Performance & Analysis of SPV Power: A Project Review

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Abstract- *The country like India, which is still progressing towards its development, need to focus on the energy sector and therefore fulfill the continuous increase in electricity requirement. In our country, there are remote areas where there is no grid supply. Solar energy is easily approachable at such locations and can easily fulfill the basic demand. Government is subsidizing cooking fuel spending 10,100 - 20,500 crores of Rupees every year. The present scenario shows that coal-based power plants are the main generators of electricity. This affects our environment in following ways*

INTRODUCTION

Emission affecting our environment in the present world, the main factors involved in the generation of power for ultra large projects involve heavy investments, different fossil fuels, water as coolant, etc. statistics and cope with sudden conditions in time.The major damage caused to the surroundings and the world is due to CO_2 or the carbon dioxide which results in global warming up to the levels. Impact on Water the huge amount of heat is produced in power plants which require quite a large amount of water. The power plants utilize water as a coolant to dispose of the waste which should be carried away.

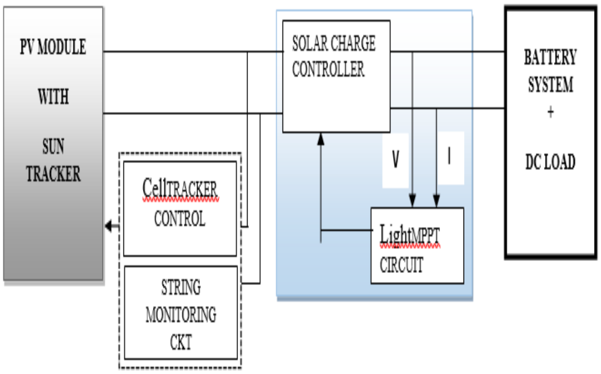
Effect on Biological Environment the Biological imbalance affects both the flora and the fauna. These days the forest and agricultural land is continuously being acquired for urbanization which is creating a great imbalance for the species. Effect on Socio-Economic Environment the local disturbance and misbalance caused in the close vicinity of power plants is directly related to its size.

Solar Energy status in India

Due to India's increasing population resulting in increasing energy demand with progressively increasing economic growth, echo friendly electricity can be obtained from the renewable strength reassess. Therefore, sun strength eightfold, and CO_2 emissions could be five times. India's usual worldwide percentage of CO_2 emissions appears to get double from modern five according to cent to approximately eleven percent.

The Proposed Solar PV System

Main objective is to reduce the cost of solar system by maximizing the efficiency of solar system. For this we developed a SIMULINK model of solar photovoltaic system for 170-watt panel. After the simulation study, A 510-watt solar tracking system is developed. The small system is developed so that it could be built on the small area of the roof to fulfill the requirement of energy for domestic appliances in future. The block diagram of the system is shown



in figure 3.1

Crystalline solar cells

Crystalline solar cells are wired in series and parallel as per power requirement. Each solar cell exhibit 0.6 V. Thus, in order to produce an open-circuit voltage of around 40V, 72 cells required which may generally charge 24 V batteries

Monocrystalline

Monocrystalline cells are constructed from single crystal silicon. They are manufactured using a single large crystal. Square cells which are placed under glass for protection of cells from rain, dust and moisture

Polycrystalline

Poly crystalline solar cells are made from wafers of silicon which is cut from a multi-crystal square cast ingot of silicon. Poly cells in comparison with monocrystalline PV cells are smaller in size, poor in efficiency but cheaper. Still poly crystalline cells are the favorite and widely used domestically around the world. They have blue flaked appearance under glass

Amorphous

Amorphous silicon is the thin film solar cells technology made up of deposition of silicon on glass backing substrate from reactive gas i.e. silicon; substrate may be plastic or steel as well. It is named so as “amorphous” due to its non-crystalline structure.

Vaporware

The technology is still on paper which says that the plastic spray is under research which will increase the efficiency of solar cells by 5%.

Modeling A PV Module By MATLAB: Used for Experiment

BHEL Solar BP SX 170S PV module, pictured in Figure 3.6, is chosen for a MATLAB simulation model. The module is made of 72 Single-crystalline silicon solar cells in series and provides 170W of nominal maximum power. The version includes a modern source (Isc), a diode (D), and a sequence resistance (Rs). The impact of parallel resistance (Rp) could be very small in a unmarried module, as a consequence the version does now no longer encompass it[29]. To make a higher version, it is usually temperature effects at the short-circuit modern (Isc) and the reverse saturation modern of diode (Io). It makes use of a unmarried diode with the diode ideality factor (n) set to gain the great I-V curve match.

$$I_0 = \frac{I_{sc}}{\left(e^{\frac{qV}{kT}} - 1\right)} \quad (3.1)$$

$$I_{sc}(G) = \left(\frac{G}{G_0}\right) I_{sc}(G_0) \quad (3.2)$$

$$I = I_{sc} - I_{01}\left[e^{q\left(\frac{V+I.R_S}{kT}\right)} - 1\right] - I_{02}\left[e^{q\left(\frac{V+I.R_S}{kT}\right)} - 1\right] - \left(\frac{V+IR_S}{R_p}\right) \quad (3.3)$$

$$I = I_{sc} - I_0\left[e^{q\left(\frac{V+I.R_S}{nkT}\right)} - 1\right] - \left(\frac{V+IR_S}{R_p}\right) \quad (3.4)$$

$$I = I_{sc} - I_0\left[e^{q\left(\frac{V+I.R_S}{nkT}\right)} - 1\right] \quad (3.5)$$

Where: I is the cell current (the same as the module current),

V is the cell voltage = {module voltage} ÷ {no of cells in series},

T is the cell temperature in Kelvin (K)

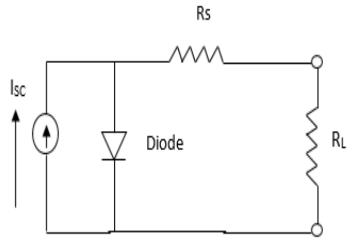


Figure 3.7: Equivalent circuit used in the MATLAB simulations

First, calculate the short-circuit current (I_{sc}) at a given cell temperature (T):

$$I_{sc}I_T = I_{sc}I_{T_{ref}}\left[1 + a\left(T - T_{ref}\right)\right] \quad (3.6)$$

Where: I_{sc} short circuit current at T_{ref} is given in the datasheet (measured under irradiance of 1000W/m^2),

T_{ref} is the reference temperature of PV cell in Kelvin (K), usually 298K (25^{o}C),

a is the temperature coefficient of I_{sc} in percent change per degree.

The short-circuit current (I_{sc}) is proportional to the intensity of irradiance, thus I_{sc} at a given irradiance (G) is :

$$I_{sc}(G) = \left(\frac{G}{G_0}\right) I_{sc}(G_0) \quad (3.7)$$

$$I_0 = \frac{I_{sc}}{\left(e^{\frac{qV_{OC}}{kT}} - 1\right)} \quad (3.8)$$

The reverse saturation current (I_o) is temperature defendant and the I_o at a given temperature (T) is calculated by the following equation .

$$\frac{I_0}{T} = \frac{I_0}{T_{ref}}\left(\frac{T}{T_{ref}}\right)^{\frac{3}{n}} . e^{-\frac{qE_{\in}}{nk}\left(\frac{1}{T}-\frac{1}{T_{ref}}\right)} \quad (3.9)$$

$$dI - 0 - I_0.q\left(\frac{dV+R_3.dI}{nkt}\right).e^{q\left(\frac{V+I.R_S}{nkT}\right)}$$
(3.10)

$$R_s = -\left(\frac{dI}{dV}\right) - \frac{nkT}{I_0.e^{q\left(\frac{V+I.R_S}{nkT}\right)}} \quad (3.11)$$

Then, evaluate the equation (3.11) at the open circuit voltage that is $V=V_{oc}$ (also let I=0).

$$R_s = -\left(\frac{dI}{dV}\right)_{at\, V_{oc}} - \frac{nkT}{I_0.e^{q\left(\frac{V+I.R_S}{nkT}\right)}}$$
(3.12)

$$I = I_{sc} - I_0\left[e^{q\left(\frac{V+I.R_S}{nkT}\right)} - 1\right] \quad (3.13)$$

$f(I) = Isc - I - I0\ [eq(V+I.Rs\ nkT\ ) - 1] = 0$ (3.14)

Plugging this into the equation (3.17) gives a following recursive equation, and the output current (I) is computed iteratively.

$In+1= In - Isc{-}In{-}I0[eq(V+I.Rs\ nkT\ ){-}1]\ {-}1{-}I0(q.Rs\ nkT).eq(V+I.Rs\ nkT\ )$ (3.15)

MPPT Charge Controller

We are well aware of traditional charge controllers which transfer the PV current directly to battery. Now, the new controllers that came into existence are Maximum Power Point Tracker that claims to boost the current of battery to 45% theoretically, however practically observed to have 22% to 30% increase. The feature to maximize the power drawn from solar PV system is called maximum power point tracking (MPPT). MPPT's vary the voltage and current ratio delivered to the battery to generate maximum power output. This voltage is known as Vamp maximum voltage of the PV cells and it varies with temperature. MPPT charge controller tracks this variance and adjusts the ratio accordingly, thereby working as current booster for battery bank.

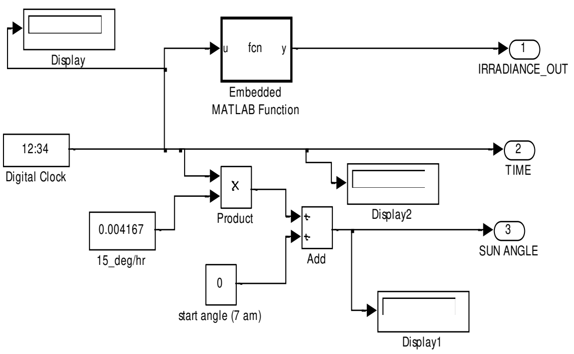
Performance Analysis Solar Tracking System in SIMULINKTM

In this section, the main objective is to simulate the solar tracking system during the automatic mode using SIMULINK. For the performing SIMULINK based simulation model, all the data were obtained from either the components' datasheets or the experiments conducted. The simulation run was performed in every second of the entire 12 hours or 42000 seconds. We preferred ODE45 solver type of variable step size throughout the simulations. The simulation model is implemented in such a way that when the sun irradiance falls on the sensors, the DC motor moves the PV panel in an incremental way till it is not perpendicular to sun. (sunrise) to 180 degrees (sunset) from 6 am to 6 pm. During these

12 hours, to track the Sun and maximize the energy, the PV panel should rotate 180 degrees. Therefore, it can be calculated, the sun changes its position 15 degrees per hour or 0.004147 per

STATIC PV PANEL MODEL

The solar panels used for proposed sola tracker PV system, was purchased by BHEL Bangalore. The solar panels selected for research purpose is capable of generating 170W power each. As per the vendor specification of a panel is shown in the table: 4.1 Mentioned below are at standard

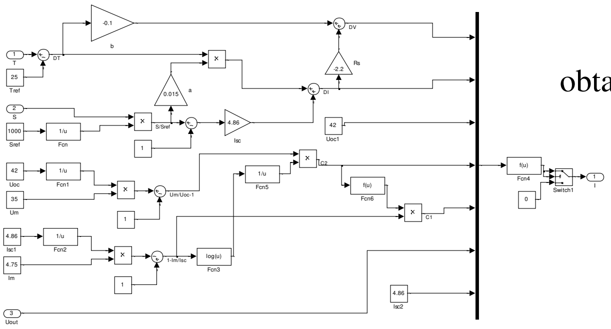


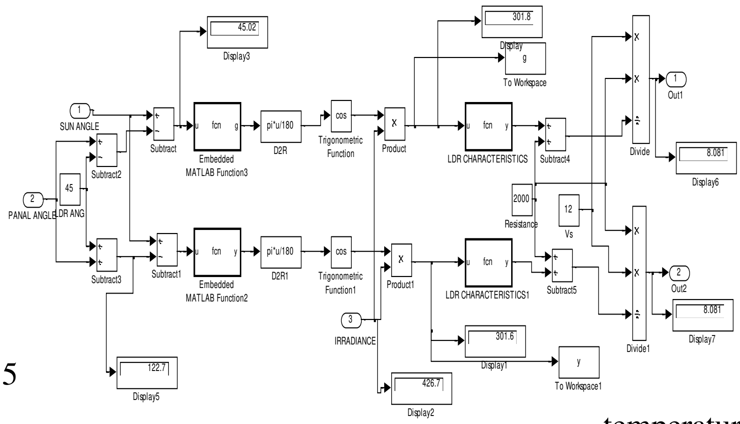
test conditions of 100 MW /cm2. at air mass 1.5

and at 250C cell temperature system, was purchased by BHEL Bangalore. The solar panels selected for research purpose is capable of generating 170W power each. As per the vendor specification of a panel is shown in the table: 4.1 Mentioned below are at standard test conditions of 100 MW /cm2. at air mass 1.5 and at 250C cell temperature.

simulated time in second; the corresponding sun angle (with respect to the base) is obtained. The actual irradiance data measured by a pyro-heliometer was used in the Sun model,

Figure 4.6 shows the mathematical model of PV cells as explained previously 1, is implemented in SIMULINK platform. Here the actual temperature and irradiance data used in the block was obtained with





temperature sensor and pyro-heliometer, reading was taken throughout the day

throughout the year.

Figure 4.6 Model of PV cells

The solar irradiance and temperature data were taken as the difference of 10 minutes in the whole day; obtained data were implemented in SIMULINK model, after processing in cubic curve fitted tools. In Smart single axis tracker PV System two LDRs were used for sensing the light intensity, these LDR can be fitted in any position but face of LDR should be parallel to installed panels. For implementing the sun tracking algorithm LDRs were positioned at 45° and 135°. Whenever, the sun light falls on the sensors, LDR sensor generates different voltages, the LDR based tracking concept was explained in the previous section with flow chart. The smart Tracker with LDR block has been implemented in SIMULINK platform as show

Figure 4.9 LDR (Light Dependent Resistor) Sensor Model LDR is a variable resistance and its fee relies upon at the depth of mild, called mild established resistor. As the depth of mild changes, the resistance and voltage fee of sensor change. This idea is carried out in SIMULINK primarily based totally LDR version as proven in parent 4.9.

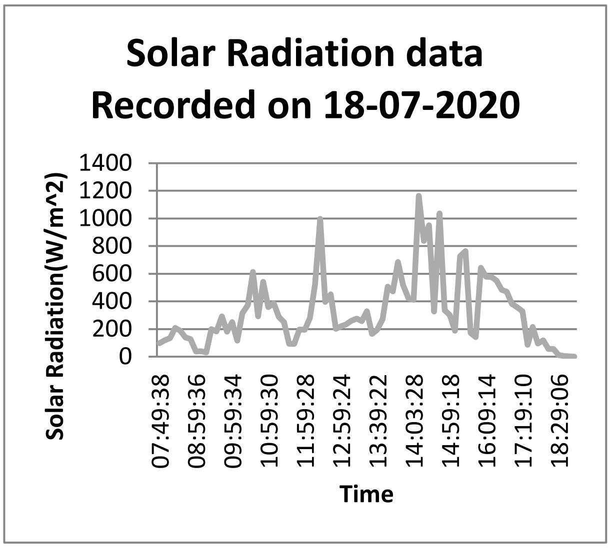
TRACKER CONTROL CIRCUIT MODEL

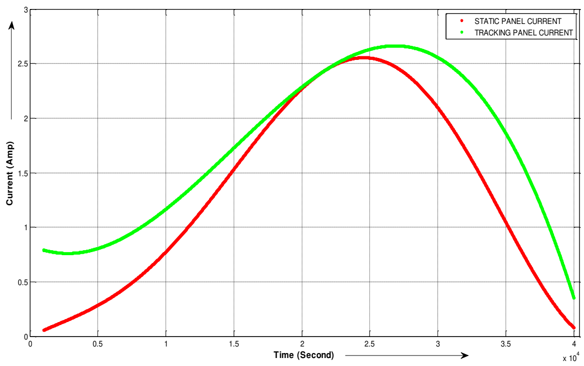
The extrude in voltage because of mild at the LDR dispatched to comparator primarily based totally manipulate circuit in order to provide the sign to DC motor to rotate the tracker system. DC motor will rotate tracker until the output of comparator does now no longer attain to zero. The manipulate circuit designed with the use of various good judgment gates (AND, OR, and XOR). Figure 4.10 suggests the designed manipulate circuit turned into carried out As we know in DC motor the torque is proportional to the armature current and it also affected by strength of the magnetic field, here we are using PMDC motor, therefore the strength of magnetic field is constant due to presence of permanent magnets. therefore, in this case, the torque developed by the motor is directly proportional to the armature current present the relationship by equitation (4.2) K_t is a proportionality constant and back EMF (e) is proportional to the Angular velocity of the shaft multiplied by a constant factor shown in the equation below.

Figure 4.11 SIMULINK Model of PMDC Motor In our proposed system, we want to avoid the use of battery for the tracking purpose. Figure 4.12 shows the Schematic diagram of DC motor directly connected to PV module. Figure 4.13 shows the simulation results.

SIMULATION RESULTS

As the single axis azimuthally (Tracker travel





from East to West) simulation was done. The following simulation results of the 170-watt solar tracker PV system obtained as shown in Figure 4.26. Observed from the simulation result plots, the solar tracker is able to follow the sun position and can produce higher current output as compared to the static PV system. The simulation was performed by implementing the actual irradiance and temperature data recorded with pyrheliometers and temperature sensor on whole day on different atmospheric condition. Figure 4.24 and 4.25 shows the plot of irradiance and Temperature data recorded on date 13-07-2020.

Figure 4.12 Schematic diagram of Series-wound DC motor directly connected to PV module

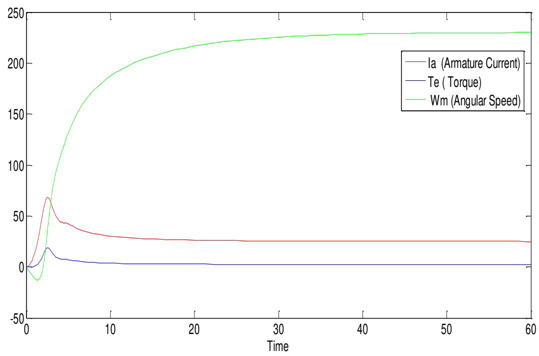


Figure 4.13 Simulation result of SWDC motor directly connected to PV module

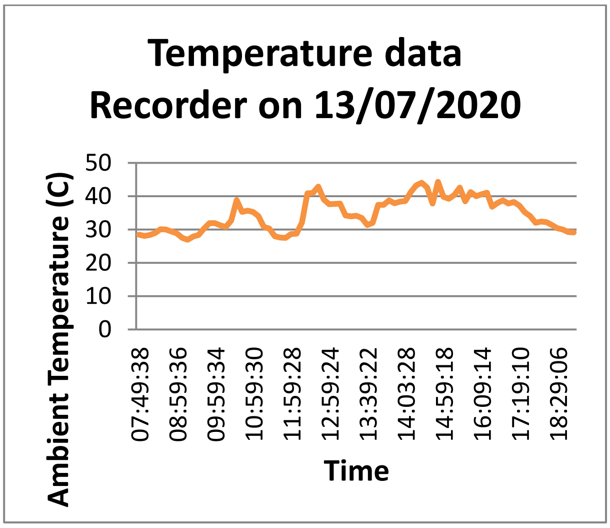


Figure 4.24: Actual Temperature Variation data on date: 13-07-2020

Data collected was discrete in nature; therefore, to achieve the continuous signal cubic curve was fitted in both recorded data temperature as well as irradiance and simulation was performed.

In figure 4.26, It could be observed at the point 25000 (Second) the difference between tracker panel current and static panel current is higher than other points.

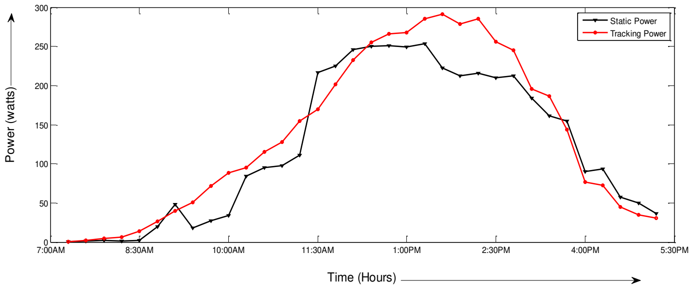


Figure 4.26 Simulation Result of Tracking

and Static Panel Current Vs Time

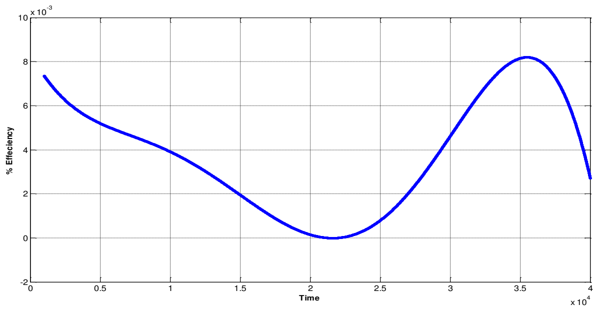


Figure 4.27 Simulation Result of Efficiency Vs time

The efficiency plot of the Tracking PV system with reference Static PV System is shown in figure 4.27. At the point 23000 Second (12.30 AM) the tracker and static panel current value is same therefore efficiency reaches to zero and at point 35000 Second (2.20 PM) efficiency is maximum because of tracker panel current increases rapidly due to increase in irradiance value . The static panel current increases gradually because effective irradiance falls on static panel.

ELEVATED TRACKING RESULTs

The voltage and current readings were taken were taken on date 15-09-2020, when the tracking PV system is allowed elevated (Y-axis) degree of freedom only. The Static PV system was mounted at 27^0-degree south face Tracking PV system was free to along North to south direction (Y-axis, elevated direction). Data collection was done from 7.30 am to 5.00 pm. The improvement in efficiency due to single axis (Y-Axis) tracking has been calculated as 14% as compared to that of static PV system.

Figure 5.9 Variation in power produced by PV systems due to one degree of freedom (Y-axis).

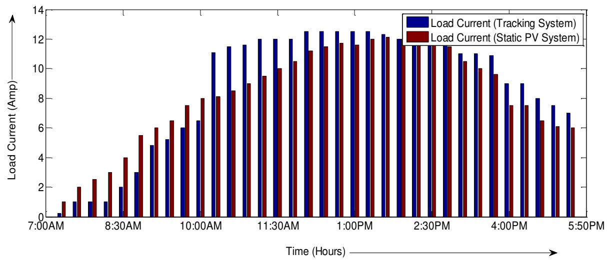


Figure 5.10 Variation in load current due to one degree of freedom (Y-axis tracking)

5.4 CONCLUSION

The result obtained from the experimental setup, stats that the SPV power plant with tracking system produces more energy as compared to static SPV power plant. during whole day panels with the sun tracker rotates 132 degrees in horizontal means east to west rotation. the SPV panels with tracker can produce 38% more energy as compared to static SPV system. If we analyse the elevated tracking concept only than 17% efficiency is more as compared to static SPV system.

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