

MODELLING & SIMULATION OF SOLAR PV ARRAY FIELD INCORPORATED WITH SOLAR IRRADIANCE AND TEMPERATURE VARIATION TO ESTIMATE OUTPUT POWER OF SOLAR PV FIELD

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ABSTRACT

Photovoltaic systems are designed to feed either to grid or direct consumption. Due to global concerns, significant growth is being observed in Grid connected solar PV Plants. Since the PV module generates DC power, inverter is needed to interface it with grid. The power generated by a solar PV module depends on surrounding such as irradiance and temperature. This paper presents modelling of solar PV arrays connected to grid-connected plant incorporated with irradiance and temperature variation, to design simulator to study and analyse effect on output power of solar PV arrays with irradiance and temperature variation, also to estimate the output power generated by PV arrays. The mathematical model is designed implemented separately on simulator for each PV components connected in PV systems, which are PV cell, Module, sting, array and field of arrays. The results from simulation based on model are verified by the data collected from power plants and experiments done on solar PV cell.

Keywords: Photovoltaic, Irradiance, Temperature, Array, Model, Simulator.

I. INTRODUCTION

Photovoltaic power generation is gaining acceptance today as source of clean and pollution free energy. These power generators shows significant growth in grid connected as well as stand-alone applications. Our objective was to create mathematical model for solar PV array connected across these generators, incorporated with irradiance and temperature variation and implement the model using simulation for study and analyse the effect on output of field of solar PV arrays and also to estimate the power output of a solar PV arrays connected across power plants. We implemented our mathematical model using iVisionMax[1] PC suit to create simulation. We verified results from simulator based on our model by comparing it with data collected from power plants and results from experiment on solar cell.

II. LOGICAL THINKING

To create a model for solar PV system and implement it on simulation software we made some assumptions regarding atmospheric conditions effect on PV array. With the model for simulating PV arrays, we also wanted

simulator to implement graphical representation of Arrays, therefore we used some basic design models for graphical design of PV system in simulator. The assumptions we made for simulation are as follows:

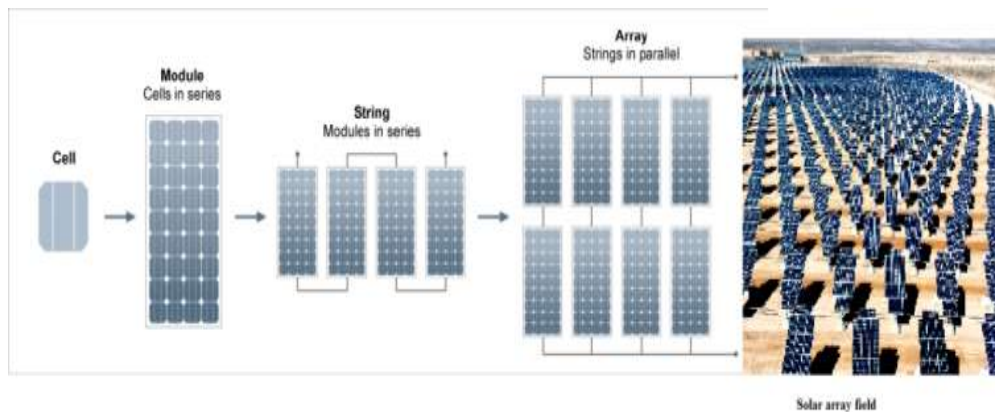


Fig. 1 Illustration of Solar Array Field

Figure 1 shows the illustration of solar array field which shows the order in which solar field is designed, we can see that field of arrays are made by solar array connected together, array is made up of strings connected in parallel, string is made up of modules connected in series and module is made up of cells connected in series. We designed software to simulate whole field, each array, each string and module connected in the field separately. We designed dedicated windows for every level.

2.1 Assumptions

2.1.1 Input

Inputs to simulator are as follows:

Climate conditions= Sunny and Cloudy, Solar irradiance= 0 W/m² to 1000 w/m², Module temperature = -5°C to 80°, [10] Shadow density = 1% to 100%.

2.1.2 Effect of Other Atmospheric Conditions

All other atmospheric conditions such as humidity, wind speed, edging of sunrays, dust and snow are already imposing their effect on solar irradiance and module temperature as well.

Therefore,

$$\text{Module Temperature} = b_0(\text{ambient temp.}) + b_1(\text{wind temp.}) + b_2(\text{irradiance}) + b_3(\text{humidity}) + b_4(\text{dust or snow}) + b_5(\text{shadow}) \quad (1)$$

Where, b₀, b₁, b₂, b₃, b₄, b₅ are regression coeff. Which are may vary according to location. It means that module temperature is already affected by other conditions and it's the same in case of irradiance.

2.1.3 Climatic Conditions

Climate conditions are depends upon the seasons of particular locations therefore we are assuming following conditions: Sunny Conditions: In sunny conditions, we are assuming that the location where the PV array is set up is free from all kinds of shadows including cloud shadow as well as other monumental shadows (clear sky). Solar PV modules are directly coming across Sun with no shadow effect and output of PV array is clearly dependent on solar irradiance and Module temperature. The tilt angle of Solar PV modules should be equal to latitude and the orientation of the Array should be always facing South (True south). Cloudy conditions: In cloudy conditions, we are introducing shadow over modules which will affect irradiance as well as module temperature. We are inputting shadow density of a cloud in simulator which will change the given irradiation and module temperature as input before and accordingly output will be changed. to simulate cloudy conditions we are assuming that cloud shadow is covering all the PV modules in PV array field with same amount of shadow density and whole sun is being covered by cloud (for Eg. Rainy day).

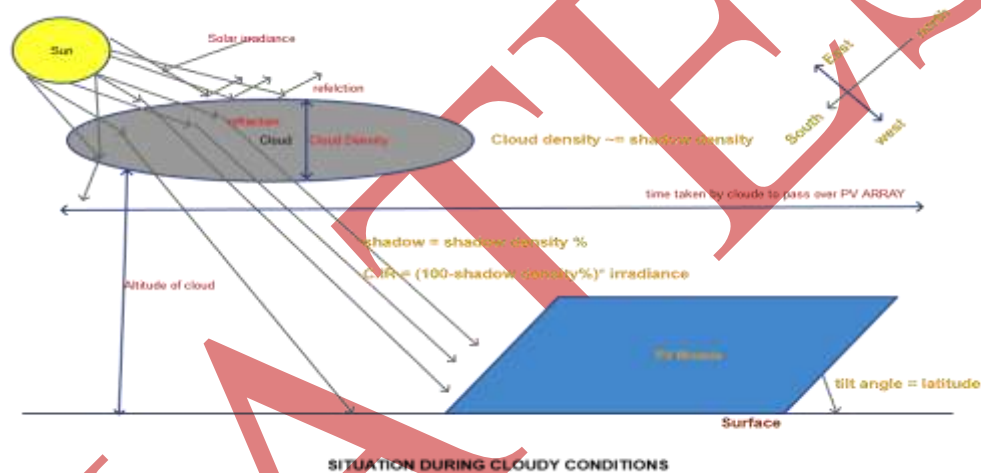
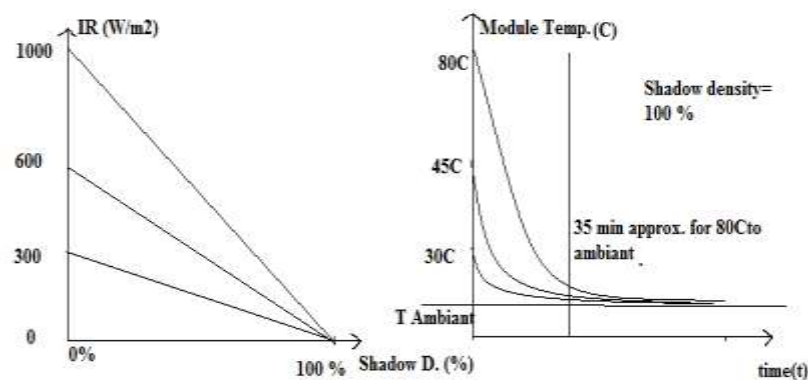


Fig. 2 Assumption of Cloudy Condition for Simulator [4]

When shadow comes over PV module or an array, what happens is that shadow will resist solar insolation and irradiance. As much as the shadow density (SD)[10], darker the shadow hence, irradiance reaching to the module is reduced by amount of shadow present due to cloud as shown in figure 3(a). Similarly, module temperature also gets affected due to shadow over module, but it doesn't happen rapidly as irradiance, it will need some time to see reduction in temperature. Therefore we are considering time for shadow to remain over PV array, to give the change in Module temperature. To simulate or mimic change in module temperature we are using Newton's law of cooling, which we will enlighten in next sub-topic. From experimenting and studying we can say that change in irradiance due to shadow is linear in nature and change in module temperature is logarithmic and exponential. Studies show that module temperature is always 20 to 30% [5] more than ambient temperature. While designing the equations for simulation we are considering ambient temperature 80 % approx. of a module temperature. Which is calculated in cloudy condition after the module temperature is specified. [7][6]



Change in Irradiance and module temp. due to SD(%)

Fig. 3 Change in Irradiance and Module Temp Due to Shadow Density (Based On Experiments and Observation)

Since the purpose of designing the simulator is to study and analyse effect of atmospheric conditions on solar PV module and its fields of arrays therefore we are not considering any other effect on the output of module. We are just concerned about how much power required from solar Array field and how it will get affected by change in atmospheric conditions.

III. MATHEMATICAL MODELLING

3.1 PV Module Mathematical Modelling

Assumptions: the following terms we are using in the programming while designing the simulation software in iVisionMax.

$V_{oltc} = V_{max}$ of a PV cell.

$C_{rin} = I_{max}$ of a PV cell.

$Refchg$ = change in voltage due to irradiance variation.

I_0 = Diode saturation current (f i_0) i.e. base value of I_0 of a cell)

I_r = Solar irradiance.

$M.Temp$ = Module Temperature in °C.

$T_{ambient}$ = Ambient temperature in °C.

$Chngeintemp$ = change in ambient temperature.

Equation 2 derives the base value of diode saturation current which is denoted as i_0 , it is already present in silicon solar cell due to its material characteristics. but Base i_0 's presence can be neglected till module temperature is 25° C. if the module temperature is increased than diode saturation current will rise and gets added with output current. Equation 3 illustrates the change in diode saturation current.

$$i_0 = \frac{qADn n_i^2}{Ln N_a} [8] \quad (2)$$

where, q is charge in a cell, A is surface area in mm², Dn is Depletion width, n_i is intrinsic concentration, Ln is length if n region, N_a is Doping density.

$$I_0 = i_0 \cdot e^{0.09672 (M.temp - 25)} [2] \quad (3)$$

I₀ is diode saturation current of a PV cell which increases with rise in temperature, it is negligible because it is too small to count but it does flows into PV cell, and it affects current as well as voltage generated in PV cell. Which will have accountable effect on output power of Solar array field connected to grid.

3.1.1 Application Of Newton’s Law Of Cooling For Change In Module Temperature Due To Cloud:

Newton's Law makes a statement about an **instantaneous** rate of change of the temperature [9].

Newton’s law of cooling

$$\frac{dT}{dt} = -k(T - T_a)$$

$$T(0) = T_o$$

Solution,

$$T(t) = T_a + (T_o - T_a)e^{-kt}$$

To apply newton’s law of cooling we have to find value of k, which is the relation between change in temperature of module with respect to time. To find k, we have to perform experiment as shown in figure 4. For experiment what we did is we heated the solar PV cell module up to 60° C in laboratory with no sunlight spectrum, we can assume that with no irradiance. We forcefully heated the module and then we observed and recorded time taken by the module to cool down to ambient temperature the table below shows us reading of the experiment, initially module temperature is 26.5 °C and ambient temperature is 25.5 °C. We used hair dryer as heating source from which we heated the module to 60 °C and we measured the temperature on multichannel RTD device as shown in figure 4. We used multichannel RTD for measuring ambient temperature as well as module temperature at same time so that we can measure exact time for cooling down of module, table 1 shows the results from the experiment:

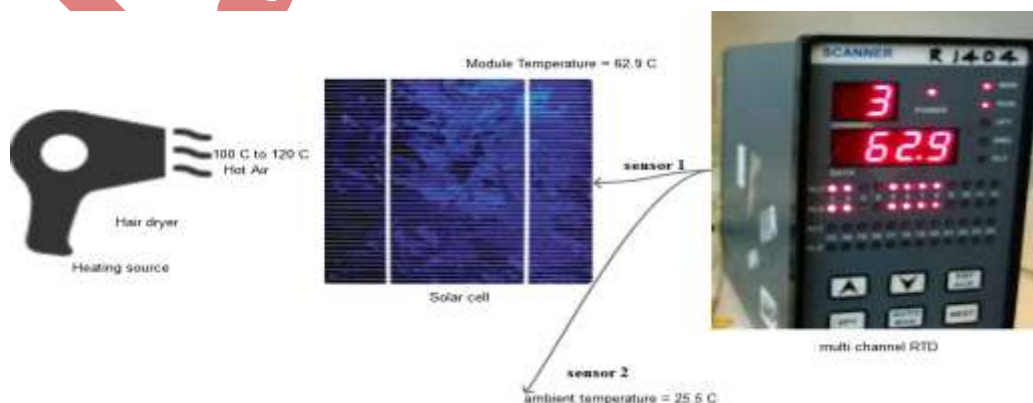


Fig. 4: Experiment Setup for Change in Module Temp Due To Cloud

TABLE I
CHANGE IN MODULE TEMPERATURE IN CLOUDY CONDITIONS

Date: 20/05/14	Ambient Temperature		Initial M.Temp.	M. Temp after time(t)	Time (min)
	Initial AT	After time(t)			
Time: 10.40 AM	25.5°C	27.6 °C	60 °C	28.2 °C	34.21 min
11.20 AM	28.0° C	27.2 °C	60 °C	27.6 °C	36.47 min
12.02 PM	28.0 °C	27.8 °C	60 °C	28.7 °C	34.47 min

It is seen that module takes approximately 35.05 minutes to cool down to ambient temperature. We repeated the same procedure 3 times on same module to see the change in module temperature with reference to ambient temperature. To find out change in module temperature due to shadow of a cloud, we have to find change in ambient temperature due to shadow, which is illustrated by equation 6 and 7.

3.1.2 Newton's Law Of Cooling Regression Coefficient

Now let's see, how to find K? When shadow is over module, 1st we have to measure change in ambient temperature. Since we are feeding module temperature directly we are using property of relation between ambient temperature and module temperature. Ambient temp is always 75% to 80% of module temperature. [5]

$$T_{ambient} = (M.temp) \cdot \left(\frac{80\%}{100}\right) \quad [5] \quad (6)$$

$$Change\ in\ temp = T_{ambient} - T_{ambient} \cdot \left(\frac{-0.08124 \cdot t}{e^{-0.08124 \cdot t}}\right) \cdot \left(e^{-\frac{(shadow\ density\ \%)}{100}}\right) \quad (7)$$

In equation 7, we are using heat transfer equation for calculating change in module temperature due to shadow and presence of shadow over module. Change in ambient temperature is function of shadow density in % and time of presence of shadow over module. Here, equation 8 is derived from solution of Newton's law of cooling. To find k we solved the equation and also did experiment on module to acquire the data for calculation, below equation 8 we can see the calculation for k using experiment results. We used the value of k as constant in equation 9.

$$k = \ln \left(\frac{M.Temp - T_{ambient} / \Delta M.Temp - T_{ambient}}{time(t)} \right) \quad (8)$$

$$k = 0.08124.$$

From table 1, we took values to solve the equation 8. Change in module temperature is function of change in ambient temperature and time required to cool down to ambient temperature with time and constant k . Equation 9 ,shows the calculation for changed module temperature based on change in ambient temperature. Here we are calculating effect of ambient temperature only not shadow effect because we have already calculated ambient

temperature over shadow. Equation 10, shows the changed irradiance due to shadow of a cloud over module. Figure 3 shows the relation of irradiance with shadow and module temperature with shadow.

$$\Delta M.temp = \text{chnageintemp} + (M.temp - \text{changeintemp}).(e^{-k(\text{time})}) \quad (9)$$

$$\Delta ir = \left(\frac{100 - \text{shd_density}}{100} \right).ir \quad [2] \quad (10)$$

3.1.3 Output Equations

As we explained mathematical modelling of the input side, now let's see equations and formulations from the output side. Equation 11, 12 and 11a are representing regression coefficients or factors which relates the change in input to change in output, *voltc* gives voltage of a cell from module specified by user. *Crin* is regression coefficient between current and solar irradiance and *refchnge* gives the relation between changes in irradiance to change in voltage.

$$voltage = \frac{Vmax}{No.of PV cells} \quad (11)$$

$$crin = \frac{I_{max}}{1000} \quad (12)$$

$$refchnge(ir\ coeff.) = \frac{11mv - voc\ of\ PV\ cell}{\ln(1000 - ir)} \quad (11a)$$

Where,

$ir = 10\ W/m^2$, $VOC = 600mv$, $11\ mv$ [according to real diode characteristics].[3]

Equation 13 gives the voltage of a module dependent upon module temperature without effect of irradiance over it, for this equation we always assume that except change in temperature other parameters are at ideal state, but we are compensating effect of other conditions such as irradiance separately which we will see in the following conditions we made. The temperature coefficient we took is always specified in specification sheet provided by manufacturers. Here we are taking it as constant but it may vary with manufacturer to manufacturer. Module current equation 14 is based in the principle states that, current directly proportional to irradiance. Where, *crin* is regression coefficient which always gets changed with module to module.as illustrated in equation 12. Equation 15 is product of voltage and current obtained from 13 and 14 i.e. power of a module.

$$V_{module} = voltage . \left(1 + (M.temp - 25) . \left(\frac{-0.34}{100} \right) \right) . No.of PV cells \quad (13)$$

Where,

(-0.34 % is temperature coeff. provided by manufacturer.)

$$I_{module} = (crin) . (ir) \quad (14)$$

$$P_{module} = V_{module} \cdot I_{module} \quad (15)$$

Condition 1: Effect of module temperature on module current if $> 25^\circ C$

As we seen earlier in equation 13 and 14 are independently related to voltage and current respectively. Here, we are relating module temperature with current. It states that if module temperature increased over $25^\circ C$, Carrier concentration is changed due to which band gap of PV module decreases, so I_0 (i.e. Diode saturation current) increases, and eventually module voltage decreases. I_0 gets introduced in Module output current. We are already defining decrease in voltage from equation 14 and we are also calculating I_0 from equation 3. Therefore we add I_0 with module current. As we can see in figure 5 I_{sc} is slightly increase with decrease in V_{oc} . Change in output current due to change in module temperature is shown in equation 16.

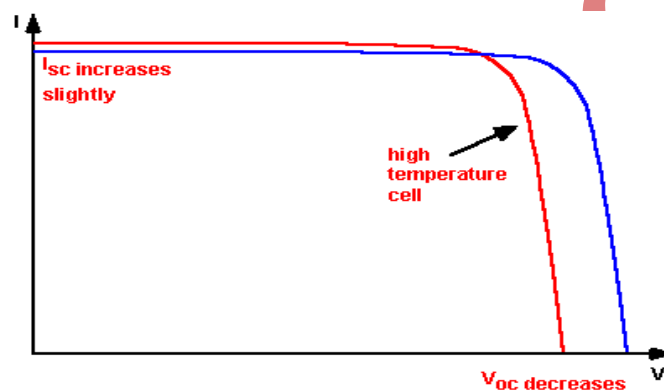


Fig. 5: The Effect Of Temperature On The IV Characteristics Of A Solar Cell.[3]

$$\Delta I_{module} = \left(I_{module} \cdot \left(1 + (M_{temp} - 25) \cdot \left(\frac{0.1}{100} \right) \right) \right) - I_0 \quad (16)$$

Condition 2- Effect of solar irradiance on module voltage if irradiance is $< 1000 W/m^2$

As we know that, irradiance is not stable in nature and there are rapid variations. Solar irradiance does not reach to its maximum value every time i.e. $1000 W/m^2$ throughout the day. The variations in irradiance not only will affect the current but also voltage of a module. To simulate change in module voltage we introduce regression coeff. $refchng$ (β) as we explained earlier in equation 11a. The module voltage will face exponential or logarithmic change due to change in solar irradiance. We illustrated this scenario by equation 17. It states that if solar irradiance is less than $1000 W/m^2$ and varies with time then effect on module voltage will be deduction in module voltage with product of irradiance regression factor $refchng$ and natural log of $1000 -$ solar irradiance.

$$\Delta V_{module} = \left(V_{module} - (\ln(1000 - ir)) \cdot refchng(\beta) \right) \quad (17)$$

3.2 PV String Mathematical Modelling

3.2.1 Design Formulation For String

String is nothing but No. of PV modules connected in series connection. The string in PV array decides output voltage of PV array field of a power plant. For example, if want to generate $70 V$ dc voltage and we are having $50 W$ PV module with V_{max} of $35V$ so we have connect two PV module in series to make a string which will

generate 70 V at standard atmospheric conditions. In case of simulator, to design string it is important to find No. of modules needed in a string based on given estimated voltage and module specified. (for eg.290 w module.)

$$\text{No. of modules in a string} = \frac{\text{Estimated voltage}}{V_{\max}} \quad (18)$$

$$V_{\max} = (\text{volts}) \cdot (\text{No. of PV cells}) \quad (18a)$$

Or

$$\text{No. of modules in a string} = \frac{\text{Estimated power}}{P_{\max}} \quad (19)$$

3.2.2 Simulation Formulas For String

All other simulation formulas used are same as module simulator except module voltage, module voltage will be multiplied by total number of modules connected in a string.

$$V_{\text{string}} = V_{\text{module}} \times \text{Total No. of modules in a string} \quad (20)$$

3) PV Array mathematical modelling

3.2.3 Design Formulations For Array

Array is made by connecting strings of PV module in series or parallel connection to meet our power requirement from PV array field. Mostly in solar arrays all the strings are always connected in parallel. Array defines current output required from PV field. In case of Solar array now there are two factors are important Array voltage and array current. Array voltage is equal to String voltage i.e. string decides the voltage of array as well as field. Array current is defined by no of string connected in parallel mostly dependent on no. of channels in array junction box (AJB or SMB).

$$\text{No. of PV modules} = \frac{\text{estimated power} / P_{\max}}{\text{total No of strings}} \quad (21)$$

Or

$$\text{No. of PV modules} = \frac{\text{Estimated voltage}}{V_{\max}} \quad (22)$$

3.2.4 Simulation Formulas For Array

Simulation formulas are same as module and string simulation except array voltage and array current.

$$V_{\text{array}} = V_{\text{string}} \quad (23)$$

$$I_{\text{array}} = I_{\text{string}} \times \text{Total No. of strings in PV array.} \quad (24)$$

4) PV Field mathematical modelling

3.2.5 Design Formulation For Field

The term field is not used prominently in the industry because PV arrays are built for generating power in power plant but since it is type of energy harvesting therefore we use the term PV array field to pronounce solar power plant. Solar array field is nothing but No. of PV arrays connected together across solar inverter or to grid inverter to generate the power. In here Field voltage and Field Current are defined by No. of modules in a string and total No. of strings in a field respectively. No. of arrays are in a field are also important here while designing.

$$\text{No. of PV modules in a string} = \frac{\text{Estimaed voltage}}{V_{\text{max of PV module}}} \quad (25)$$

$$\text{Total Pv modules in PV array} = \frac{\text{Estimaed power}}{P_{\text{max of PV module}}} \quad (26)$$

$$\text{Total Pv strings in PV field} = \frac{\text{Total modules}}{\text{No of PV module in a string}} \quad (27)$$

$$\text{No of arrays in a PV field} = \frac{\text{Total PV strings}}{\text{No of PV strings in a single array}} \quad (28)$$

3.2.6 Simulation Formulas For Field

We are already calculating total number of modules and total number of strings connected in field of arrays, as we can see it in equation 26 and 27. Therefore, simulation formulas will remain same for field simulations.

5) Calculations for constants

3.2.7 For Time Constant (T)

Here we can see the solution for finding out the τ , which we have used in equation 7. τ is nothing but time constant for heat transfer in ambient temperature.

$$\Delta T_{\text{ambient}} = T_{\text{ambient}} - T_{\text{ambient}} \cdot \left(e^{\frac{-\text{time}(C)}{\tau}} \right)$$

Based on experiment:

Tambient = 60° C

Changed ambient T = 59.6°C

Time = 3 sec (i.e. 0.05)

$$59.6^{\circ} C = 60^{\circ} C - 60^{\circ} C \cdot \left(e^{\frac{-(0.05)}{\tau}} \right)$$

$$\tau = 0.00995.$$

3.2.8 For Refchng:

We observed that for typical (156X156) Poly crystalline solar cell there is 11mv change in VOC per 10 W/m² [3]. Studies show that a cell generates 600 mv against the full sun spectrum. Using above information we can find *refchngecoeff*.

$$11 \text{ mv} = 600 \text{ mv} - \ln(1000 - ir) \cdot \text{refchnge}$$

$$\text{Refchnge} = 0.085776$$

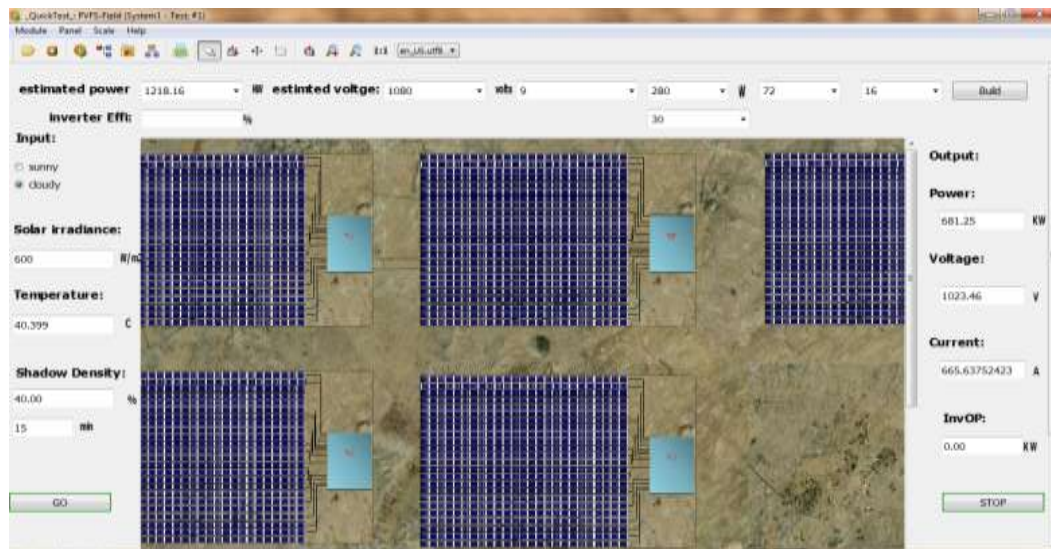


Fig. 6: PV Field Simulator Using Ivisionmax

IV. RESULTS AND VALIDATION

To verify the simulation and mathematical model, we studied couple of power plants and also we performed experiment on Solar cells, so that we can validate our model and simulation results by comparing them with the results from experiment and data collected from power plant.

4.1 Experiment Done Over Solar Cells

We performed experiment on 3 kinds of solar cells; all three solar cells are top end polycrystalline solar cells available in market. They differed from each other based on cell efficiency.

We used 16.10%, 17% and 18% efficiency solar cells and performed test on them with effect of solar irradiance and temperature variation. The set up for solar cell experiment is shown in figure 7.

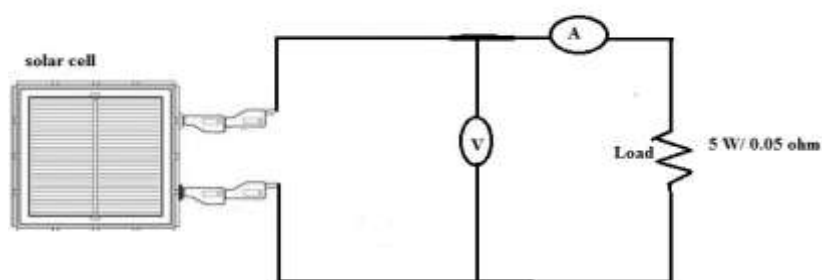


Fig 7: Setup For Solar Cell Experiment

Specifications:

Cell 1: 4.38 W (cell eff. 18 %) $V_{max} = 35$ V, $I_{max} = 9.01$ A

Cell 2: 4.13W (cell eff. 17 %) $V_{max} = 35$ V, $I_{max} = 8.49$ A

Cell 3: 3.91W (cell eff. 16.1 %) $V_{max} = 35$ V, $I_{max} = 8.04$ A

TABLE II
Comparison Results Between Experiment Results And Simulation Results

Time	Irradiance (W/m ²)	M. temp. (°C)	Actual power (W)	Simulated power (W)	Error (%)
Cell 1					
10:45	310 w/m ²	42 °C	1.19 W	1.26 W	-5.88%
10:59	252 w/m ²	53 °C	0.92 W	0.99W	-7.6%
11:53	296 w/m ²	55 °C	1.02 W	1.06W	-3.7%
Cell 2					
12:33	317 w/m ²	45.2 °C	1.14 W	1.19W	-4.3%
12:36	278 w/m ²	46 °C	0.97 W	1.04W	-7.2%
1:02	252 w/m ²	51.4 °C	0.91 W	0.93W	-2.1%
12:50	167 w/m ²	50.9 °C	0.60 W	0.61W	-1.6%
Cell 3					
13:18	287 w/m ²	51 °C	0.97W	1.00W	-3%
13:26	266 w/m ²	54 °C	0.92 W	0.92W	0%
13:45	272 w/m ²	56°C	0.88W	0.93W	-1.6%

From table II, we can see that, we got error within $\pm 10\%$ which is allowable in case of simulator. Therefore we can say that our system is near to accurate and within the permissible range right from solar cell to solar array field, Which validates our simulator as we compared the simulated results with actual results from the field.

4.2 Case Study 1- 50 KW Power Plant (L&T)

Structural design:

Type of module: 180W (bp)

$P_{max} = 160$ W

$V_{max} = 35.2$ v

$I_{max} = 4.7$ A

No. of cells in module = 60 units.

Total No. of modules in Power plant = 300 units; Inverter efficiency = 96 %

In a Power Plant, it is observed that there are two types of Array boxes are used, they are all 5 channel Array boxes classified as “Array junction Box” (AJB’s) and “Main junction Box”. First small String are made of 4 No. of modules. 5 strings are connected to each(parallel) array junction box. And 3 AJB’s are connected to Main Junction Box so eventually 12 modules are making on big string connected to Main Junction box’s one channel.

Therefore,

Total no of small strings: 75 units

Total no of big strings: 25 units

Modules in small string: 4 units

Modules in big string: 12 units

Main array Junction Box: 5 units

Table III shows comparison of results from simulator and L&T power plant, we can see the error of the comparison result is within the allowable range of error. We compared power generated by 50KW power plant with our simulated results for the same weather conditions as we can see it in table.

TABLE III
Comparison Results Of L&T P/W Plant And Simulation Result

Date & time	Solar irradiance	Module Temp.	Power (actual)	Power (Simulator)	Error (%)
10/06/14 2.15 PM	198.6 W/m ²	63.2 °C	9.49 KW	9.42 KW	0.73%
5/08/14 10.52 AM	126 W/ m ²	31 °C	6.687 KW	6.57 KW	1.7%
5/08/14 10.52 AM	147 W/m ²	31 °C	7.449 KW	7.66KW	-2.8%
5/08/14 10.53 AM	208 W/m ²	31 °C	10.14 KW	10.85KW	-7.00%
5/08/14 10.53 AM	201 W/m ²	31 °C	9.792 KW	10.48KW	-7.02%
5/08/14 10.53 AM	203 W/m ²	31 °C	9.887 KW	10.59KW	-7.1%
5/08/14 10.53	205 W/m ²	31 °C	9.918 KW	10.69KW	-7.7 %

4.3 Case Study 2- 1 MW Power Plant, Enrich Energies, Solapur.

We studied 1MW power plant situated in Solapur, from Enrich energies LTD. the comparison results of 1mw power plant and simulation results are shown in table IV. First two readings from the table are from same day dated 26/5/2014 time 13.43 pm and 16.14 pm respectively. Next three reading are of same power plant taken earlier dated 26/11/2013 time 16.41 pm, 29/11/2013 time 12.15 pm and time 12.15.33 pm respectively.

TABLE IV
Comparison Between 1 Mw Plant & Simulation Result

Irradiance (w/m ²)	Ambient temp. (°C)	Module temp.	Actual Output (KW) (Enrich)	Simulator Output	Error (%)
		(°C)		(KW)	
804 W/m ²	38.04 °C	51.49°C	703.00KW	704.39KW	-0.2%
190 W/m ²	38.75 °C	51.25°C	173 KW	165.11KW	4.5%
142.2W/m ²	31.50 °C	42.00°C	117.80KW	126.42KW	-7.3%
464.19W/m ²	26.14 °C	35.00°C	395.60KW	422.93KW	-6.9%
469.97W/m ²	26.24 °C	35.20°C	419.50KW	427.29KW	-1.1%

From table we can see that by comparing results from our simulator with actual Power plant output results, we achieved accuracy within $\pm 10\%$ error which is within the allowable margin of error. The error after comparison between experiment results, collected data from power plants and simulated results is varies from $- 7.7\%$ to $+ 4.5\%$. From these results we can say that our simulation model for studying the PV solar Array field incorporated with solar irradiation and temperature variation is near to accurate. Finally, based on the analyses performed for this work, we can help to inform one of the most problematic issues of project acceptance from a commercial perspective – that of the appropriate allowable Error margin to attach to a system rating result.

While a full uncertainty analysis is outside the scope of this paper, we can point out the largest source of error in this type of test. They include:

- Model uncertainty, which we estimate at -7.7 to 4.5%
- Solar Irradiance measurement uncertainty, which ranges between 2-5%
- Module temperature measurement uncertainty, which ranges between 2-4%

Therefore, we estimate that total Error in the comparison results of power output of Solar array field studied and tests done on solar module with the simulated results will be -4.95 to 5 %.

V. CONCLUSIONS

From above study and research we can conclude that, change in atmospheric conditions such as humidity, wind, dust and edging will lend us on showing change in temperature of array and irradiance of sun. So if we consider effect of temperature and irradiance parameters, we can obtain power output solar cell of solar field, we can able to estimate and predict output power of whole solar field. Our main goal is to model and simulate the PV solar array field to study and analyse the output change in the PV Solar array according to solar irradiance and temperature variation. With solar irradiance and module temperature we also added shadow density as another input which will mimic cloudy condition effect with time of shadow present over module. We hope we validated our simulation model by comparing the results from PV Power plants and results from our PV simulator. Hence we achieved our objective of modelling and simulation of PV solar array which can helps us to study and analyse change in nature of PV array fields output with respect to change in atmospheric conditions.

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