of system (BOS). Finally, the household appliances, such as radio or TV set, lights and equipment being powered by the PV solar system are called electrical load.
Two main types of solar energy systems are in use today:

1. Photovolatics
2. Thermal Systems

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II. SOLAR PHOTOVOLTAIC SYSTEMS

Photovoltaic systems convert solar radiation to electricity via a variety of methods. A solar cell is a semi-conducting device made of silicon and/or other materials, which, when exposed to sunlight, generates electricity. Solar cells are connected in series and parallel combinations to form modules that provide the required power. Due to the low voltage generated in a PV cell (around 0.5V), several PV cells are connected in series (for high voltage) and in parallel (for high current) to form a PV module for desired output. The materials used in PV cells are as follows:

- Single-crystal silicon
- Polycrystalline silicon
- Gallium Arsenide (Ga As)
- Cadmium Telluride (Cd Te)

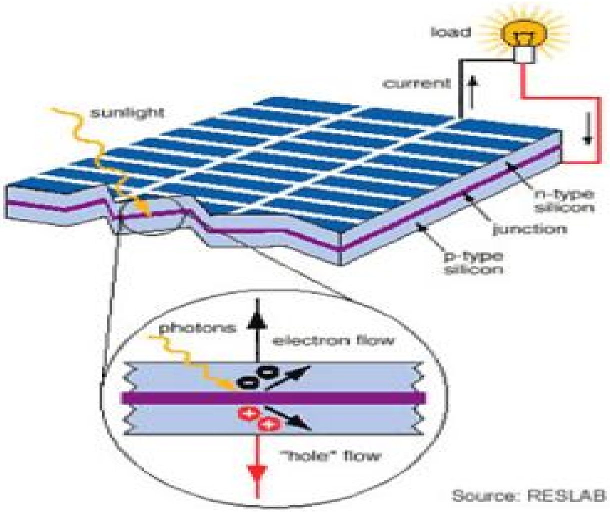

Fig. 1 Basic Operation of Solar Cell

III. STANDARD TEST CONDITIONS (STC)

The comparison between different photovoltaic cells can be done on the basis of their performance and characteristic curve. The parameters are always given in datasheet. The datasheet make available the notable parameter regarding the characteristics and performance of PV cells with respect to standard test condition.

Standard test conditions are as follows:

Temperature (T_n) = 250c
Irradiance (G_n) = 1000 w/m^2
Spectrum of x = 1.5 i.e. AM.

IV. ELECTRONIC STRUCTURE AND DOPING

Materials commonly used as semiconductors, such as Silicon, lies in the fourth column of the Periodic table of elements. The silicon crystal forms the so-called diamond lattice where each atom has four electrons at its outer layer, also called valence shell, which enables a pure crystal of material to form tight covalent bonds.

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V. P-N JUNCTION

The operation of solar cells is based on the formation of a p-n junction – formed by two different types of semiconductors. The important feature of the junction is they form a strong electric field due to diffusion. This electric field pulls the electrons and holes in opposite directions.

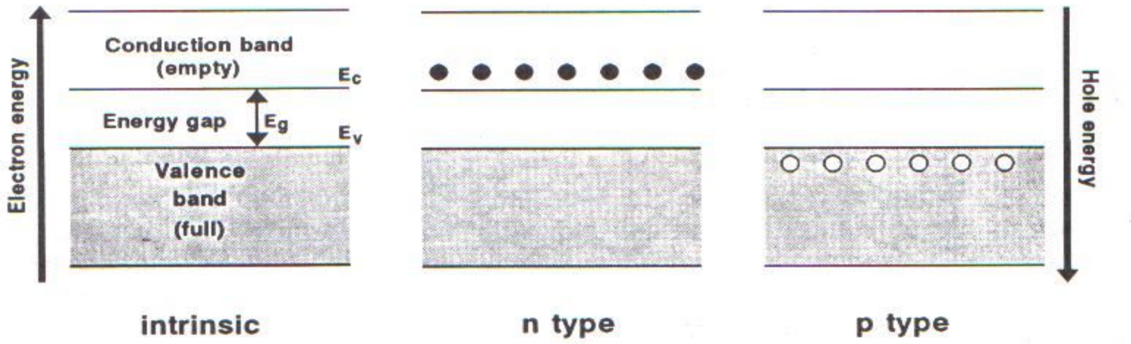

Fig. 2 p-n junction basics

A semiconductor p-n device can be switched on by irradiating the p-n junction with light rays and this is the basis of solar photovoltaic cell. The incident solar radiation passes through the p-type material into the junction. We perceive this as a flux of particles-photons-which carry the energy. Some of these photons-with energy excess of the band gap collide with the valence electrons of the silicon and are absorbed, releasing electrons to the conduction band and holes left behind in the valence band, the absorption process generates electron-hole pairs. If the silicon cell is electrically isolated on open circuit a direct EMF or voltage will appear across the terminals. If the cell has an external electrical circuit connected to its terminal then a direct current will flow.

A p-n junction photovoltaic cell performs two functions simultaneously: it harvests sunlight by converting photons to electric charges and it also conducts the charge carriers from where the charges can be collected as electrical current.

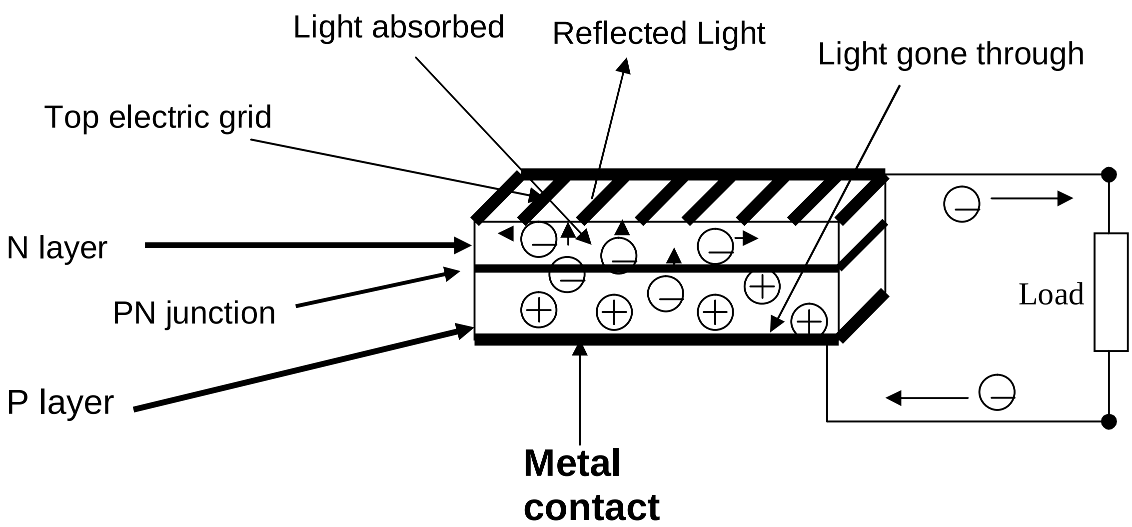

Fig. 3 Energy Conversion process in solar cells

The external characteristics of a solar cell are the property of current versus voltage. An ideal characteristic would be rectangular in shape. each different level of incident radiation results in a different characteristic. The intercept of a

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characteristic on the current axis represent zero voltage drop across the cell terminals and is the short circuit current I_{SC}, which is directly proportional to the incidental light intensity. The intercept of a characteristic on the voltage axis represents zero current and is the open-circuit voltage V_{OC} . Most cells operate with a working direct voltage level of less than 1 volt.

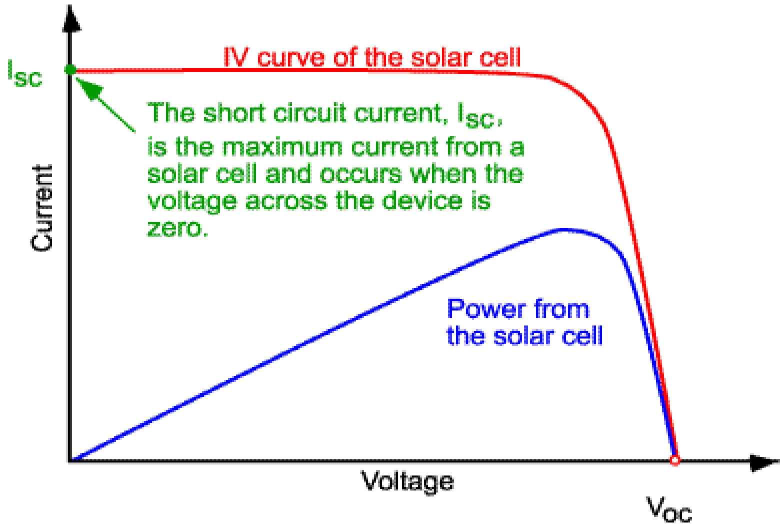

Fig. 4 Solar Cell – VI Characteristics

VI. EQUIVALENT CIRCUIT OF A PV CELL

An ideal is modelled by a current source in parallel with a diode. However no solar cell is ideal and thereby shunt and series resistances are added to the model as shown in the PV cell diagram above. R_S is the intrinsic series resistance whose value is very small. R_P is the equivalent shunt resistance which has a very high value.

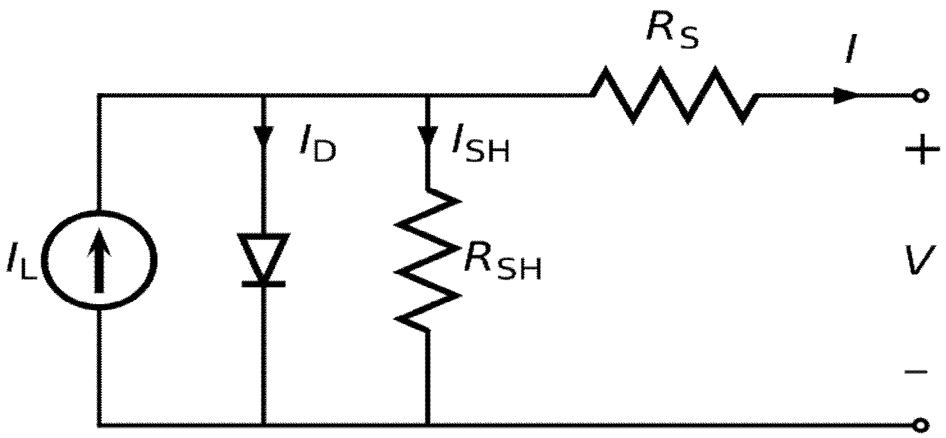

Fig. 5 Single diode model – Equivalent circuit of a solar cell

Applying Kirchoff's law to the node where I_{ph}, diode, R_p and R_s meet, we get

$$Iph = ID + IRp + I$$

We get the following equation for the photovoltaic current:

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$$I = Iph - IRp - ID$$

$$I = Iph - Io.[exp(V + I.Rs/VT) - 1] - [(V + I.Rs/Rp]$$

Where, I_{ph} is the Insolation current, I is the Cell current, I_0 is the Reverse saturation current, V is the Cell voltage, R_s is the Series resistance, R_p is the Parallel resistance, V_T is the Thermal voltage, K is the Boltzmann's constant, T is the Temperature in Kelvin, q is the Charge of an electron.

VII. SIMULATION RESULTS

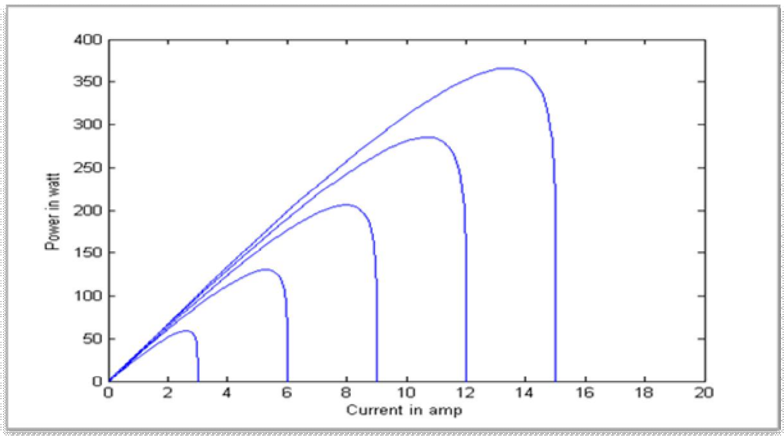

Fig.6 I-V Characteristics of solar cell under different irradiances

The characteristic I-V curve tells that there are two regions in the curve: one is the current source region and another is the voltage source region. In the voltage source region (in the right side of the curve), the internal impedance is low and in the current source region (in the left side of the curve),the impedance is high. Irradiance temperature plays an important role in predicting the I-V characteristic, and effects of both factors have to be considered while designing the PV system. Figure1 shows the I-V characteristics of pv module.

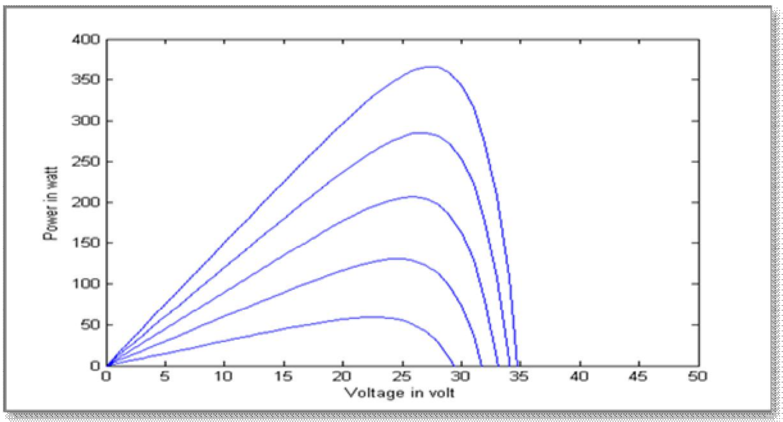

Fig. 7 P-V Characteristics of solar cell under different temperature and irradiances

we observed that by increasing the temperature level at constant irradiance, the voltage output from PV array decreases but current output increases slightly with respect to voltage and, hence the power output from PV array decreases. From the I-V, we observe that the short circuit current increases with increase in irradiance at a fixed temperature. Moreover, from the I-V and P-V curves at a fixed irradiance, it is observed that the open circuit voltage decreases with increase in temperature. Figure2 shows the P-V characteristics of PV module.

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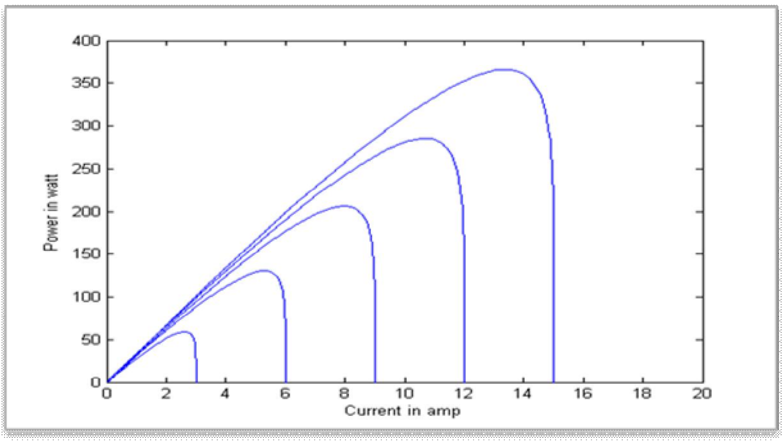

Fig. 8 P-I Characteristics of solar cell

The current to power characteristic of a solar array is non-linear, which makes it difficult to determine the MPP. The Figure3 below gives the P-C characteristics of PV model.

VIII. CONCLUSION

The P-V, P-I, I-V curves we obtained from the PV Module were designed using the basic equivalent circuit model and developed using MATLAB script function in MATLAB environment explains its dependence on the irradiation levels and temperatures for the variations in Voltage, Current and Power. However, the performance of the photovoltaic device depends on the spectral distribution of the solar radiation. The Circuit model of photovoltaic (PV) module is presented in this paper, which can be used as a common platform by material scientists as well as power electronic circuit designers to develop the better PV power plant.

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