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Solar Photovoltaic System Performance Analysis And It's Application For Smart City Electrification

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Abstract-In India maximumpart of electrical energy requirement is fulfilled by Power Grid and per unit rate often increases as the electricity consumption increases, if the consumption is higher during peak hours, per unit rate further increases as compared to the off-pick time in a day.In case of Smart City, where continuous electrical supply is a basis requirement forsmart city operating systems, which consumes high amount of electrical power. To ensure safety and security of software, it require backup source of electricity, presently these requirements are full filled by DG Sets or UPS System with battery backup. In all the cases power cost and maintenance cost is very high. For the electrification of smart city with lower power and maintenance cost the convergence of renewable energy sources and communication technology is the most important factor of generation, transmission and distribution.Integration of the solar photovoltaic energy generation system can be used as a microgrid and Nano grid stage to allow smart cities with low-tariff power consumption.A simulation model based on MATLAB SIMULINK software is developed, to analyze the efficiency of solar photovoltaic system and to improve the electrical power generation by monitoring of solar irradiance and cell temperature parameter. On the basis of output characteristics curve from designed modelsuch as power v/s cell temperature, voltage v/s cell temperature and current v/s cell temperature. By keeping solar irradiance as constant and variation incell temp is analyzed, how the output power of PV array varies.According to this analysis, consumer can manage energy consumption smartly and supply the smart city equipment with or without Grid power supply and reduce monthly electricity.

Keywords: Smart city, solar Photovoltaic system, cell temperature, solar irradiance, Generated power

I. INTRODUCTION

All systems should be linked and interoperable in order to turn a normal building into a Smart-Building and this integrated interoperability of all systems includes a smart energy management framework. [1] Functions of electrification system of any building are governed systematically by Simplified Building Energy Model System (SBEMS). As per IEA (1997), SBEMS isresponsible formanaging, controlling,monitoring and operational terminals of building electrification system. [2] Optimization of construction and plant activity and environmental conditions, automated management of facilities and functions of multiple buildings are among the various functional capabilities of SBEMS. [3] Factor influencing local grid efficiency Increased demand for electricity, short falls ofsupply of electricity, need to minimize losses, management of peak demand and incorporation of renewable energy generation system [18], the Figure 1 shows smart grid system. [4]

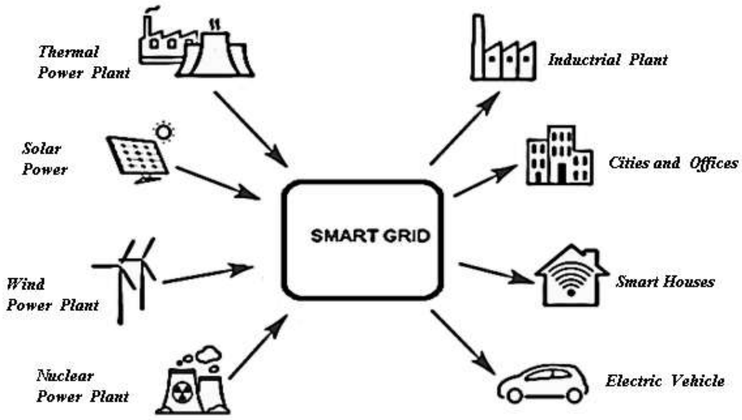

Figure 1: Smart Grid

As shown in Figure 2 the concept of Smart City is actually defining the satisfying the needs of its citizens with improved performance [5], that combines information and communication technologies, to improve conveniences, efficiencies, conservation of electrical energy, identify any problems in the operation of city systems and recover fast from ruins, gatherinformation's to make improvedresults and deploy resources effectually and efficiently. [6]

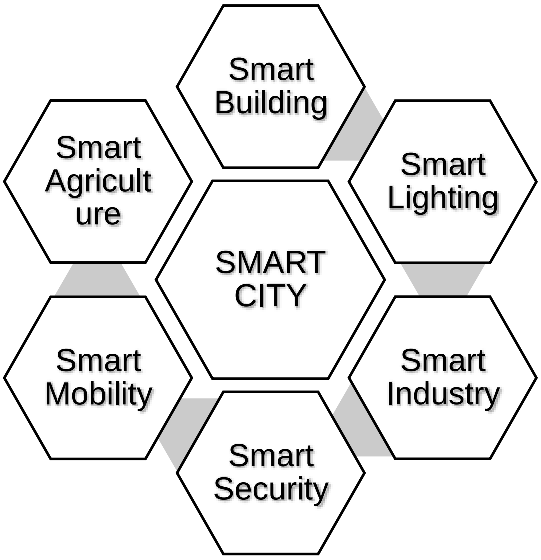

Figure 2: Smart City Benefits

[7]Some authers investigate results to improve the pv solar system analysis in their research. Ma T., et al., have suggested the PV characteristics for maximum output power but the system limited by battery bank status[8]. Priyanka Singh, N. M. Ravindra have analysed the experimentally developed performance parameters of silicon solar cells and their rate of temperature change [9]. Adnan Hussein Ali, Hassan Salman Hamad, have presented solar irradiance effectiveness and environmental temperature on the productivity of Photovoltiac models [10]. Theimpact of solar irradiance and environmentaltemperature on efficiency of Photovoltiac modelsis investigated in. Muhammad E. H. presented an algorithmbased, closedloop, dualaxis tracking system [11].R. Ayaz, et al., proposed PV Model for find power outputs of the Photo voltaic module under real conditions for resistive loading[12]. I O. M. Benaissa, et al., suggest a Simple and Precisethe PV cell model takes external temperature and solar radiation into account,a maximum power point tracking (MPPT) equation is also suggested. The equation implemented in the DC-to-DC converter is applied to check maximum out-put power of Photovoltaic cell.[13] In other studies Banuand Loan, usesvarious tools like empirical data, Lookup Table, Curve Fitting Tools to establish solar module operatingcharacteristics. The downside to this approach is that it is very complicated or even unpredictable [14].

II. MATERIAL AND METHOD

The solar photovoltaic cell equivalent circuit diagram shown in the Figure 3.A number of connecting photovoltaic cells either inseries or in parallel makes the Photovoltaic Array.[15]

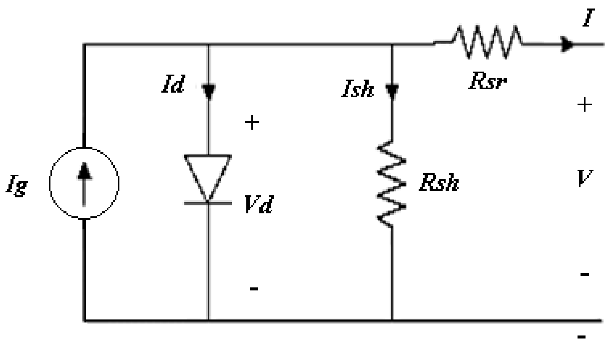

Figure 3: Photovoltaic Equivalent Circuit diagram

Simulink ModelThe mathematical equation for PV solar cell written below
At open circuit condition,

$$I = I_{sc} - I_{os}\left(e^{\frac{q(V+IR_2)}{nkT}} - 1\right) - \frac{V+IR_s}{R_{sh}} \quad (1)$$

In Equation (1) I = Load current of solar cell (In Amp), Isc = Short circuit current (Amp),I_{gs}=Saturation current (Amp), R=Load resistance and R_{sh}= Shunt resistance in (Ω)
At short circuit condition,

$$I_{sc} = I - I_{os}\left(e^{\frac{q(V_{sc}+IR_2)}{nkT}} - 1\right) - \frac{V_{sc}+IR_s}{R_{sh}} \quad (2)$$

Where q = electron charge, *k* = represents Boltzmann constant, T = p-n junction temperature (K) and V*oc*= the open circuit voltage of a solar photovoltaic cell (Volt)

$$I_{os} = AT^{\gamma} e^{\left(\frac{-E_g}{nkT}\right)} \quad (3)$$

In Equation(3) A represent temp. constant, γ temp.dependence exponent, *E.g.:* energy gap *(eV).*

$$I_g = I_{sc}\frac{G}{G_{ref}}\gamma\left[1 + \left(T - T_{ref}\right)\right] (4)$$

HereI_g =Photo current is a function of the solar irradiance *G,* reference cell temperature (25+273) = 298°K and cell temperature *T*.

$$Isc = \frac{\left[V*\left(\frac{Np}{N_s}\right)+(I*Rs)\right]}{Rsh} (5)$$

Here in Equation (5) N_p=Number of Photovoltaic modules connected in parallel,
V_t- diode thermal voltage (V),R_{sh} =Shunt resistance (Ω), R_s = series resistance (Ω),

$$P_{mp} = \frac{G}{G_{ref}} P_{mp,ref}\left[1 + \gamma\left(T - T_{ref}\right)\right] (6)$$

In Equation (6) $P_{mp}$and $Pmp_{,ref}$ is the maximum power at particular value of V and I, and reference value of maximum power, G – Solar Irradiance in w/m^2, Gref – Reference solar Irradiance 1000w/m^{2,}

$$Ios = Irs\left[\frac{T}{Tr}\right]^3 exp\left[\frac{q \times Ego}{nK}\left(\frac{1}{T} - \frac{1}{To}\right)\right] \quad (7)$$

III. MATHEMATICAL DEVELOP MATLAB /SIMULINK NMODEL FOR SOLAR PHOTOVOLTIAC SYSTEM

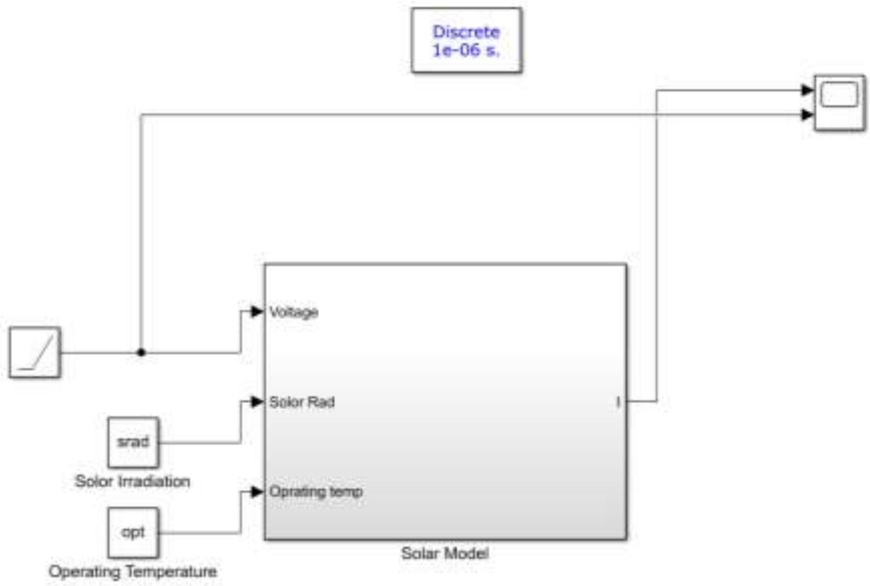

Figure 4: Developed MATLAB/Simulink Model for Solar Photovoltaic System

In figure 4 solar model has been developed using MATLAB and SIMULINK, all the parameters value taken from standard name plate rating of solar module. Simulink model designed by mathematical equation of equivalent circuit of solar photovoltaicgiven section II, In MATLAB environment[15]. Standard test conditionsare set in MATLAB programming and Solar irradiance and solar temperature range are taken for the analysis. Mainly photovoltaic array size is depending upon the Designed load and sunshine hours per day. [16] The slandered test conditions for the for the operation of Solar photovoltaic is Solar Irradiance :1000w/m2, cell Temperature :25℃ and wind speed:1m/s.
The temperature of solar panel iscalculating with the help of ambient temperature and nominal operating cell temperature. [17]

$$T_c = T_{amb} + \left(\frac{NOCT - 25}{100}\right) s \quad (8)$$

where "s" is Insolation.

IV. RESULT AND ANALYSIS

With Proposed model the Solar photovoltaic array characteristicsare estimated at standard test conditions P – V, G-I, G-Characteristics under varying irradiation the constant temperature in Figure. is given. At a steady cell temperature of 25 ° C, the solar irradiance ranges from 100w / m² to 1000w/ m² with the value range [18]

A. Characteristics under varying solar irradiation with constant cell temperature

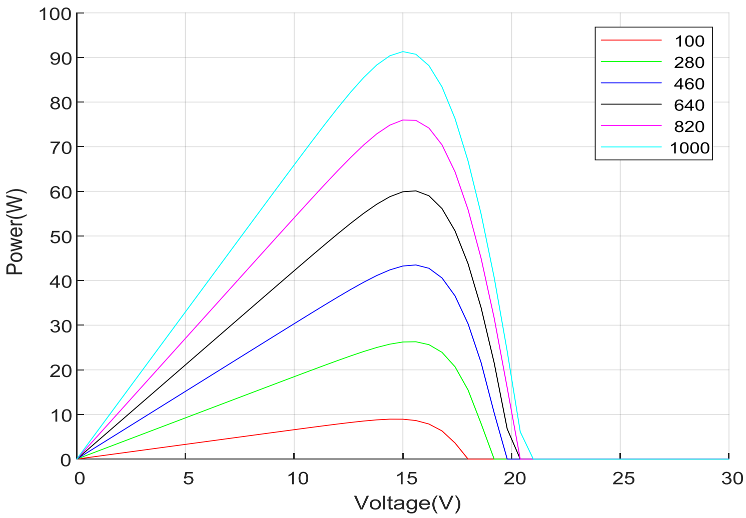

Figure 5:P-V Characteristics

The P-V characteristics curve of the solar photovoltaic array is shown in Figure (5), As the change in Solar irradiance with low value to high, the improvement in output power has been seen in the curve with increase in open circuit voltage.

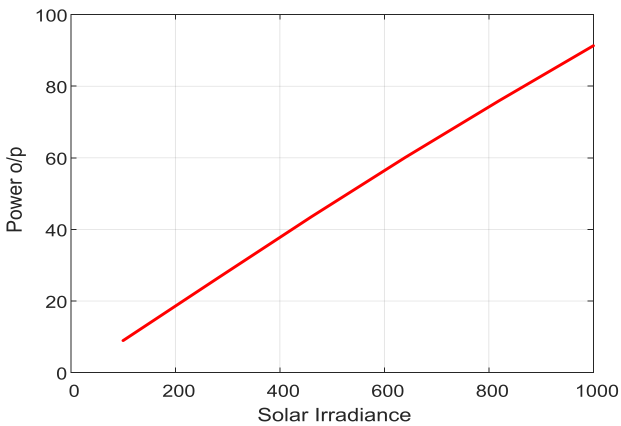

Figure 6: Output Power (Watt) Vs Solar Irradiance(W/M²)

In Figure 6,Change in Solar irradiation means change in environmental condition,hear at constant cell temperature of 25°C,as change in irradiance from 200 to 1000w/m² there would be increase in magnitude of out power with same voltage, the increase in output power is due to increase in mobility of electron.

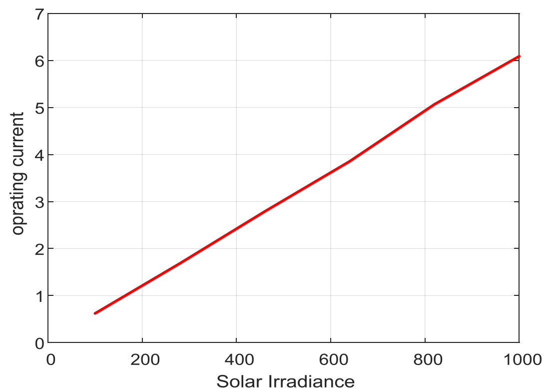

Figure 7: Output Power (Watt) Vs Solar Irradiance(W/M^2)

Figure 7 shown that as increasing the value of Solar irradiance range from 100w/m^2 to 1000w/m^2, the value of output current increases rapidly and the improvement in output power generated by Solar photovoltaic model.

B. Characteristics under changing cell temperature and constant solar irradiation

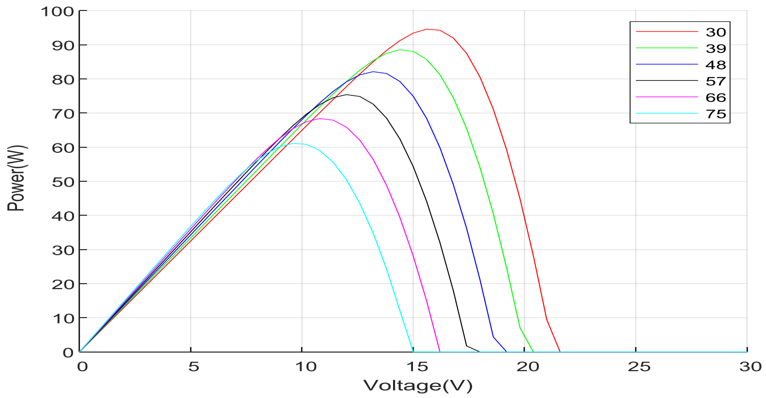

Figure 8: Power -Voltage Characteristics

In Figure 8,Shows that at constant solar irradiation, increase in cell temperature, output power reduces because of substantially reduction in voltage, whereas current increases insufficiently.

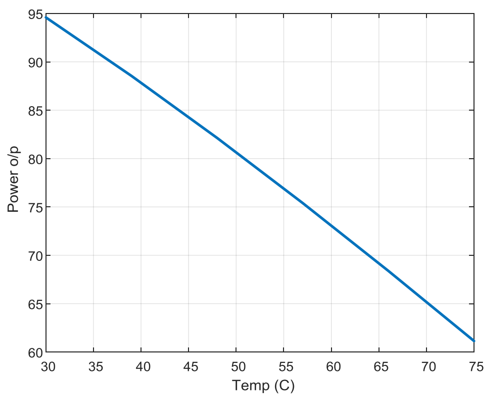

Figure 9: Output Power(Watt) Vs Cell Temparature(°C)

Figure 9 shows as the change in cell temperature from 30°C*to* 75°C, its output current increases exponentially, although the voltage is reduced linearly. Now, the reduction in voltage is so expected that it can be used to determinecell temperatureprecisely. As a consequence, heat will severely reduce the output of power from the solar photovoltaic panel.

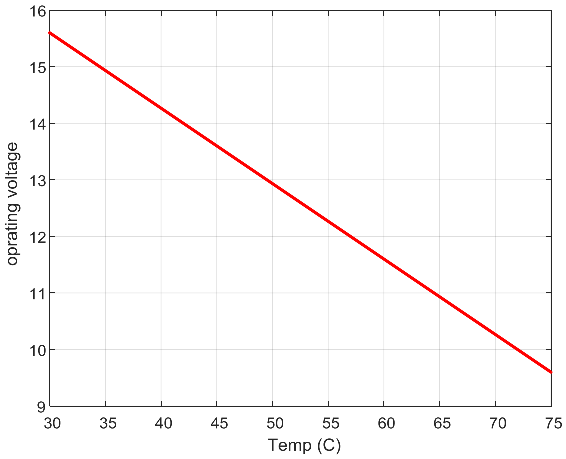

Figure 10: Operating Voltage(Volt) Vs Cell Temparature(°C)

The Figure 10 shows the value of the Voc is decreases linearly with change in cell temperature low to high. The scale of this decrease is inversely proportional to Voc

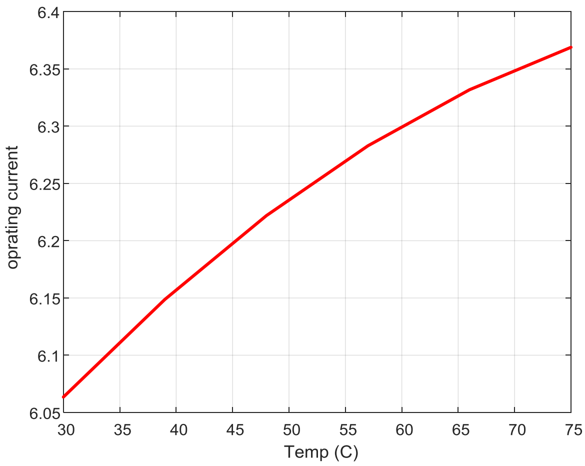

Figure 11: Operating Current(Amp) Vs Cell Temparature(°C)

As shown in Figure 11 whereas thechange in temperature from low valueto high, there is reduction in exponent value in the characteristic's equation and the value of reverse saturation current is increases. The photogenerated current Ig change a little with change in cell temperature because of avariation thermally generated carriers in the cell.

V. CONCLUSION

It is inferred from the above findings and study that the proposed MATLAB and Simulink model shows the effect of cell temperature and solar irradiance on the working condition of the solar Photovoltaic system. The model offers an accurate and consistent performance for improvement of renewable solar photovoltaic systemoutput for smart city electrification.
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