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Enhanced PV Solar Power System Design with a MPPT Controller as a Function of Temperature

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Abstract**:** ***Solar PV power generation is the best option compared to the fossil fuel based power plants now-a-days .Definitely the thermal and nuclear power plant will retire in the future due to the development of the above mentioned .It is extensively developing in the world compared to other renewable options in hand ,cost of manufacturing and installation costs are coming down .This paper discusses an enhanced PV solar power system design with a MPPT controller as a function of temperature compared to other techniques where dealt with variable sunirradiance ,unshaded ,partial shading. This will help designers and maintenance directors in designing stage and maintenance process.***

Index Terms**:** ***Partial shading, Solar Array, Power Converter, sun Irradiance, Temperature Effect.***

I. INTRODUCTION

The solar ,wind and tidal are renewable energy resources which are abundant in nature .Now-a-days these are the options for the massive power production.The demand for PV generation systems is growing in the power system distribution area [1].The sun irradiance is 1345 w/m^2 ,but some of it is deflected and the irradiance reaching earth is 1000 w/m^2 .MPPT algorithm tracks the GMPP to changing temperature and sun irradiance .Since the solar installations are costly affair ,many techniques were proposed in past,present such that maximum power is extracted from solar array at all times since higher returns or revenue is expected from it .Each of the past techniques has its own drawbacks , many of them failing to track GMPP quickly[2].

This paper presents the development of MPPT controller as a function of temperature where as past MPPT controller methods worked on changing insolation and partial shading conditions is dealt.Using this algorithm ,maximum power is transferred and time to track global MPP is decreased and reduction of oscillations in the steady state[3] .When a load is connected to PV array directly it may not be operating in the GMPP .Power Electronic interface is used to control the power to load ,multiple well known direct control algorithm are used to perform the maximum power point tracking (MPPT).

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MPPT algorithms are used to control the duty cycle or the operating voltage of a photovoltaic system to ensure maximum power at all times .In industry field perturb and observe (P&O) is used compared to other algorithm the power generated from the PV array is observed and correspondingly duty cycle or operating voltage is adjusted to operate in GMPP. Incremental conductance (Inc-Con) is robust in nature ,but complex with respect to P&O ,here duty cycle is adjusted ,when incremental conductance is compared instantaneous conductance to track GMPP many experiments revealed that at some percentage of the module open circuit voltage occurs MPP and it is 80% ,this is the basis for the Fractional open circuit voltage (FOC) [4].PID controller in practice with tuned parameters we get reduced overshoot and risetime in the output voltage .This will reduce the oscillations in tracking the MPP[5].

II. MATHEMATICAL MODEL OF PV CELL

A. Ideal single diode equivalent circuit

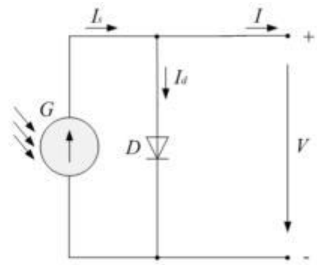

Fig. 1: Photo voltaic cell equivalent circuit

The equations are

$I_d=I_o*[exp(V_d/V_T)-1]$ (1)

$V_T=KT/q$ x nI x Ncell (2)

B. Practical single diode equivalent circuit

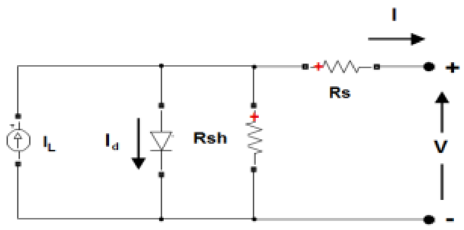

Fig. 2: Practical single diode equivalent circuit

PV module modeling is based on the following non linear equation (Rp=Rsh).

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$$I = I_{ph} - I_0\left(e^{\frac{V}{n_s V_T}} - 1\right) - \frac{V+IR_s}{R_p} \qquad (3)$$

At maximum power point situation

$$I_{mp} = I_{ph} - I_0\left(e^{\frac{V_{mp}+I_{mp}R_s}{n_s V_T}} - 1\right) - \frac{V_{mp}+I_{mp}R_s}{R_p} \qquad (4)$$

The equations at temperature T are

. Voc_T=Voc(1+beta_Voc(T-25)) (5)
Isc_T = Isc (1+alpha_Isc(T-25)) (6)

III.Modelling of PV cell

The PV module is (TS250-Tata solar) this model below can be used for both unshaded and shading scenarios .In this paper the effect of irradiance ,partial shading and main effect of environmental temperature that leading to enhancement of present solar system design in KLEF are discussed.This concept can be applied to solar systems worldwide.

Fig. 3: Matlab model for unshaded/shaded for one PV module.

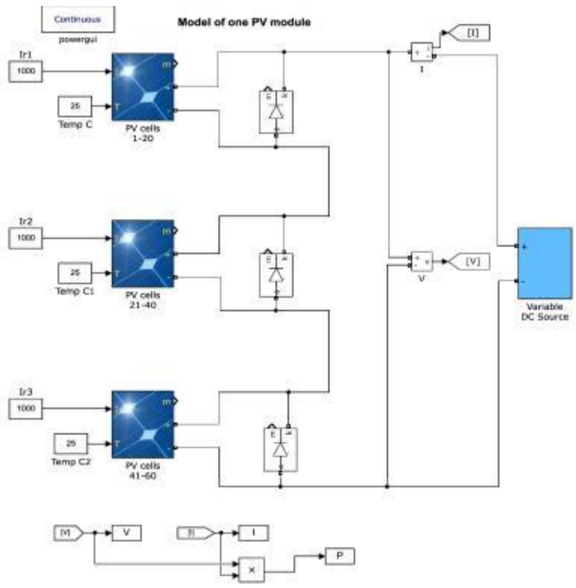

Table-1:Electrical parameters of (TS250 module of KLEF)

Dimensions	1667x1000x33mm
Weight	19.1kg
Cell no	60 multi crystalline
Nominal ouput power (Pm)	250W
Vm	30.17V
Im	8.16A
O.C Voltage(Vm)	38.1V
S.C. current(A)	8.58A

IV .Results and discussion

A. Observation I: I-V and P-V characteristics of PV cell under variable irradiance and constant temperature conditions.

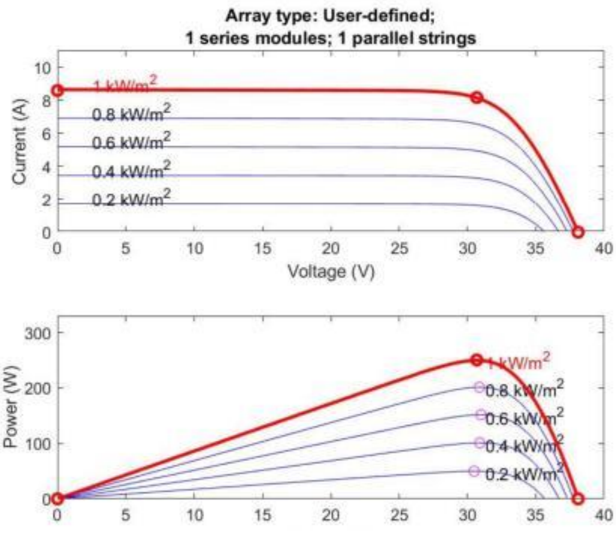

Fig. 4: PV characteristics under function of irradiance

The curves are for different sun irradiance and they have only one maximum point at different irradiation.The temperature is maintained constant at 25^0c and this is standard test condition (STC)value.

Table-2: Simulated Results

Irradiance(kw/m^2) at temperature 25ºc	Voltage(Vm)	Power(Pm)
1	30.7V	250.5W
0.8	30.9V	201.4W
0.6	31.02V	151.8W
0.4	30.91V	101.8W
0.2	30.51V	49.8W

B. Observation II: Global characteristics of PV module under partially shaded condition (figure -3 reference).

The module is having three strings each having 20cells each and given standard irradiance of 1000w/m^2 to first one and partial shading irradiance of 300w/m^2 and 600w/m^2 to second and third strings respectively.

The Global maximum (Pm=104W) which is 34% less than the expected (250/3*(1+0.3+0.6)=158W).Bypass diode protect the modules when cells are shaded or damaged

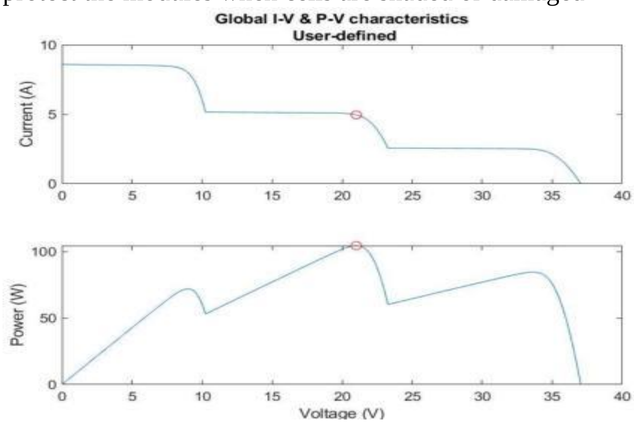

Fig. 5: PVcharacteristic under the effect of shading

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So many multiple peaks are there but one with the red circle is global maximum power point (GMPP) which is important and the mppt should locate this point accurately.

C. Observation III:PV characteristics under different temperatures.

Table -3: Electrical parameters at Normal operating cell Temperature (NOCT).

Parameters	Value
NOCT	47 +/-2
P max	180W
Vmpp	151.8W
Impp	6.64A
Temperature coefficient of Pmax(%/°c)	-0.4383

An approximate expression for calculating the cell temperature is given by Tcell=Tair+(NOCT-20)S/80, S-irradiance.

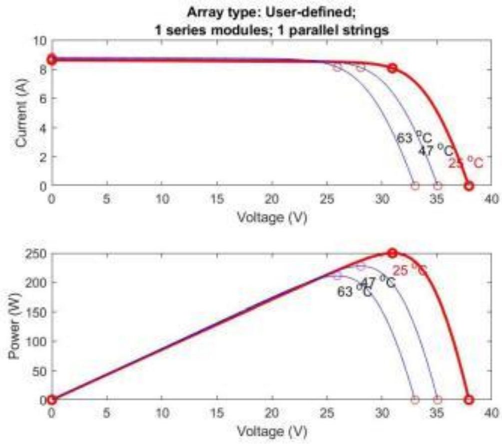

Fig .6: PV characteristic as a function of temperature

Under STC conditions (1000w/m^2,25°C) the module output is 250W .But at NOCT the module output in practice is 180W (20°c ambient+ 800w/m^2).In KLEF area ambient is 33°c taken.Then the cell temperature is 63°c which give a power output 170W.

Table- 4: Simulated Results

Temperature(°C)	At1000 irradiance	At800Irradiance(NOCT)
25	250W	---
47	227.6W	180W
63	211.1W	170W

D.Observation IV:Power –time characteristics of MPPT model as a function of variable irradiance and variable temperature (INC-CON algorithm+integral regulator).

Table- 5: Ratings of KLEF Solar Power system

Specifications	System 1	System2	System3	System4 (proposed)
PVmodules	108	60	108	49
Power from PV aray(KW)	27	15	27	26
Technique used by mppt	Perturb& Observe	Perturb& observe	Perturb& Observe	Perturb& Observe/I&C
Dc link voltage	760	760	760	760
Inverter (KVA)	30	15	30	30
Inverter type	3 level IGBT bridger	3 level IGBT bridge	3 level IGBT bridge	3 level IGBT bridge
Inverter control	SRF	SRF	SRF	SRF

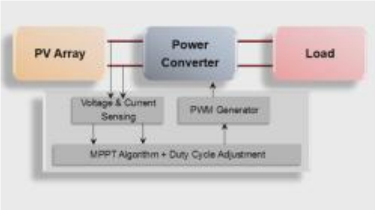

Fig .7: General Block diagram of MPPT model

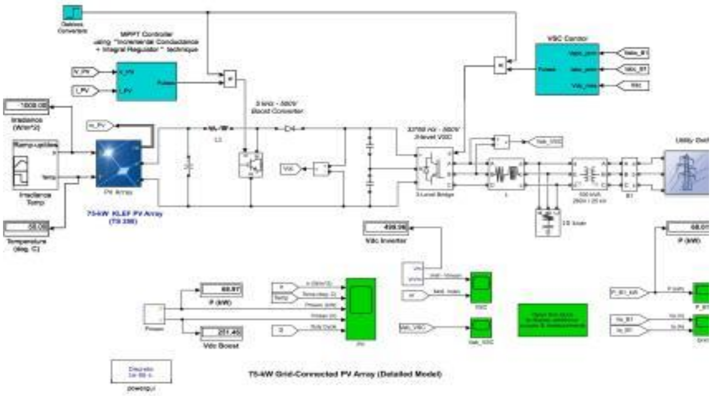

Fig.8:Matlab model for MPPT+IN-CON+Integral Regulator (69KW Array).

This MPPT model gives information about the temperature impact.Actually solar array consisting of (TS250) modules has to generate 69KW as intended ,but at 50°c,it is generating only 62kw because of temperature rise.

Take INC-CON algorithm for simulation purpose for newness,P&O also give the same results

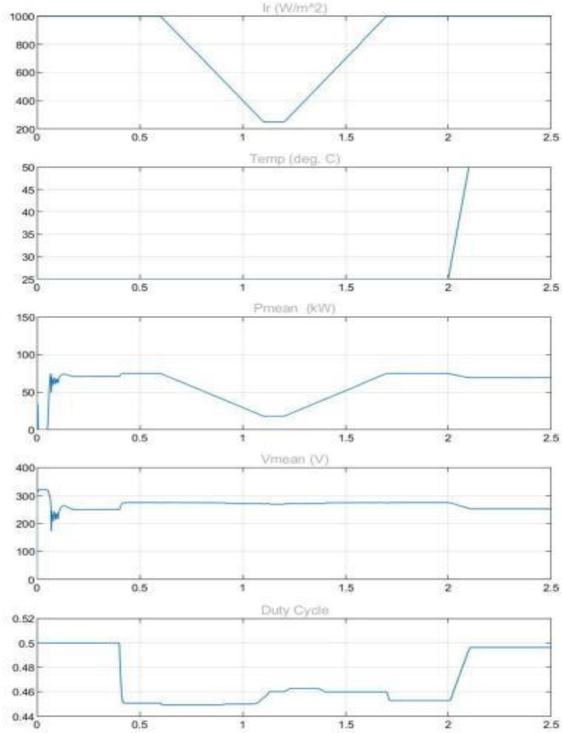

Fig.9: Power-Timecharacteristics as a function of irradiance and Temperature.

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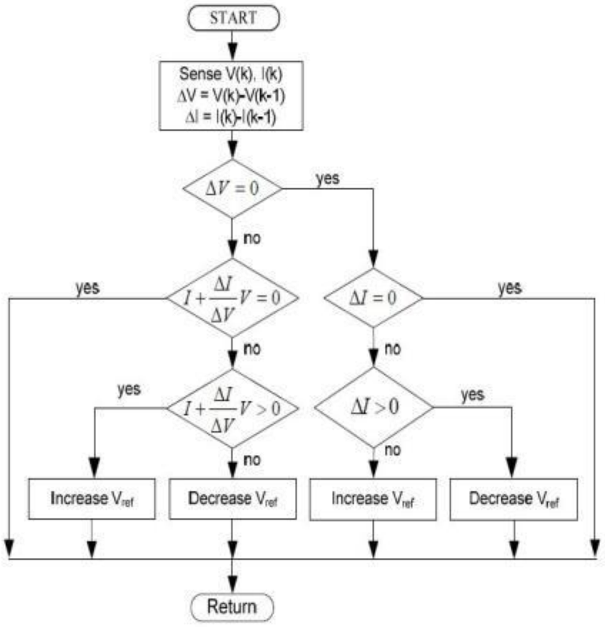
Table -6: Simulated Results.

Module Temperature(ºC)	Power(Pm) At 1000 irradiance	At 800 irradiance NOCT
25	69KW	---
47	62.84KW	50.72KW
50	61.99KW	---
63	58.32KW	46.65KW

Taken the last reading at the table that is 63ºC corresponding to 58.32KW for analysis .Since the ambient temperature is 33ºc in KLEF so the module surface temperature will be 63ºc(33+30).

V. Flow Chart



Flowchart for the Incremental Conductance method

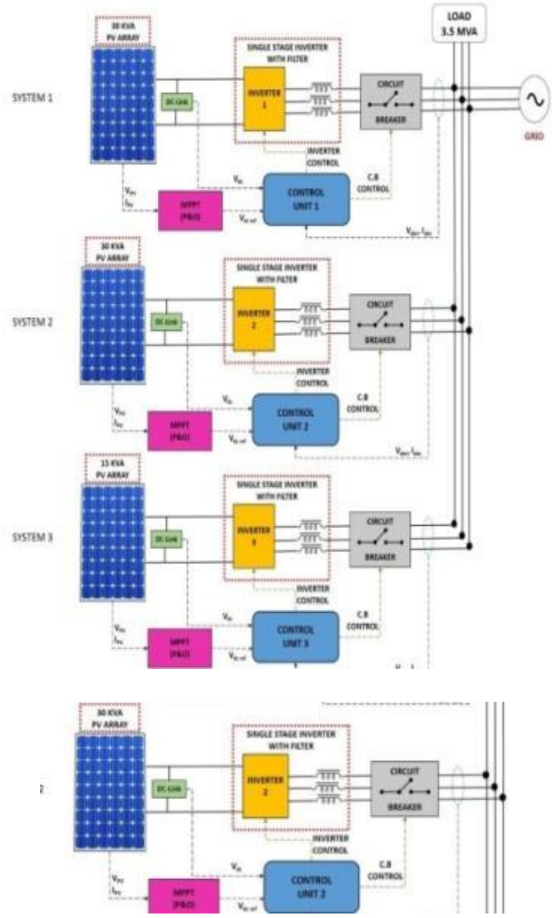
VI. KLEF Solar Power System

Fig.10: KLEF PV Installations.

Three number of systems are there in KLEF with 276 nos of modules of 250W individual capacity each so designed to have a total capacity of 69KW (276*250W).
Due to temperature effect,the module is derated from there Nominal capacity that is from 250W to 211W.
So the overall installed capacity derated from **69KW to 58.32KW**.For generating the power this much only available .Nearly 12KW power capacity is lost.
The system power output is having a reduction of 15% because of temperature effect.
But due to soiling ,shading ,mismatched modules ,cable loss connectors,light induced degradation of the array ,inverter efficiency etc.The derating factor is taken as 10% extra.So the overall derating factor is 0.75 to be applied to the installed capacity to get available capacity.

Available capacity=overall derating factor* installed capacity

Block diagram of the overall system proposed



VII. Techno-Economic Analysis

Cost of 1 unit of energy is =Rs 6.41/KWH.The installed capacity is 69KW at STC conditions.
So it generate annually (nominal value)
Peak Sun irradiance taken -5KW/m^2
STC value=69KW*5*365=1,25,925KWH------(1)

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In real world conditions it will generate theoretically
Overall derating factor taken----0.75
=STC value *overall derating factor=94,443KWH
Practical measured energy from (solar –log 2000 GPRS)
Hardware connected to the computer through a router
Annually is ----90,000KWH-----------------------(2)
Difference from(1) and (2) that is the STC value and the practical value is 35,925KWH.
So the units difference back calculated to get
Overall lost capacity =35925/(5*365*0.75)=26KW
So while designing the system only the 69KW nominal peak capacity taken so add 26KW lost solar power is necessary to add to the peak value. The deficit units corresponding to lost solar power taken from GRID for internal power usage instead of that the central idea is that if 26KW lost solar power as system-4 is to be added to the overall system. Now the new installed capacity is 95KW (69+26KW) out of which now full 69KW initial designed capacity is available for power generation.

Saving in Electricity billing charges per annum is, as per enhanced design is =35,925*6.41=2,30,280 Rs

Taken a particular Block in the campus for reference to apply the idea of enhancing the design if other blocks are also taken into the picture and huge savings will be obtained .This method may increase the installation cost, but long term returns are more beneficial to us and overall quality is improved.

VIII. CONCLUSION

India and other countries in the world wants solar installations in all the states .So in coming years there is a clear targeblet it wants all the power from solar panels which is achievable more over it also adds to the environmental benefit that' is reduction of green house gases .variation in ambient temperature will derate and reduce the life of the solar array.While selecting the solar panels for applications normally some margin of wattage is selected .Check the ratings with respect to temperature and ambient temperature of the site where it is installed such that deration is tackled .This will benefit designers and maintenance personnel .Secoundly at night the PV systems is dead so at day with the enhanced design extra units are supplied to campus usage /to grid .And at night we can take from grid source or batteries in campus if energized.

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