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Effect of Environmental Parameters on Solar PV Performance with MPPT Techniques on Induction Motor Driven Water Pumping System

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Abstract: A photovoltaic cell produces electrical energy directly from visible light but their efficiency is fairly low and hence is expensive as compared to other available energy resources. Various factors affect pv system efficiency. This paper presents the important environmental factors which affect working of pv system by using MPPT techniques.These effects are Solar Irradiation, temperature, humidity and wind speed. The variation of these factors at different condition has been studied to improve the working of MPPT techniques for more reliable applications. In India, there is a huge demand for energy due to various reasons like industrial development and increasing population. The main drawback in replacing conventional energy sources with new and more environmentally friendly alternative sources such as solar and wind energy is how to capture them for maximum energy and how to deliver the maximum power at a minimum cost for a given load. The output power of photovoltaic cells or solar panels has nonlinear characteristics which are affected by temperature, light intensity, and other environmental conditions and hence it is necessary to study them and rectify them for maximum and output.

To assess the overall performance with varying weather conditions, a PV model based on the Shockley diode equation has been used to predict the electrical characteristics of the cell with regard to changes in the environmental conditions of irradiation, temperature, humidity and wind speed.

Keywords: MPPT, CVC, P&O, P-V, DC-DC CONVERTER.

INTRODUCTION

The utilization of electrical energy is exponentially increasing all over the world because of very high energy consumption resulting in decay of fossil fuels. To overcome this, there is urgent need to explore the sustainable and alternative energy sources e.g. solar, the wind, fuel cell, tidal biomass, geothermal, biodiesel etc. However, each REsource having its own limitation such as PV system has low efficiency because its power output depends on climatic conditions like wind speed, humidity, and temperature also. To enhance the PV system efficiency, various types of maximum power point tracking (MPPT) techniques are reported in the literature.

Among various renewable and sustainable energy sources, solar energy provides the opportunity to generate power without emitting any greenhouse gas. The photovoltaic (PV) system technologies have increasing roles in electric power technologies, providing more secure and pollution free power sources. A photovoltaic system can directly convert solar energy into electrical energy. The current - voltage output of the photovoltaic battery is nonlinear, coupled with changes in the sunshine, temperature, and other factors, the output is constantly changing with varying conditions. The PV array can supply the maximum power to the load at a particular operating point which is generally called as maximum power point (MPP), at which PV system operates with maximum efficiency and hence produces maximum power. This paper highlights the factors that affecting the efficiency of solar pv system with mppt assistance.

APPROACH

A general configuration of the current PV system comprises:

- A stand-alone PV panel
- An MPPT composed of a DC-DC converter topology along with its MPPT algorithm.

- An inverter for AC load is needed.
- A battery bank.

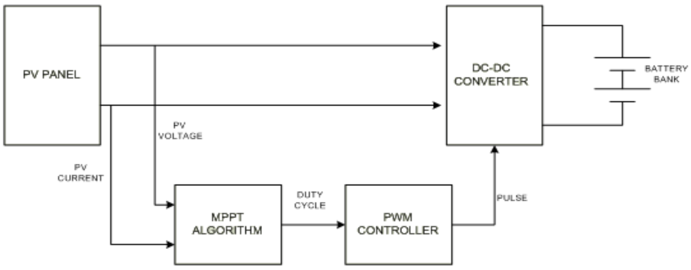

Fig1: standalone PV system

OBJECTIVES AND METHODOLOGY

Two paths are possible in the study of PV solar energy: experimental and numerical simulation. Simulations are numerical experiments that may provide some kind of thermal performance information, as can experimental simulation, and these will be the focus of this research study. The steps used in this research are modeling, programming, simulation and the evaluation of the MPPT techniques.

The objectives of this paper are as follows:

- To determine an efficient MPPT algorithm suitable in PV residential applications in order to extract the maximum possible energy from the panel.
- To provide an optimized MPPT algorithm with fast tracking and low power fluctuation characteristics under changing environmental operating conditions.
- The MPPT techniques assisted PV generated power can be used for simple DC resistive load and also for induction motor load in water pumping system.

The methodology adopted is as follows:

- To investigate and understand the strengths and weaknesses of some classical MPPT algorithms under variable operating conditions.
- To develop a PV model and MPPT model using Matlab and Simulink to assess the performances of the existing MPPT algorithms and address their drawbacks by the use of some optimization solutions suitable in PV residential applications.

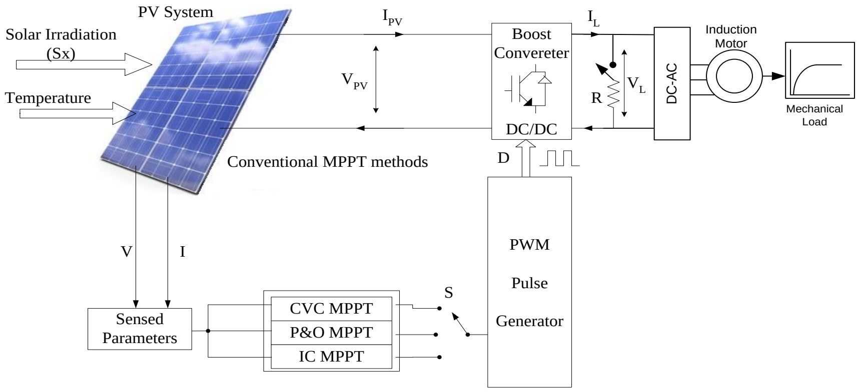

Fig: 2 MPPT Techniques for Solar PV Power Assistance for Induction Motor Driven Water Pumping System

PHOTOVOLTAIC MODEL

PV array is formed by combining various PV cells into series-parallel to generate electrical power. The electrical equivalent circuit of single diode PV cell and module are shown in Figure 3 as,

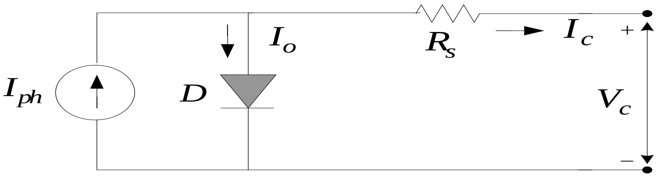

Fig: 3 Equivalent electrical circuits of PV cell

PV cell voltage (V_C) is the function of current (I_{ph}) which depends upon solar irradiation and can be expressed in Eq. (1) as,

$$V_C = \frac{AkT_C}{e}\ln\left(\frac{I_{ph}+I_o-I_c}{I_o}\right)-R_sI_c \qquad (1)$$

The operating temperature T_c of PV cell varies with solar irradiation level S_c and ambient temperature T_a. The temperature dependent correction factor for voltage and current (C_{TV} and C_{TI}) for PV cell are expressed in Eq. (2) as,

$$C_{TV} = 1+\beta(T_a-T_x)\ \&\ C_{TI} = 1+\frac{\gamma_T}{S_C}(T_x-T_a) \qquad (2)$$

The effect of an irradiation level (S_x) dependent of the correction factor, C_{SV} and C_{SI}. The correction factors C_{SV} and C_{SI}. For voltage and photocurrent, are expressed in Eq. (3) as,

$$C_{SV} = 1+\beta_T\alpha_S(S_x-S_c)\ \&\ C_{SI} = 1+\frac{1}{S_c}(S_x-S_c) \qquad (3)$$

Where the reference solar irradiation and actual irradiation level are represented by S_c and S_x respectively. The correction factors C_{TV}, C_{TI}, C_{SV} and C_{SI} are useful to determine the actual values of the PV cell voltage V_{cx} and photocurrent I_{phx}, and expressed in Eq. (4) as,

$$V_{cx} = C_{TV}C_{SV}V_C\ \&\ I_{phx} = C_{TI}C_{SI}I_{ph} \qquad (4)$$

MAXIMUM POWER POINT TRACKING

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel.

It is an electronic system that operates the photovoltaic modules in a manner to extract the maximum power from the system. It is an operating point at which maximum power can be extracted from the system. Usually represented as MPP.

- The output of the solar module is a function of solar irradiance, temperature.
- Generally, MPPT is installed in between PV system and load. Coupling to the load for maximum power transfer may require either providing a higher voltage at lower current or lower voltage at higher current.
- PV modules still have relatively low conversion efficiency; therefore, controlling maximum power point tracking (MPPT) for the solar array is essential in a PV system.

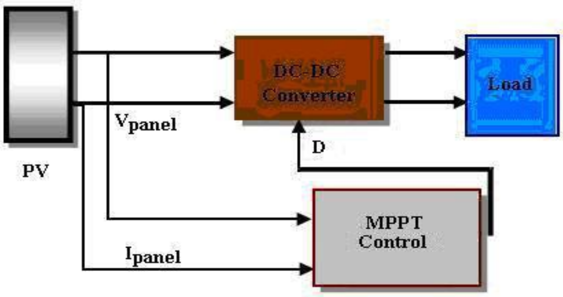

Fig: 4 Photovoltaic MPPT System

Different MPPT techniques

There are different techniques used to track the maximum power point. Two of them discussed here are:

1) Perturb and Observe method (P&O)

2) Constant voltage conductance method (CVC)

Constant voltage controller (CVC) method

This method is proposed to force the voltage across the pv terminals held at a fixed value, typically exact to ensure the most energy pass to the connected load.

The CVC technique is possibly the only simple mppt algorithm. This algorithm may be implemented without a virtual controller. The drawback of the algorithm is that the mpp relies upon at the specific sun panel kind. Consistent voltage control can be done effortlessly with analog equipment. However, mpp monitoring performance of this technique is lower than other algorithms. The block diagram of cvc mppt algorithm is shown as,

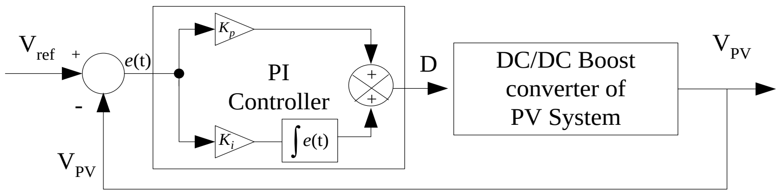

Fig:5 Block diagram of CVC MPPT method.

The proportional-essential manipulate equations can be expressed using eq.5 as,

$$D = K_p e(t) + K_i \int e(t)dt \qquad (5)$$

K_p and K_i are the gains to be adjusted for the preferred output from the pv device. The proportional reaction can be adjusted by way of constant term K_p called proportional gain. The integral in a pi controller is the sum of errors over a time period and gives the accrued offset that has to be corrected formerly. The accumulated error is then elevated by means of the gain (K_i)) and added to the controller output.

Perturb & Observe (P&O) MPPT method

This is one of the typically used appt strategies. In this method, perturbations are carried out to the reference current or voltage signal of the PV mechanism. The steps carried in this method are depicted with the assist of flowchart shown in fig. as,

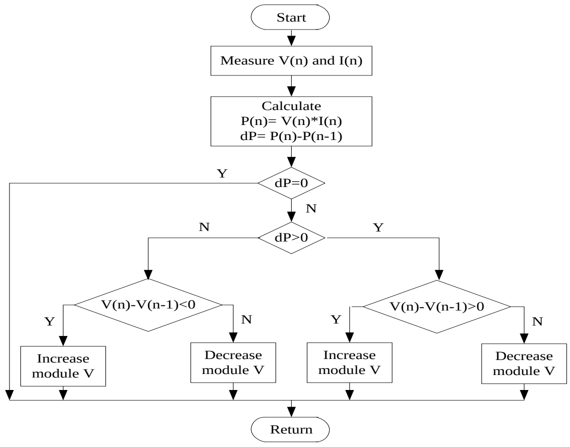

Fig: 6 algorithms of P&O method

In this approach, the voltage of the pv device is considered as a reference signal. The aim of this technique is to force the reference voltage of the pv machine to Vmpp, which immediately forces pv voltage to tune Vmpp which is done by means of applying small and consistent perturbation to the pv voltage a step-by way of-step. After every perturbation, the variant in output power (dp) is measured. A positive change of dp suggests that output is approaching mpp. Consequently, a perturbation of effective sign is applied to the pv voltage in the next stage. On the other hand, if dp is negative, a terrible sign perturbation is applied. Those steps are repeatedly performed until the mpp of the system is reached wherein dp is same to zero.

RESULT AND DISCUSSION

EFFECT OF ENVIRONMENTAL PARAMETERS WITHOUT MPPT

(i) Constant Parameters (Irradiation, Temperature, Wind Speed, Humidity)

Table: 1 Table showing constant parameters values

Irradiation	temperature	humidity	Wind speed
550W/m^2	298K	10%	4m/s

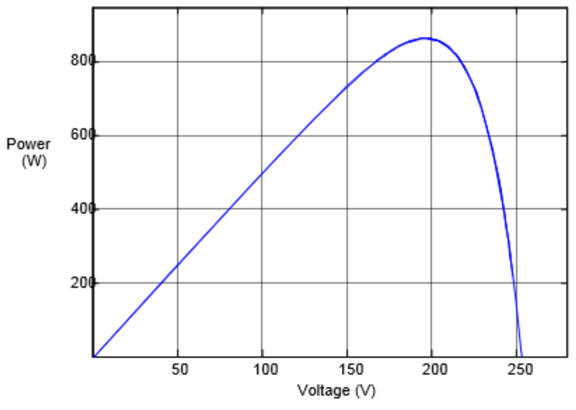

Fig: 7 P-V Graph

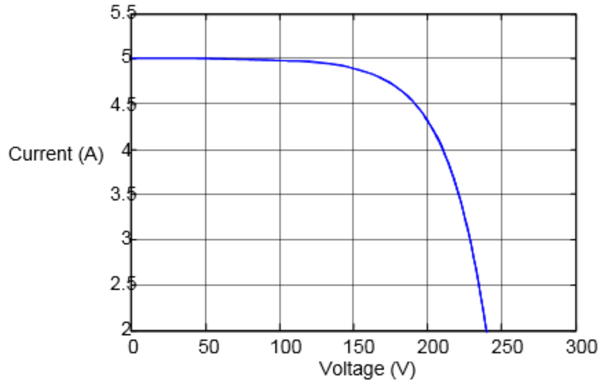

Fig: 8 I-V graph

(ii) Variable irradiation and constant other parameters

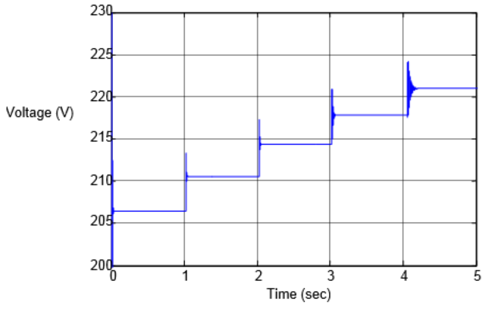

Fig: 9 Voltage at variable irradiation

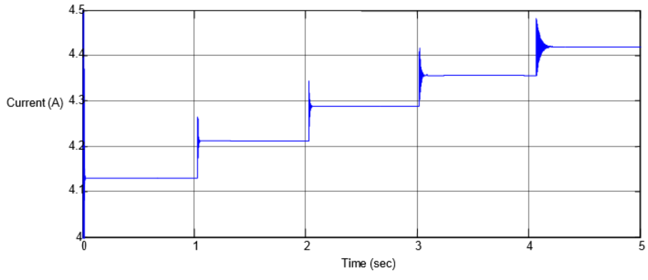

Fig: 10 Current at variable irradiation

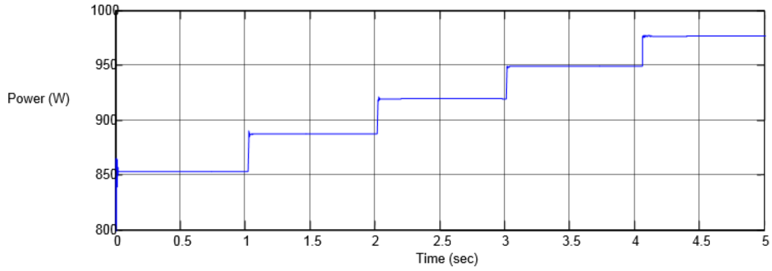

Fig: 11 Power at variable irradiation

Table: 2 Table showing values at variable irradiation

Irradiation(W/m^2)	**600**	**650**	**700**	**750**	**800**
Voltage(V)	206.5	210.5	214.6	217.8	220.75
Current (A)	4.19	4.22	4.28	4.35	4.41
Power(W)	852.7	886.5	919.3	948.8	976.56

(iii) Variable temperature and constant other parameters

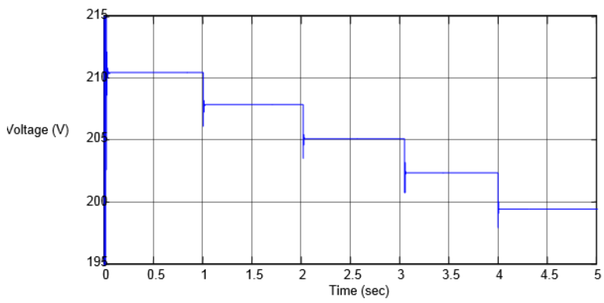

Fig: 12 Voltage at variable temperature

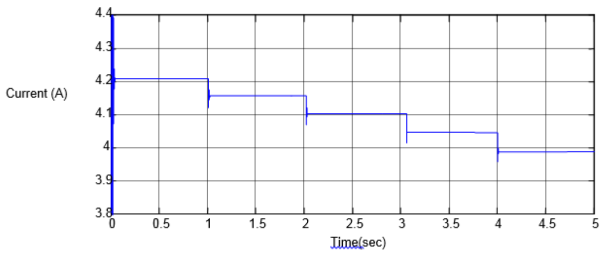

Fig: 13 Current at variable temperature

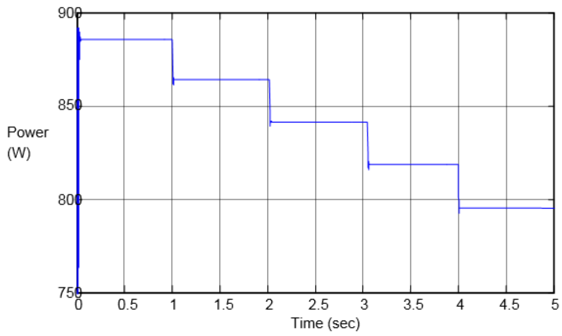

Fig: 14 Power at variable temperature

Table: 3 table showing values at different temperature

Temperature	283K	293K	303K	313K	323K
Voltage(V)	211	207.5	205	203	199.5
Current(A)	4.22	4.17	4.1	4.05	3.99
Power(W)	890.42	865.28	840.5	822.15	796.05

(iv) Variable humidity and constant other parameters

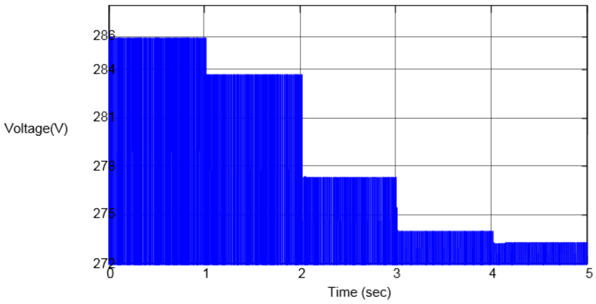

Fig: 15 Voltage at variable humidity

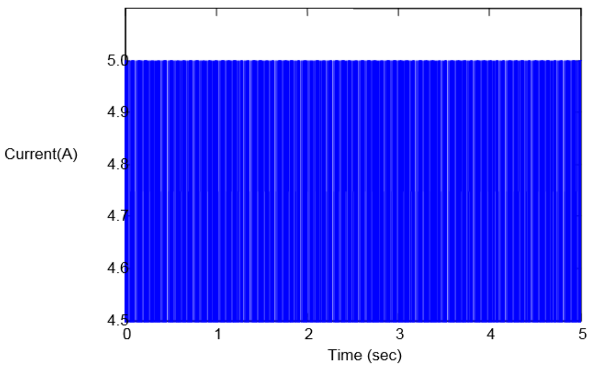

Fig: 16 Current at variable humidity

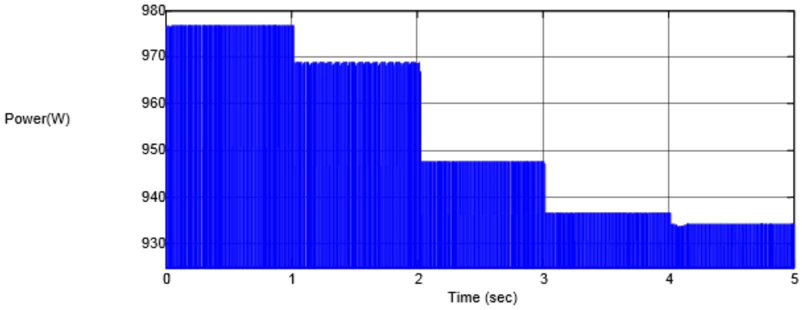

Fig: 17 Power at variable humidity

Table:4 Table showing values at variable humidity

Humidity (%)	**10**	**20**	**30**	**40**	**50**
Voltage(V)	284.5	282.5	277.5	274	273
Current(A)	4.85	4.82	4.8	4.79	4.88
Power(W)	970.5	969	948.5	933	915.5

(v) Variable wind speed and constant other parameters

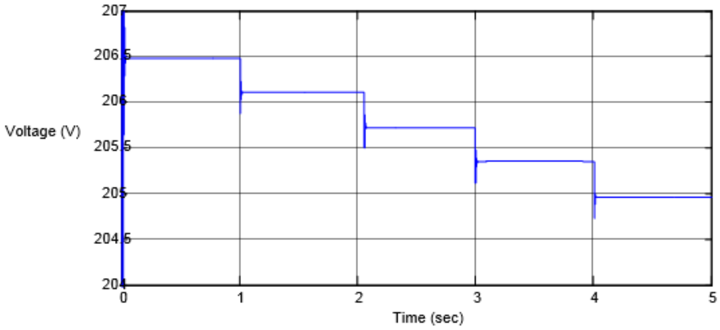

Fig: 18 Voltage at variable wind speed

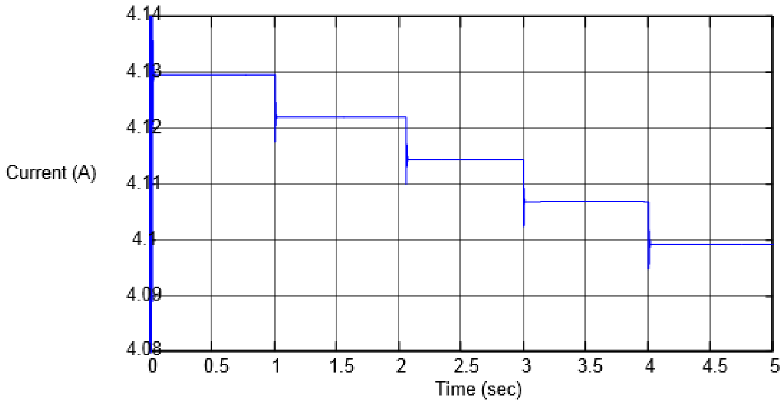

Fig: 19 Current at variable wind speed

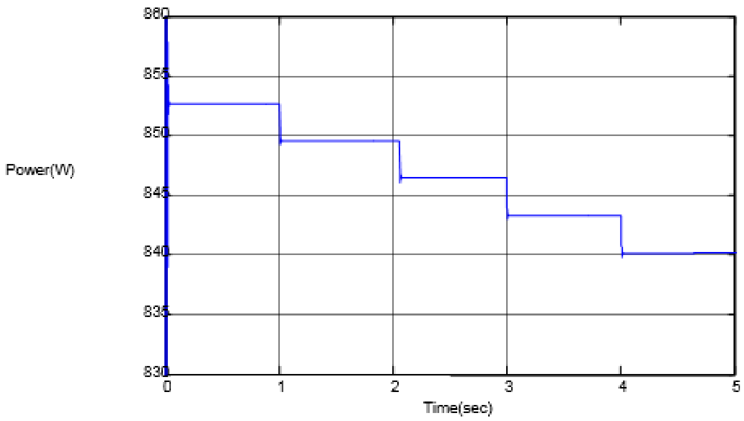

Fig: 20 Power at variable wind speed

Table: 5: Table showing values at different wind speed

Wind speed(m/s)	**4**	**6**	**8**	**10**	**12**
Voltage(V)	206.5	206.1	205.8	205.4	204.9
Current(A)	4.129	4.122	4.115	4.108	4.099
Power(W)	852.6	849.5	846.8	843.8	839.8

It can be concluded from above result that with an increase of irradiation maximum power increase while with an increase of temperature, humidity and wind speed maximum power decreases.
Hence, now in mppt based water pumping system effect of irradiation will be considered as one of the main factors for comparison between techniques of mppt on boost voltage, electromagnetic torque, and rotor speed.

EFFECT OF IRRADIATION WITH MPPT TECHNIQUES
EFFECT ON P&O METHOD

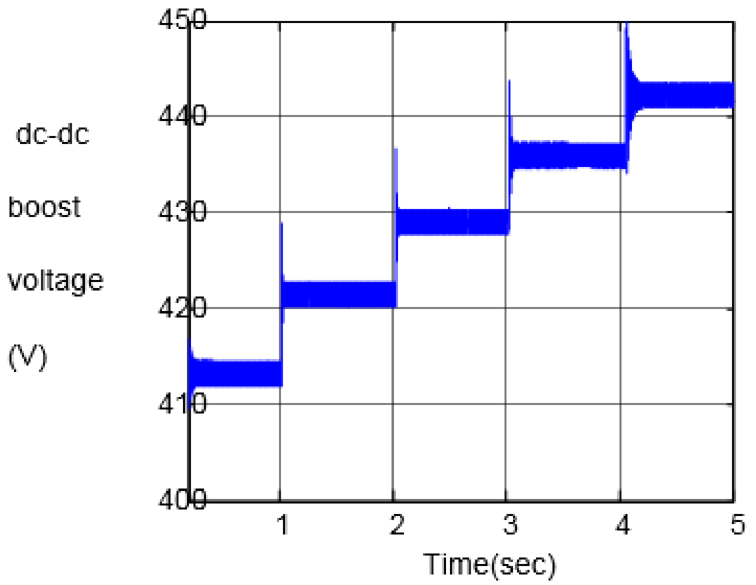

Fig::21 Effect of irradiation on dc -dc boost voltage

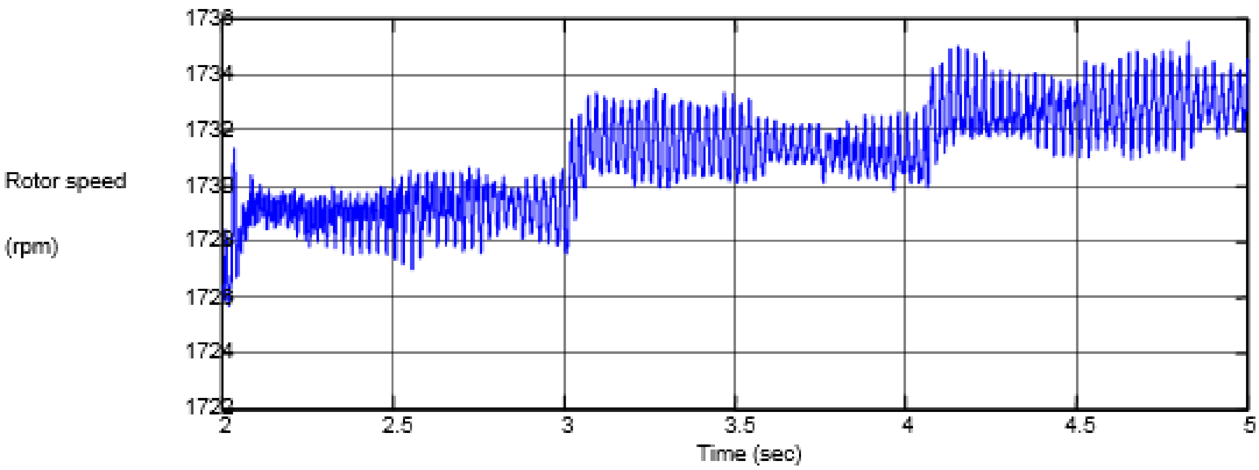

Fig: 22 Rotor speed at variable irradiation

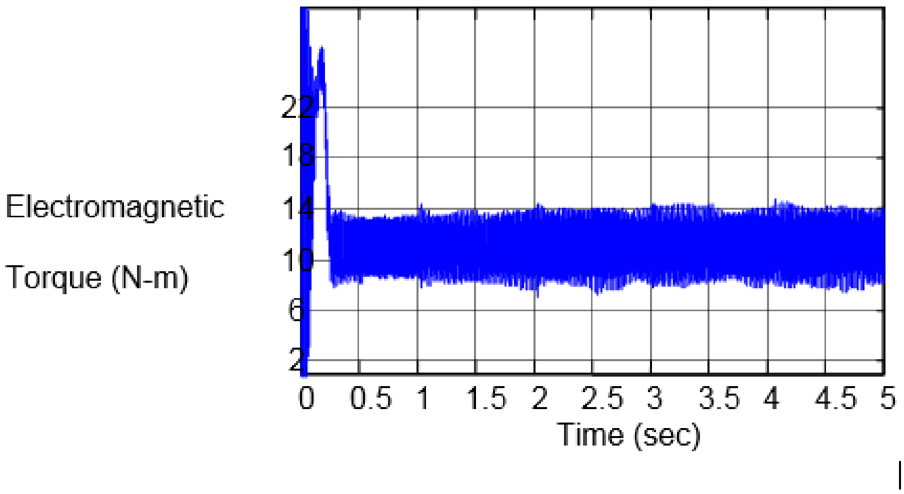

Fig: 23 Electromagnetic torque at different irradiation

Table: 6 Table showing values at different irradiation for P&O

Irradiation (W/m^2)	Dc Dc boost voltage (V)	Speed (rpm)	Setting time (sec)
600	413	1724	0.25
650	421	1726.5	0.25
700	429	1728	0.25
750	434	1731	0.25
800	442	1734	0.25

EFFECT ON CVC METHOD

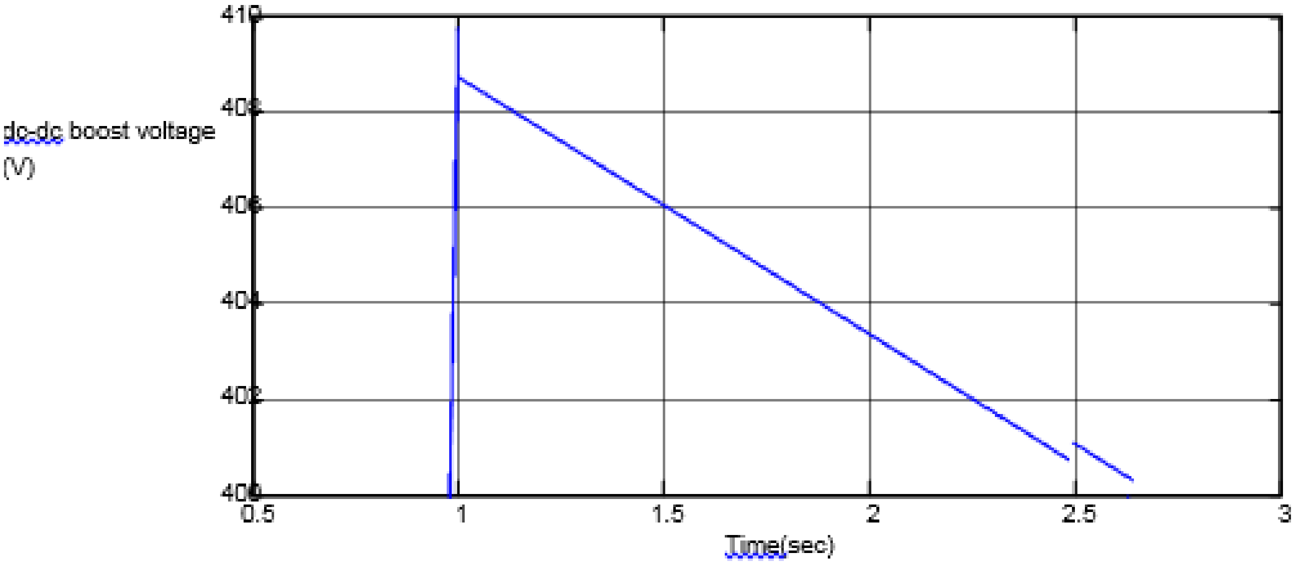

Fig: 24 Effect of irradiation on dc -dc boost voltage

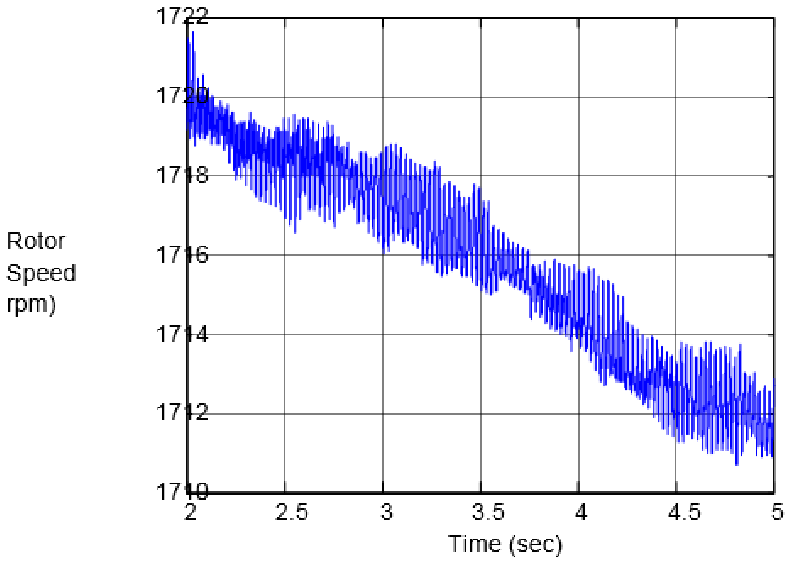

Fig: 25 Rotor speed at variable irradiation

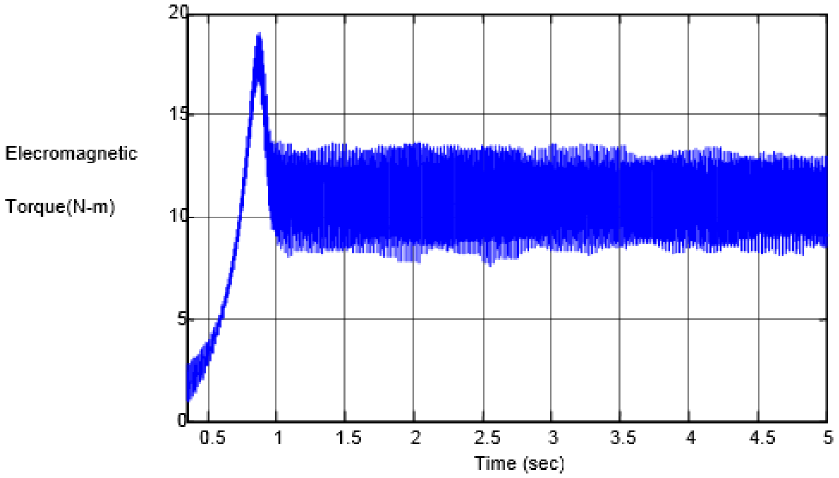

Fig: 26 Electromagnetic torques at different irradiation

Table: 7 Table showing values at different irradiation for cvc method

Irradiation (W/m^2)	**Dc Dc boost voltage (V)**	**Speed (rpm)**	**Setting time (sec)**
600	408.5	1720	0.95
650	407	1718.5	0.95
700	406	1716	0.95
750	404	1714	0.95
800	402	1712.5	0.95

The two MPPT algorithms, P&O and CVC, discussed in earlier section are implemented in MATLAB simulations and tested for their performance. Since the purpose is to make comparisons of two algorithms, each simulation contains only the PV model and the algorithm. They are verified to locate the mppt voltage, speed and settling time of water pumping system on varying irradiance as the system output and tracking increases with irradiation only while with temperature, humidity and wind speed it decreases.

CONCLUSION

P&O shows better performance in comparison with CVC method on variable irradiance on basis of settling time and rotor speed. While on increasing irradiation speed of water pumping system with P&O method increases and it settles in less time as compared to CVC method whose speed decreases with increasing radiation and also settling time is more than P&O method. Hence for better performance and efficiency under varying condition, P&O method is the best option which fast track changing irradiation at less time with improved and better performance.

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