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Design of Fast Acting MPPT for Solar PV array fed water pump driven by BLDC

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Abstract. Sunlight based water siphoning frameworks is a star dynamic methodology in rural applications. This paper presents demonstrating of Photo-voltaic (PV)panel, Maximum power point tracking(MPPT) controller considering slope climbing, irritate and watch calculations, displaying of Brushless direct current (BLDC) engine. PV board associated with burden with and without MPPT controllers is mimicked and results are exhibited. The exhibitions of BLDC engine with variety of irradiance are displayed

Keywords: Solar water pumping, PV System, BLDC Motor.

I. INTRODUCTION

Sunlight based Photovoltaic frameworks (SPV) have been in presence since numerous years. The PV frameworks are partitioned into two sorts specifically OFF-GRID (Stand alone) Systems and ON (Grid-Connected framework) in light of use. In an OFF-Grid framework, the power produced from the PV Arrays is used totally by the heap while in ON-Grid framework the power required by the heap is conveyed by PV board and abundance power can be given to the Grid .

There are two sorts of establishment of PV board to be specific settled and turning. By and large power from the PV Panel isn't steady dependably; it fluctuates with barometrical conditions viz., irradiance and temperature. Consequently, to extricate greatest power from the PV cluster and supply it to the heap, a controller circuit must be available between PV board and burden. By and large the controller circuit is charge controller. For all intents and purposes Charge controllers are of two sorts PWM and MPPT Type.

This paper introduces an off-Grid sun powered siphoning framework with BLDC engine for agribusiness applications. It manages MPPT Charge controller for a settled PV Panel .The Motors commonly utilized for horticultural applications are AC Induction Motors [1] and Conventional DC Motors. As of late with investigation of new perpetual magnet materials there is a sharp decrease in their cost, which results in expanded accessibility of BLDC engine. Henceforth Brushless DC Motors (BLDC) are additionally being utilized for household, business and agrarian applications.

The methodology used in this paper is

1. Modeling of PV Panel [2].
2. PV Panel connected to sensitive load with and without MPPT [4-6]
3. PV Panel connected to BLDC motor with MPPT [8-9].

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II. MODELING OF PHOTOVOLTAIC CELL

The sun based cell can be demonstrated as a silicon diode which produces voltage when light is enlightened on it. Sun based cells are consistent current sources and can be spoken to as appeared in the Fig1

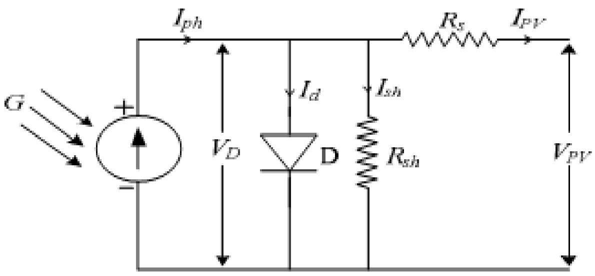

Fig1:mathematical model of PV cell

PV panel is modelled using mathematical equations (1)-(6) as given below

The current from PV panel is given by

$$I_{pv} = I_{ph} - I_d - I_{sh}$$

Where I_{pv} = Current from PV panel I_{ph} = Photo generated Current I_d = Diode current I_{sh} =Shunt current

The Photo generated current is given by

$$Iph = G \times (Isc + (K_i \times (T_{op} - T_{ref}))) \qquad (2)$$

Where G = Irradiation (w/m^2) I_{sc} = Short circuit Current K_i = Temp.Coefficient of I_{sc} (2.2*10^{-23}) T_{op} = Operating Temperature in ^{0}C T_{ref} = Reference Temperature (25 ^{0}C)

The diode current is given by

$$I_d = I_s \times (e^{q \times (\frac{V_{pv} + I_{pv} \times Rs}{Ns \times n \times V_t \times c})} - 1) \qquad (3)$$

Where Is = Saturation Current V_{pv} = PV Panel output voltage R_s = Series resistance (0.01 Ω) V_t = Thermal Voltage = $\left(\frac{K*Tc}{q}\right.$ n = Ideality Factor (1-2) C = Total no. of Cells N_s = No. of cells in series Q = Charge of an electron = 1.602*10^{-19} C

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K = Boltzmann Constant = $1.38*10^{-23}$

The saturation current is given by

$$I_s = I_{rs} \times \left(\frac{T_{op}}{T_{ref}}\right) \times e^{\left(\frac{1}{T_{op}}-\frac{1}{T_{ref}}\right)\times\left(\frac{E_g\times q}{K\times n}\right)} \tag{4}$$

Where the reverse saturation current is given by

$$I_{rs} = \frac{I_{sc}}{e^{\left(\frac{q\times V_{oc}}{K\times C\times T_{op}\times n}\right)}-1} \tag{5}$$

Where E_g = Energy Gap of PV material =1.12ev

The shunt current is given by

$$I_{sh} = \left(\frac{V_{pv}+(I_{pv}\times R_s)}{R_{sh}}\right) \tag{6}$$

The number of cells to be connected to form an array is considered by taking a practical PV Panel electrical data Table 1.The I-V and P-V characteristics of the modeled PV panel conform to the manufacturer data.

Table 1. Manufacturer Electrical data

Maximum Power	252W
Voltage at Maximum Power	31V
Current at Maximum Power	8.1A
Open Circuit Voltage , Voc	38V
Short Circuit Current , Isc	8.95 A

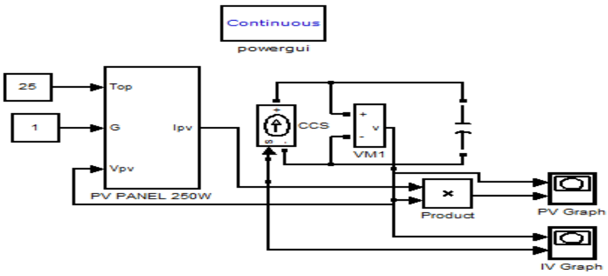
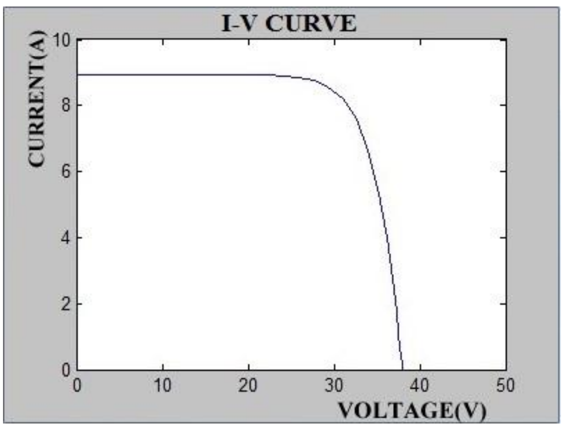


Fig2:simulink model of photovoltaic panel

For instance, for a 250w PV panel as shown in the fig2. The I-V and P-V characteristics of the Panel for an Irradiance=1000w/m^2 & temp = 25^{o}C is shown in the fig3.



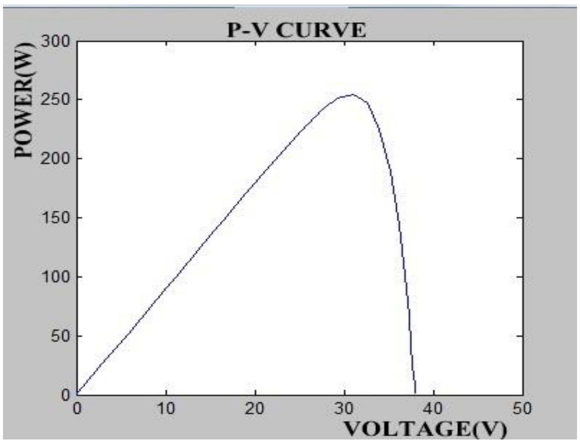


Fig3: I-V and P-V curves of a PV panel

The detail of PV board for the most part incorporate open-circuit voltage (Voc), cut off (Isc), voltage comparing greatest power (Vmpp). For a specific irradiance, greatest power is gotten just at one esteem. For instance, for a 250w board with irradiance of 1000w/m2 and Temperature of 25o/c the greatest power acquired is at 31V as appeared in the fig3. This is called voltage at most extreme power point (Vmpp) .Table II indicates variety of Vmpp with changing irradiance

III. Maximum Power Point Tracking Controller

MPPT Controller is dc-dc converter which can increment or lessening the yield control for a given contribution as appeared in the fig4. It is undifferentiated from a transformer in AC circuits. The voltage can be changed by differing the obligation proportion given to the switch in DC-DC Converter (Buck/Boost/Buck-Boost/Sepic/Cuk converters and so forth)

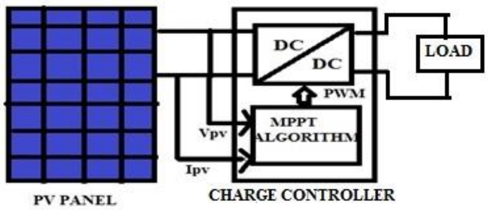


Fig4: PV Panel connected to load with charge controller

A Technique called Pulse width balance (PWM) is utilized during the time spent increment/lessening of information voltage. The yield voltage of a PV Panel is straightforwardly relative to irradiance and conversely relative to temperature.Maximum control from PV board is gotten comparing to a specific voltage (Vmpp) . At that irradiance the voltage is set with the end goal that dependably Vmpp is kept up against the board it is conceivable to extricate most extreme power from the PV cluster.

It is seen that from the I-V and P-V bends of a PV board, Vmpp change concerning irradiance. Following is fundamental to guarantee steady voltage for consistent irradiance.

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The DC-DC Converter [3] as appeared in the fig5 considered here is a Boost Converter. The estimations of 'L' and 'C' are determined dependent on the info voltage and required yield voltage.

The way toward following the most extreme power point as for changing irradiance and keeping up power by then is the essential capacity of greatest power point tracker. Greatest power point tracker comprise a calculation to fix the obligation proportion to be given to the DC-DC converter. As appeared in the fig6 the calculations take the examples of voltage, current from PV board at moment and decide the obligation cycle to be given to DC-DC Converter. The most regularly utilized calculations are Perturb and watch calculation and Hill climbing calculation. [4-6] the simulink model of Hill climbing MPPT calculation is appeared in the fig7. Fig 8 and Fig9 gives the simulink model of PV board associated with 'R' load with and without MPPT controller .

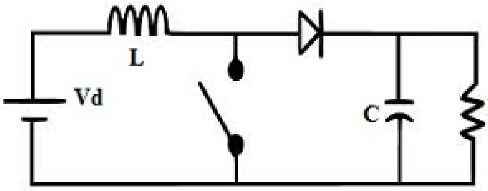

Fig5: Boost converter

For a resistive Load connected to Boost converter the value of 'L' is given by the equation

$$L = \left(\frac{T_s \times V_o}{2 \times I_{ob}}\right) \times \left(D \times (1-D)^2\right) \quad (7)$$

The value of 'C' considered here is very large enough to maintain constant voltage at the load.

The Value of 'L' can be varied in accordance with input, output voltage and power

Where

L = Inductance value in Henry Ts = Switching frequency in Hz

V_O = Output voltage (V) D = Duty cycle or Duty ratio.

I_{ob}= Boundary current (A) I_{ob} determines whether output current is continuous or not

In Boost converter, inductor current and yield current are equivalent. For any expansion in burden, than the most extreme conceivable dimension results in increment in yield current, the increment dimension of current can't be given by the source. Henceforth 'L' and 'C' assurance is Important. It is seen from the over that obligation cycle is required for task of DC-DC converter. Assurance of obligation cycle is practiced with MPPT calculations.

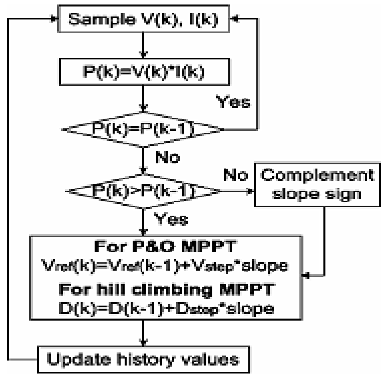

Fig6: P & O, Hill climbing MPPT algorithms

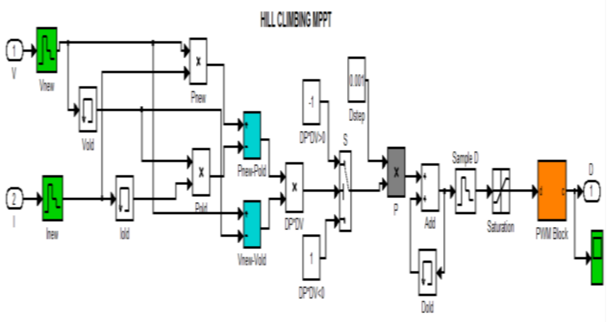

Fig7: Hill climbing MPPT algorithm simulink model

IV. MODELING OF BRUSHLESS DC MOTOR (BLDC)

The most generally utilized engine for siphoning applications is acceptance Motor or Conventional dc Motor. As a result of its tough development Induction engine is utilized in numerous Industries, Commercial and Domestic applications. Traditional dc engines has unrivaled speed controlling procedures and henceforth utilized in numerous enterprises [7-11]. The dc engines are commonly utilized for Constant speed applications, lifts, lifts, cranes and so on. The real downside of brushed dc engine is periodical support because of wear and tear of the brushes. As size of the machine expands it experiences recompense issues. The downside of customary dc engine has been overwhelmed by brushless dc engine (BLDC).BLDC engine as the name proposes does not have brushes and has better execution attributes comparative than Induction engine. Because of end of brushes it has the favorable circumstances like Induction engine and execution better than Induction engine. The capacity of commutator in a traditional dc engine is supplanted by Electronic recompense with static switches as appeared in the fig 8. Consequently BLDC Motor can likewise call Electronic Commutation Motor (EC Motor). The simulink model of BLDC engine is appeared in the fig9. In this work a 1 HP BLDC engine is considered with Photovoltaic framework with MPPT. The simulink model of absolute framework is appeared in the fig

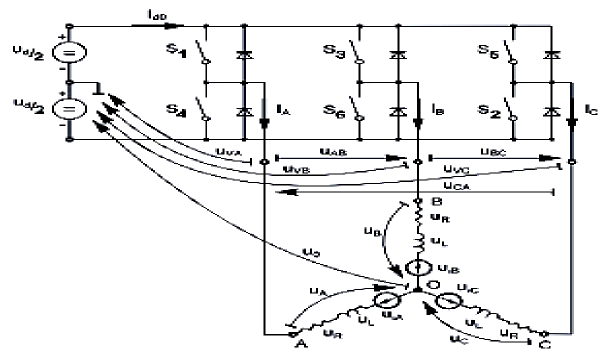

Fig8: Electronic commutation of BLDC motor

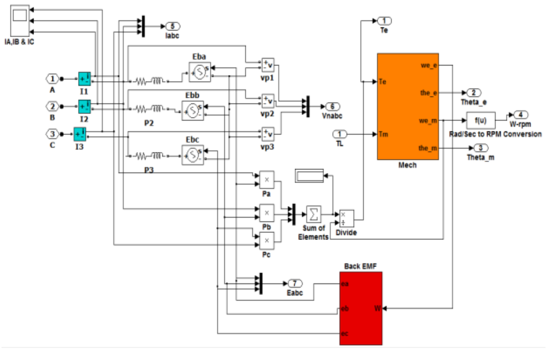

Fig9: Simulink model of BLDC motor

The equations for phase voltages of a BLDC motor is given by

$$V_a = R\times i_a + \left(L\times\frac{di_a}{dt}\right) + e_a \quad (8)$$

$$V_b = R\times i_b + \left(L\times\frac{di_b}{dt}\right) + e_b \quad (9)$$

$$V_c = R\times i_c + \left(L\times\frac{di_c}{dt}\right) + e_c \quad (10)$$

Where Va, Vb &Vc are Phase Voltages (V) R & L are resistance (ohm) and Inductance (H)

Ia, Ib & Ic are input currents (A) ea, eb & ec are Back-Emf's of phases (V)

The equations for Back-emf's of the motor

$$e_a = K_w \times f(\theta_e)\times\omega \quad (11)$$

$$e_b = K_w \times f(\theta_e - \frac{2\Pi}{3})\times\omega \quad (12)$$

$$e_c = K_w \times f(\theta_e + \frac{2\Pi}{3})\times\omega \quad (13)$$

Where ea, eb & ec are back-emf(V) of phase winding K_w= Back-emf constant of one-phase [V/rad.s^{-1}]

=Electrical rotor angle. = $\frac{P}{2} * ($

=rotor speed [rad.s^{-1}]

θ=Mechanical rotor angle

Total Torque output (Te), Nm

$$T_e = \frac{e_a\times i_a + e_b\times i_b + e_c\times i_c}{\omega} \quad (14)$$

The Mechanical part equation is

$$T_e - T_l = \left(J\times\frac{d\omega}{dt}\right) + (B\times\omega) \quad (15)$$

T_l - Load Torque, Nm J - Inertia of rotor and coupled shaft [kgm^2]

B - Friction constant [Nms.rad^{-1}] ω - Speed (rpm)

V.SIMULINK MODEL OF PV PANEL CONNECTED TO LOAD WITH AND WITHOUT MPPT

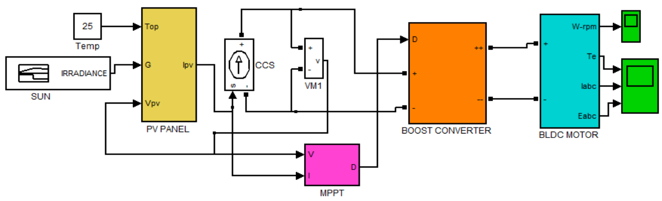

Fig10: Simulink model of Total system

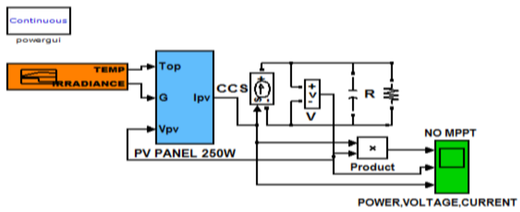

Fig11: PV Panel connected directly to Load

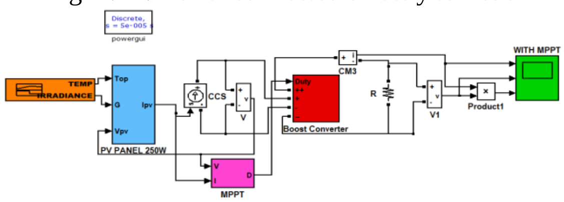

Fig12: PV Panel connected to Load with MPPT controller

PV panel Connected to BLDC Motor with MPPT

The performance of BLDC motor with changing irradiance and constant temperature is depicted in the figures 13(b)-16(f)

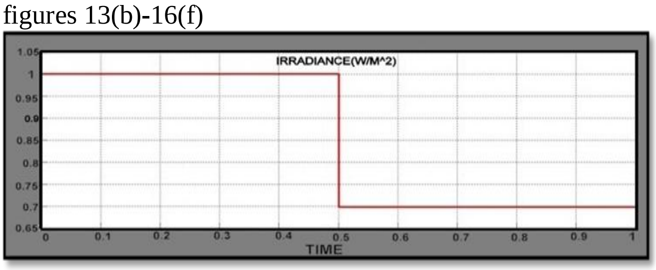

Fig 13(a): Change in Irradiance as Input to BLDC motor

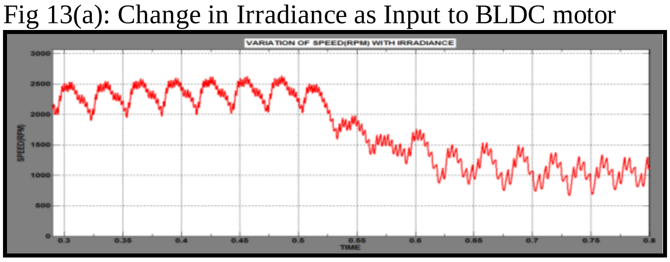

Fig 13(b): Change in SPEED (rpm) with respect to irradiance

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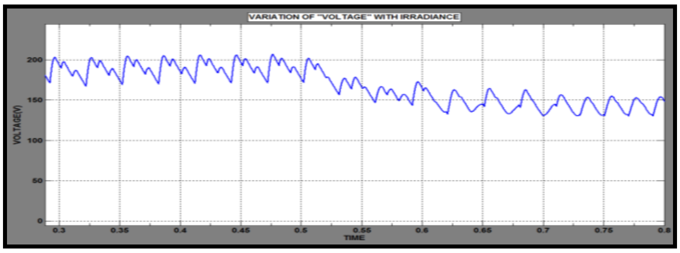

Fig 13(c): Change in VOLTAGE with respect to irradiance

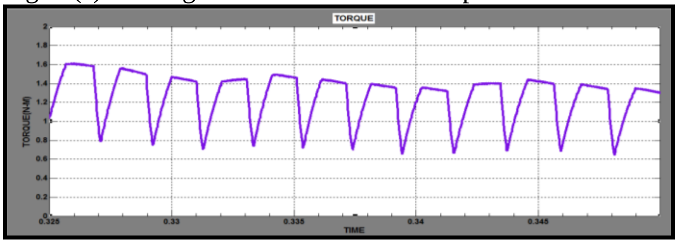

Fig 13(d): Output Torque(Newton-metre) of BLDC motor

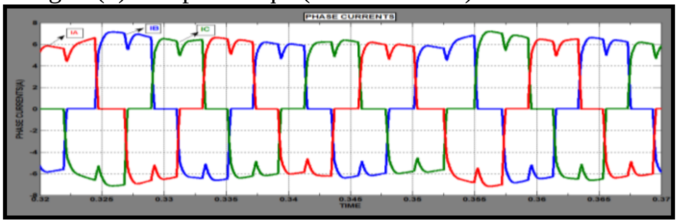

Fig 13(e): Trapezoidal shaped phase currents

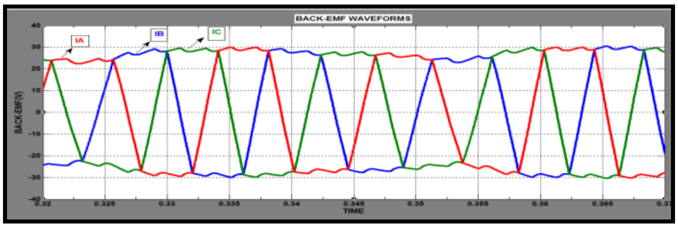

Fig 13(f): Trapeziodal shaped Back-emfwaveforms

The irradiance information considered is appeared in fig 13(a). It is seen that as for change in irradiance there is a comparing change in speed as appeared in fig 13(b), change in information voltage to the BLDC engine as appeared in fig 13(c).The torque as appeared in fig 13(d) is throbbing a result of marvel called cogging, swell. The trapezoidal shape stage flows and back-emf waveforms are appeared in fig 13(e) and fig13 (f). Any endeavor to diminish cogging results in more swells in torque because of deviation from perfect wave shape. Hysteresis or PWM controllers can be utilized to get the rectangular state of machine flows. Torque isn't consistent yet throbbing because of swells happened amid exchanging succession. So as to keep up consistent Torque a Hysteresis Current controller can be utilized.

VI. HILL CLIMBING, P & O MPPT WITH SUDDEN VARIATIONS IN IRRADIANCE

Contingent upon the kind of utilization the calculation is picked. For instance in applications where it isn't important to follow quick changes in irradiance Hill climbing MPPT calculation can be utilized. Also in situations where sudden changes in irradiance must be followed Perturb and watch can be utilized. Two MPPTs are considered for study.The examination of Hill climbing MPPT and Perturb and watch MPPT is done to decide effective following of calculation.

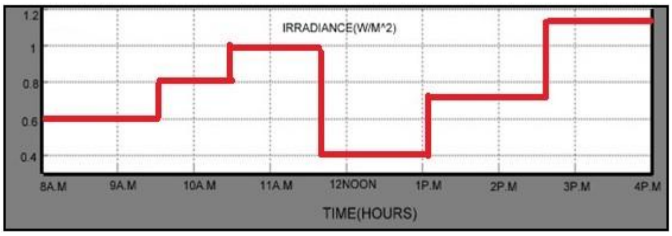

Fig14 (a): Sudden changes in irradiance & temp=25^o/C

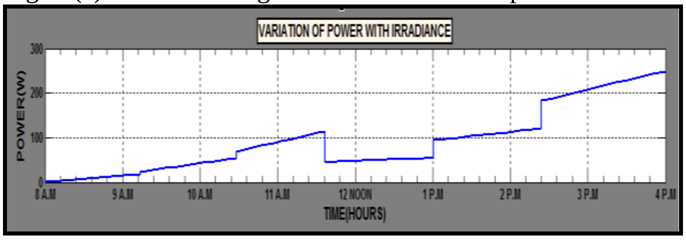

Fig14 (b): Power obtained with PV Panel connected to load

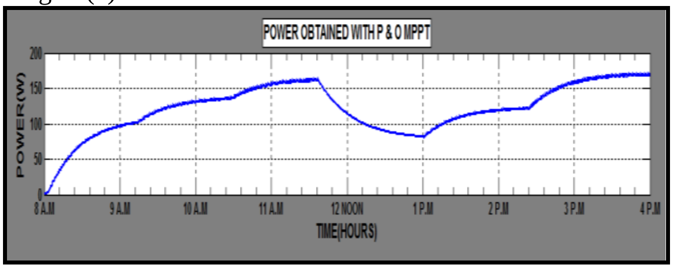

Fig14 (c): Power obtained when PV Panel connected to load with Perturb & Observe MPPT

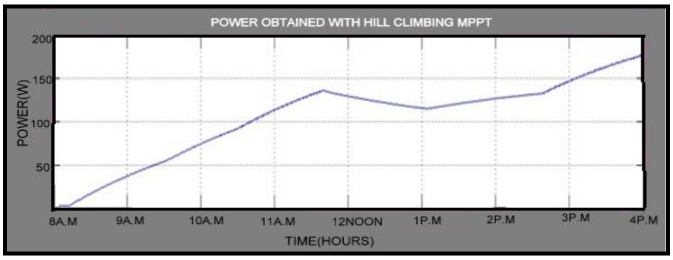

Fig14 (d): Power obtained when PV Panel connected to load with Hill climbing MPPT

The irradiance information considered is appeared in the fig 14(a). It is seen from fig 14(b) the PV board helpless to convey most extreme power when associated specifically to stack. Fig 14(c) and 14(d) demonstrate that with changes in irradiance, the P&O calculation can follow the progressions and keep up most extreme power for specific irradiance while Hill climbing calculation can't follow quick changes and look after power.

Henceforth P and O is reasonable at whatever point sudden changes in irradiance happens, slope climbing is utilized in circumstances where the need to follow the power with changes in irradiances turn out to be genuinely consistent.

VII. RESULTS AND DISCUSSION

The I-V and P-V curves of a PV panel may vary with changes in irradiance and temperature as shown in the fig3 and fig15. The changes output voltage, current, power and V_{mpp} with corresponding changes in irradiance and temperature is tabulated below (Table II)

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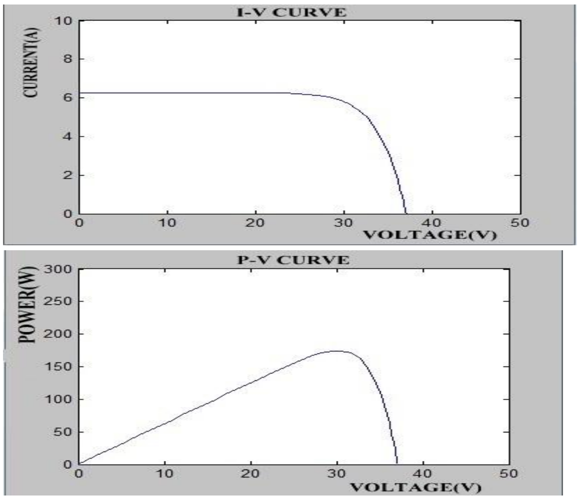

Fig15: irradiance=700w/m^2 and temp=25^o/Centigrade.

Table II Output characteristics of PV panel with varying irradiance and temperature

Irradiance (w/m2)	Tempo /C	Open circuit Voltage (Voc)	Short circuit current(Isc)	Maximum Power(Pmax)	Voltage at max power point (Vmpp)
1000	25	38v	8.95A	252w	31v
800	25	37.45v	7.25A	200w	30v
600	25	36.73v	5.5A	150w	29v
1000	40	36.2v	9A	248w	28v
1000	50	35.02v	9A	230w	28v
1000	55	34.41v	9.1A	225w	26v

From the Table II, it is observed that with respect to changing irradiance and temperature the voltage, current, power & voltage at maximum power point (V_{mpp}) varies. With decrease in irradiance there is a decrease in open circuit voltage, short circuit current whereas with increase in temperature there is an increase in short circuit current, decrease in open circuit voltage.

VIII. CONCLUSION

In this paper, a broad examination of a free PV system for agricultural application is poor down. The examination fuses exhibiting and multiplication of PV energized BLDC motor which can be used for siphoning application. Close execution examination of explicitly related PV siphoning systems with structures using MPPT controller. Exact exhibiting of PV cell has been researched with clear diode tantamount circuit appear. The numerical model of PV module is a manual for have closer examination of the assortment in yield traits with trouble in irradiance and temperature. Slant climbing, pester and watch computations are gotten for MPPT controller. Incline climbing is definitely not hard to execute, recognize and fitting in conditions where dynamic response essential isn't basic. The BLDC motor show responds well with changes in irradiance and temperature. It is seen that with changes in irradiance/temperature there is a relating change in speed, back-emf and stage streams of the motor. The execution of the PV system with MPPT controller is reenacted and affirmed for a resistive weight and for a BLDC motor. MPPT based arrangement offers better essentialness utilization stood out from explicitly related structure. From the diversion results it is seen that, the execution of showed PV based siphoning systems using BLDC motor working elegantly by passing on the torque required to drive the siphon.

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