MPPT algorithm for a PV array fed BLDC motor driven air conditioning system

S.MUNISEKHAR G.V.MARUTHESWAR P.SUJATHA K.R.VADIVELU

Abstract: - The fastest and novel adaptive voltage reference MPPT tracking algorithm for PV cluster sustained BLDC drive for aerating and cooling application is proposed in this paper. The fastest maximum power point tracking (MPPT) algorithm tracks the power instantaneously if there is any change in the solar irradiation. Low cost and energy efficiency is achieved by removing the conventional DC/DC boost converter stage which reduces the switching losses and further reduces the overall cost of the system thereby minimizing the power conversion stages. The proposed quickest MPPT algorithm for BLDC motor driven PV array fed air conditioning system is designed and modelled such that the performance is not affected even under the dynamic conditions. The proposed system is validated by simulation studies.

Key-Words: - Instantaneous, Low cost, efficient, MPPT, BLDC, air conditioner compressor

I.INTRODUCTION

The solar power has now gained the ground to meet the customer need of the power for the air conditioner system to work fast with less consumption of power in these days. The utility for their solar energy is thus contributing for the effective supply of power to the grid. The availability of solar power from the nature is abundant.

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The Solar energy is a considerable source of power connected to the grid. Among the loads connected to the grid air conditioner is considerable load. To meet such type of loads solar energy can feed to air conditioner so that the demand on the grid is abridged. Here some nations like India are encouraging the active utility of solar power. According to some studies, the tracking of Maximum power point tracking was done in many ways. The MPPT algorithm based on switching signals modification method was presented in Ref. [1], the method is based on the modification of the modulation carrier and consequently, the switching signals in order to produce a noticeable variation in both the voltage and power. In the paper entitled Novel fast dynamic MPPT (maximum power point tracking) technique with the capability of very high accurate power tracking proposed a technique which tracks the global MPPT under partial shading conditions and the MPPT efficiency was more than 99.6 % and the convergence time was less than 140 ms [2].A new capacitor peak current (CPC) control MPPT technique was designed for maintaining the PV output voltage constant when there is fast irradiance variations and the noise coming from the converter output[3]. In fuzzy logic technique, the PV module/panel voltage and current are converted into fuzzy parameters using a fuzzification unit, then a decision is performed using fuzzy roles, and finally, appropriate outputs are produced using defuzzification unit [4, 5]. An adaptive perturb and observe (MPPT) method based on cuk converter topology was proposed to track the maximum power point fast and accurately [7]. To overcome the drawbacks of conventional controllers to track maximum power point (MPP), an intelligent peak current controlled perturb and observe MPPT controller was designed and simulated [8]. As atmospheric conditions change to drift the system away from the MPP a variable step length algorithm is proposed to eliminate the tradeoff. Finally the results were validated on a prototype system which has excellent performance [10]. The requirement for fast tracking of MPPT power is to reduce the wastage of power loss and increase the efficiency and stability of the system.

In the present work we propose the following:

1. A novel instantaneous adaptive voltage reference MPPT tracking algorithm.

2. Lower cost and higher efficient topology was proposed by avoiding the conventional boost converter stage.

The structure of the paper is as follows:

First, section I provides the introduction of the paper, Section II describes the Proposed Architecture of BLDC Drive Directly Fed from the PV Panel and Section III deals with novel instantaneous MPPT algorithm. Sections IV explains about the Fast Peak Current Control of the BLDC Motor. Section V explains about simulation studies and Section VI discuss about results and conclusion.

II. PROPOSED ARCHITECTURE: BLDC DRIVE DIRECTLY FED FROM THE PV PANEL

The proposed system as shown in Fig 1 consists of solar panel, a DC link capacitor, voltage source inverter, BLDC motor and a compressor. There is no separate boost converter stage in the proposed system. The power generated from the solar panel is given to the BLDC motor driven air conditioner compressor; the required voltage to the motor is maintained by dc link capacitor with proposed algorithm.

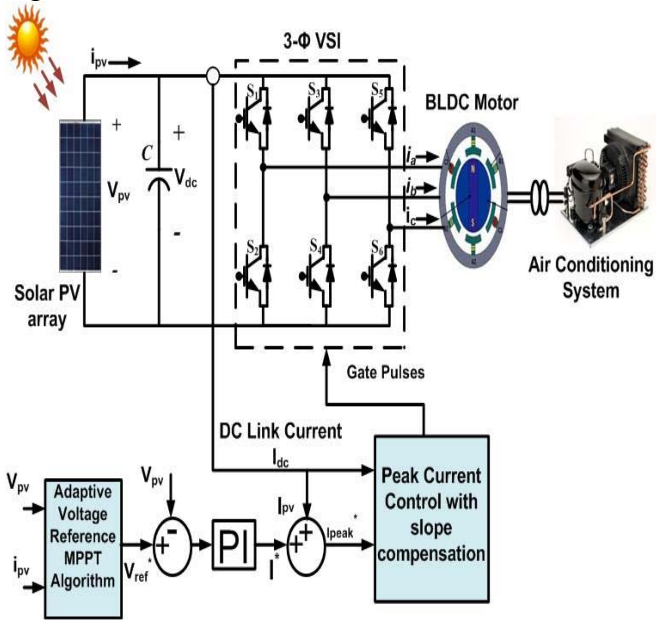


Fig. 1. Block diagram of proposed system

A. *PV array Design*

The solar cell produces DC electricity from sunlight. The power output (Po) of PV cell depends on temperature(T), insolation and load current(I).

$$P_o = f(\text{ insolation, I,T }) \qquad (1)$$

From equation (1) it is clear that the power output is directly proportional to temperature, insolation and load current. In fig 2, the PV cell equivalent circuit is shown which consists of series and shunt resistance (Rs & Rp), a current source I_{ph},d a diode.

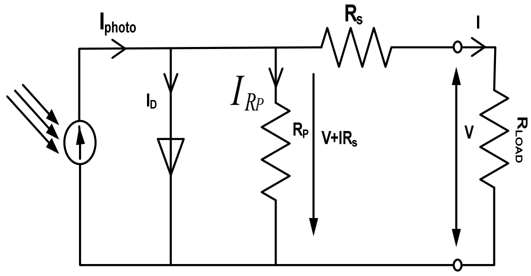


Fig. 2. Equivalent circuit of solar cell

The non linear characteristic of pv cell approached by a one diode model is given by following equations:

$$I = I_{Photo} - I_0\left(exp\frac{q(V+IR_s)}{kT} - 1\right) - I_{R_p} \qquad (2)$$

$$R_p = R_{p,dark} \cdot e^{-\alpha E} \qquad (3)$$

The PV module voltage and current characteristic are described as

$$I = I_{Photo} - I_0\left(exp\frac{q(\Sigma V+IR_s)}{\square T} - 1\right) - I_{R_p}$$

with: a avalanche factor E irradiance in W/m²

I_0 diode saturation current in A

I_{photo} photo current in A

I_{Rp} current of parallel resistor in A

K Boltzmann const. ($1.381*10^{-23}$ J/K)

m avalanche exponent

q element. charge ($1.602*10^{-19}$ As)

R_p parallel (or shunt) resistor

R_s series resistor

T absolute temperature in K

V_{br} breakdown voltage in V

α coefficient for dependence of irradiance in R_P , in m²/W

The PV module parameters at standard test conditions (solar irradiance = 1000 W/m^2,Temperature=25^{o}c))are given in table 1 as shown below. To get the desired rated power 200 Watts and rated voltage 360 volts for air conditioner compressor 20 solar PV modules are connected in series.

Table 1. Photo Voltaic Module Parameters

SPECIFICATIONS OF PV ARRAY AT STC

(S = 1000W/m^2, T = 25^{o}C)

Rated Peak power, P_{mpp} (Watt)	10
Open circuit voltage, V_{oc} (V)	21.4
Short circuit current, I_{sc} (A)	0.67
Voltage at MPP, V_{mpp} (A)	18.1
Current at MPP, I_{mpp}(A)	0.55
Series connected cells, N_{ss}	36

III.NOVEL INSTANTENEOUS MPPT ALGORITHM

The MPPT tracking under buck converter topology has some advantages i.e. due to presence of capacitor. When there are sudden changes in solar power, the capacitor will allow sudden changes in current therefore the tracking of MPPT power as shown in fig 3 is faster i.e. it takes less time to reach the maximum power.

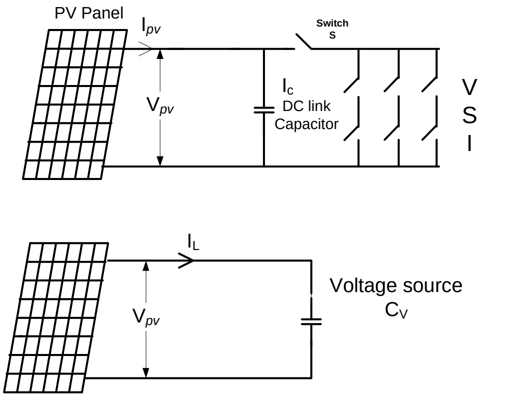


Fig. 3. Tracking of MPPT with buck circuit

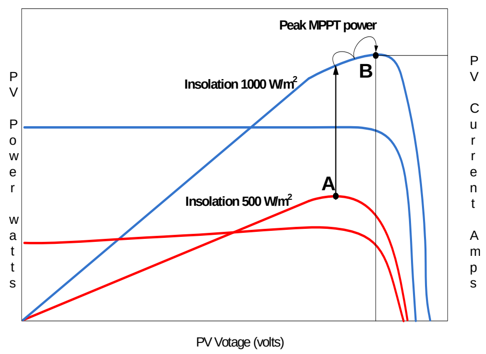


Fig. 4. Trajectory path in tracking MPPT power with capacitor

As shown in fig 4 as change in insolation from 500 W/m^2 to 1000 W/m^2 occurs to move from point A to point B the time taken and number steps are less because the capacitor will allow sudden change in the current but it will not allow any sudden change in voltage. The sudden changes in the panel output are instantaneously absorbed by the capacitor without the intervention of any control mechanism (like constant voltage operation). For an increase in the insolation the capacitor starts building slowly while the PV current and PV power increase instantaneously and vice versa. Since this mechanism works instantaneously contributes to faster MPPT. The sudden change in PV current is measured and is fed to the current controller in the feed forward path of the BLDC peak current controller. This PV current feed forward technique along with peak current control for BLDC motor also acts to make the MPPT tracking faster. As the final step the "modified constant voltage MPPT algorithm" achieves the final MPPT tracking using perturb and observe method, which is rather slow when compared to the first two mechanisms.

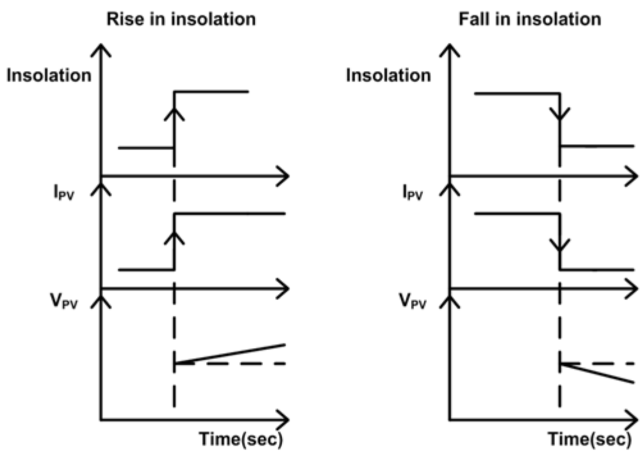


Fig. 5. Rise and fall in voltage and current with respect to insolation

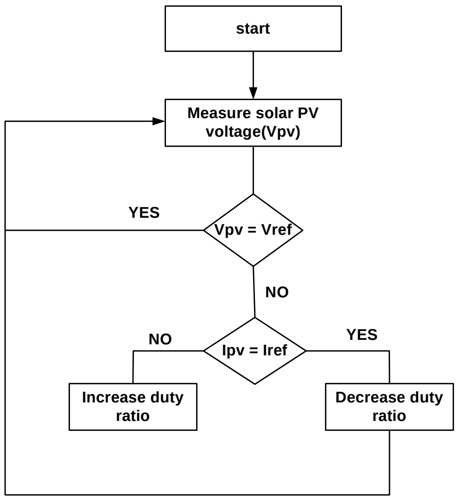


Fig. 6. Flow chart of CV method

The sudden change in insolation is easily absorbed by the capacitor and hence it is obviously the fastest MPPT algorithm. The instantaneous MPPT tracking algorithm need to sense the voltage (V_{mpp}) and current (I_{mpp}) of solar PV panel, such that the PV system operates at maximum output power (*Pmpp*). In this paper, a novel adaptive constant voltage reference MPPT algorithm for PV system is proposed using constant voltage method. The flow chart for constant voltage method is shown below in figure 6.

The CV method is based on the observation from solar pv curves that the ratio of the PV array's maximum voltage, Vmp, to its open-circuit voltage, Voc, is approximately constant:

$$V_{mp} / V_{oc} = K < 1 \qquad (4)$$

The Constant Voltage method suffers from the following drawbacks they are (a) The operating point is never specifically at the Maximum power point and different data have to be considered for different physical regions (b) Low accuracy and considerable power wastage occurs because it does not take into report dynamic changes in the solar insolation and temperature.In the modified adaptive constant voltage reference MPPT algorithm method the drawbacks present in constant voltage method are overcome i.e. the MPPT tracking efficiency, accuracy and wastage of power loss is increased.

In MACV method the voltage V_k ,current I_k and Power P_k are sensed from the solar panel and the change in the power $\Delta P = P_k - P_{k-1}$ is estimated. If the change in power is greater than zero then the change voltage is greater than zero, than assign the value for i = 1 otherwise assign the value for i = -1.The new power and reference voltage is as follows,

$$P_{k-1} = P_k$$

$$V_{ref} = V_{ref} + (i * step) \qquad (5)$$

Again the change in voltage is checked if it is greater than zero then $V_{ref} = V_{ref} + 0.25$ otherwise if the condition fails then the reference voltage is decremented as follows

$V_{ref} = V_{ref} - 0.25$.Finally if $V_{ref} > V_{refmax}$ if the condition is true then the voltage $V_{ref} = V_{refmax}$.

IV.SIMULATION STUDIES AND RESULTS

The MATLAB simulation results for the proposed MPPT algorithm is verified under dynamic variations of irradiance from 500 W/m^2 to 900 W/m^2 and at constant temperature 25^0 C over a time interval of 0<t<1 sec is shown below.

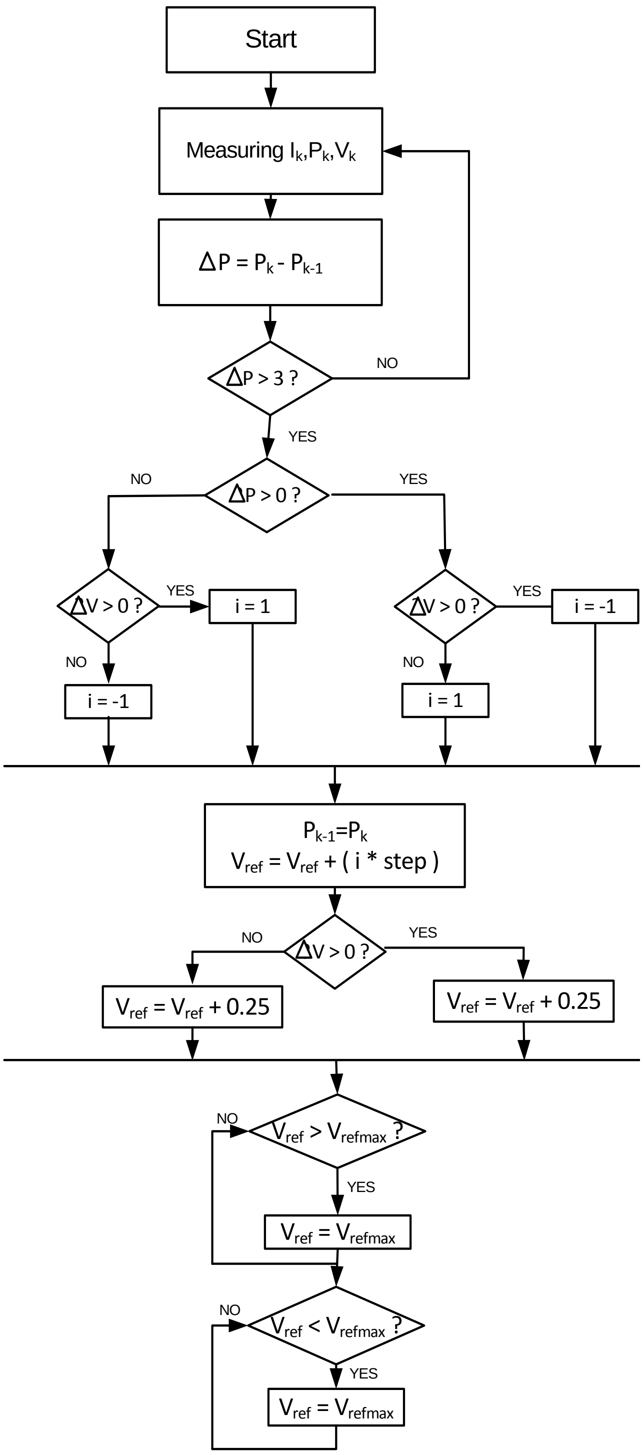


Fig. 7. Flow chart of modified constant voltage MPPT Algorithm

Figs 8 & 9 shows the speed and torque of the BLDC motor and it is observed for 700 W/m^2 and the values of speed and torque are 100 rad/s and 1.2 N-m. Figs. 10(a)-(c) shows the stator back emf in phase a, phase b and phase c ,the magnitude of back emf at 1000 W/m^2, time interval 0.2<t<0.4 sec is 110 volts and when the solar insolation suddenly falls from 1000 W/m^2 to 600 W/m^2 at time interval of 0.4<t<0.6 sec the back emf value is 100 volts. Figures 11(a)-(c) show the stator currents in phase a, phase b and phase c, the magnitude of stator current over a time interval of 0.2<t<0.4 sec for 1000 W/m^2 insolation is 0.75Amps and the magnitude of stator current over a time interval of 0.4 < t < 0.6 sec for fall in insolation from 1000 W/m^2 to 600 W/m^2 insolation is 0.5Amps.

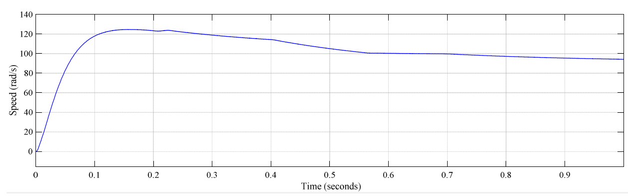


Fig. 8. Speed of BLDC Motor

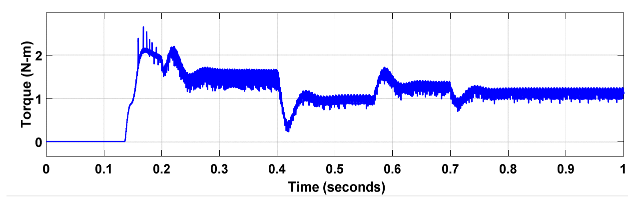
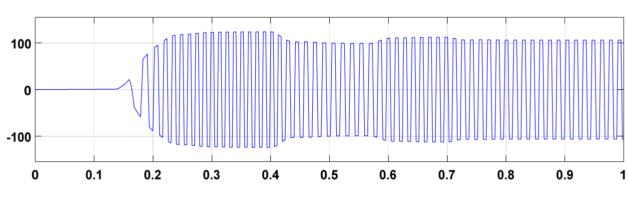
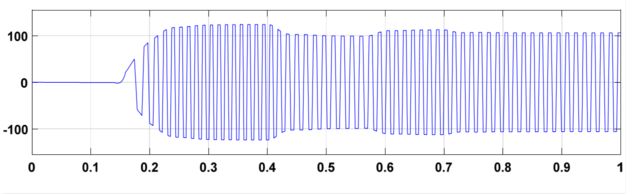


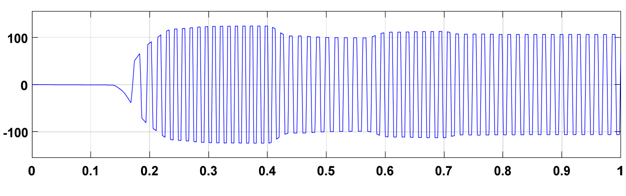
Fig. 9. Torque of BLDC Motor



(a)

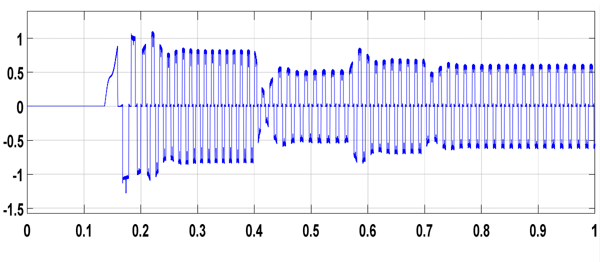


(b)

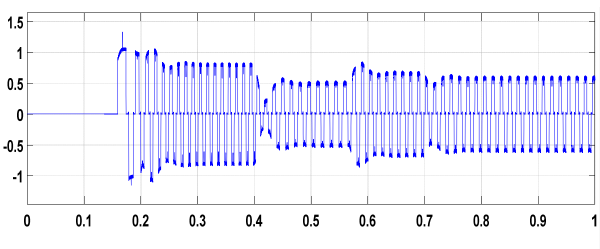


(c)

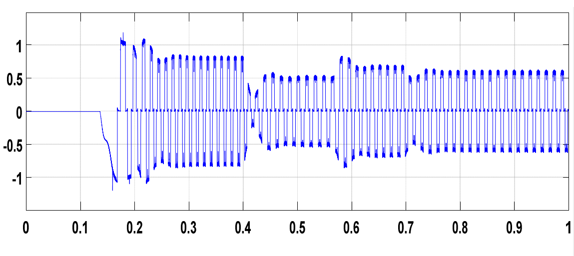
Fig. 10. stator back emf's in phase a, phase b, phase c



(a)



(b)



(c)

Fig. 11. Stator currents in phase a,phase b,phase c

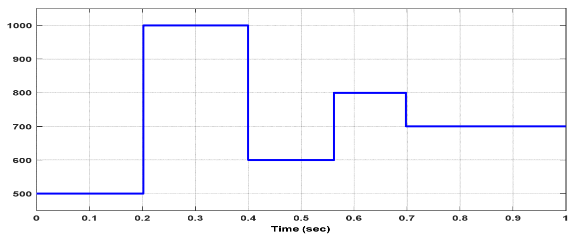


Fig. 12. Solar Insolation input for PV panel

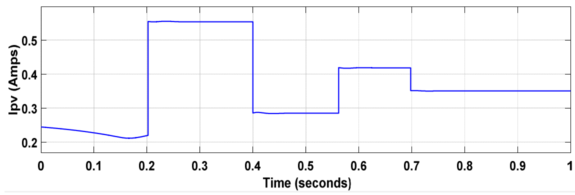


Fig. 13. PV panel Current(I_{pv})Amps

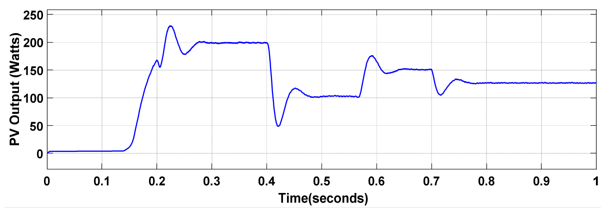


Fig. 14. PV panel Power (watts)

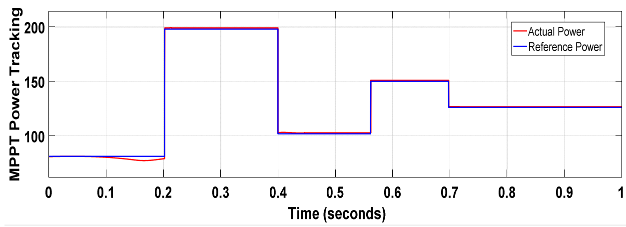


Fig. 15. Tracking of MPPT power

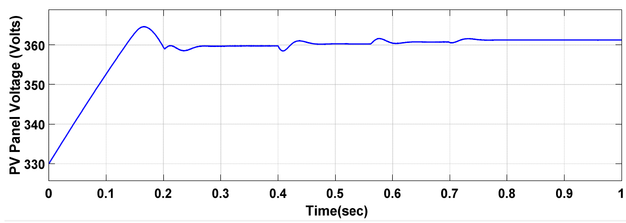


Fig. 16. PV panel Voltage (V_{pv}) volts

Fig. 15 shows tracking of MPP for proposed MPPT algorithm for sudden increase and decrease in insolation for 500 W/m^2 to 1000 W/m^2. Fig. 13 & 14 shows the PV panel current and power of the PV panel and it is observed for 700 W/m^2 and the values of current and power are 0.35 Amps and 140 watts. Fig. 16 shows PV panel voltage and it is observed as 360 volts.

V. CONCLUSION

In this study, a novel adaptive constant voltage reference MPPT technique was proposed to extort maximum power from solar panels and simultaneously uses PV voltage and current deviations to track the Maximum power point of a PV array under varying irradiance conditions has been presented in this paper. The fastest MPPT algorithm is simulated and discussed to extract maximum power from solar panels without using DC-DC converters thereby reducing switching losses which in turn increases efficiency and reduces the cost for PV array fed BLDC Motor driven air conditioning system. The MATLAB simulation results effectively exhibit that, the proposed adaptive constant voltage MPPT algorithm works fine and shows good dynamic and steady state performance.

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