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Improving Maximum Power Point Tracking for Photovoltaic System Using Ant Colony Optimization Based PI Controller

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Abstract-For improving efficiency of photovoltaic system, this paper proposed a maximum power point tracking (MPPT) system using a drift free modified perturb and observe (P&O) algorithm with ant colony optimization (ACO) based proportional integral (PI) controller. The anticipated MPPT system overcomes the disadvantages of conventional P&O and tracks maximum power point (MPP) accurately with no oscillations. The modified P&O algorithm mitigates the drift effect of usual P&O with correct decision making in its algorithm. The ACO based PI controller decreases the steady state error and MPP is achieved after very short transient time. An evaluation is made with different algorithms for proposed MPPT technique using Matlab/Simulink. Simulation results show that MPP is achieved rapidly without drifting and oscillations. Feasibility of the presented system is confirmed with changing irradiance and more energy is captured from PV panel on respective irradiance.

Keywords-Ant Colony Optimization (ACO), Maximum Power Point (MPP), Maximum Power Point Tracking (MPPT), Modified Perturb and Observe (P&O), Photovoltaic (PV) System, Proportional Integral (PI) Controller.

I. INTRODUCTION

The worldwide energy demand is increasing gradually but there are not enough sources to meet up that demand by means of usual energy sources. The decreasing deposits of non renewable energy sources including oil, coal and natural gas have created an alarming situation for the world. These sources have largest carbon foot prints as well. Carbon foot print is the total amount of carbon dioxide and other green house gases emitted during process of energy production. Due to the increase of industrialization and population intensification, electrical energy requirements have also increased.

Recent awareness of global warming and increasing cost of non renewable energy sources has drawn more attention towards the usage of renewable energy sources. These sources are natural sources that can be restocked in a specific time span. Solar energy is a well known renewable source of energy having benefits like; free from global warming, present lavishly and abundantly, requires less maintenance and solid long life. Due to these benefits solar energy is utilized to accomplish the world's increasing appetite for energy. Photovoltaic (PV) system is exploiting to transfer solar energy into electrical power. With high initial cost and low energy transfer efficiency of PV, there must be a technique to be used to work PV system on MPP. In Fig. 1 P-V characteristics curve has been shown, MPP is also labeled with different irradiance values for PV module BP SX 150S utilized in this paper. The changing solar irradiance and atmospheric temperature affects the PV output [i, ii]. Hence MPPT technique is the main need of PV system to take out maximum power. Until now, several MPPT techniques was introduced to take out maximum power from PV such as P&O, fractional short circuit current, incremental conductance, fuzzy logic and neural network [iii-xix].

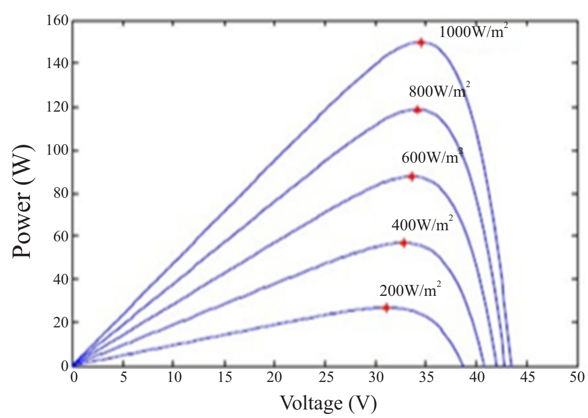

Fig. 1.P-V curves for PV module BP SX 150S with different irradiance

In [xx] a linear relationship between current at MPP (I_{MPP}) and intensity of irradiance is presented, so current I_{MPP} is found by the level of irradiance and Proportional integral controller (PI). PI controller is utilized so PV array current goes behind I_{MPP}. PI controller is used to achieve MPP speedily, but there are draw backs of oscillations around MPP and slow transient response. [xxi]. In addition, PV system has nonlinearities which degrade the capabilities of PI controller. To sort out these problems different solutions in literature have been presented [xxii, xxiii]. PI controller is tuned by Fuzzy systems to overcome drawbacks but these are complex, time consuming and need expert's knowledge to understand. A social inspired algorithm is proposed for optimization of PI controller. Ant System Optimization (ASO) is an algorithm based on behavior of ants [xxiv].

A simple attempt to operate PV at MPP is proposed. A drift free modified P&O algorithm is utilized, that is prior to conventional algorithm. ASO is implemented to tune the gains of PI MPPT controller. ASO actually increases efficiency of PI controller and its performance parameters. A DC-DC converter utilized to convert highest power to load and it works as an interface for PV module and load too.

II. EXPERIMENTAL TECHNIQUE

A. MPPT Algorithm

The P-V and I-V distinctiveness for PV module of series BP SX 150S used in this paper are shown in Fig. 1 and Fig. 2. The BP SX series provides cost-effective photovoltaic power for general use, operating DC loads directly or, in an inverter-equipped system, AC loads. The utilized BP SX 150S is one of the largest products in this series, providing 150 watts of nominal maximum power.

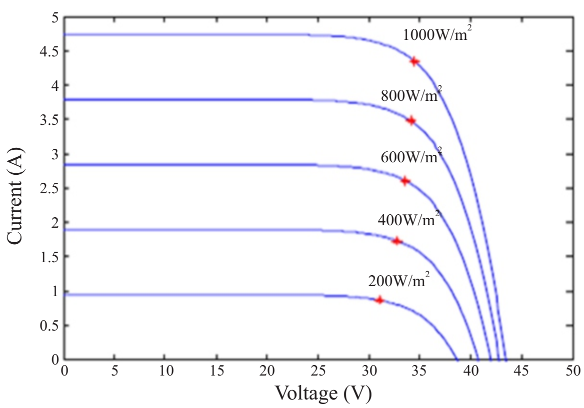

Fig. 2. I-V curves for PV module BP SX 150S with different irradiance

B. Drift Free Modified P & O Algorithm

The P&O algorithm is generally used for its advantages; it is effortless, more efficient, accomplished in analog and digital both forms and free from periodic tuning. In Fig. 3 flow chart for this algorithm is shown. Even though it has significant advantages but when atmospheric conditions change rapidly, the algorithm causes MPP to drift away from exact point. This algorithm cannot track MPP efficiently under changing and high levels of irradiance and has a drift existence loop as given away in Fig. 3.

In Fig. 4 the MPP is at spot 2: Suppose operating point is at position 1 but when irradiance increases, the operating point will move towards point 4 for the same perturbation time. The voltage is increased so duty cycle is decreased according to the flowchart shown in Fig. 3; thereby settling operating point at position 5 moving away from MPP is called drift.

To prevail over drift problem; modified P&O algorithm [xxv] is used which is free from the drifting problem of MPP under changing irradiance. In conventional P&O amendment in power (dP) and voltage (dV) is employed in decision process but in modified P&O algorithm change in current (dI) is also taken into account to avoid drifting of MPP.

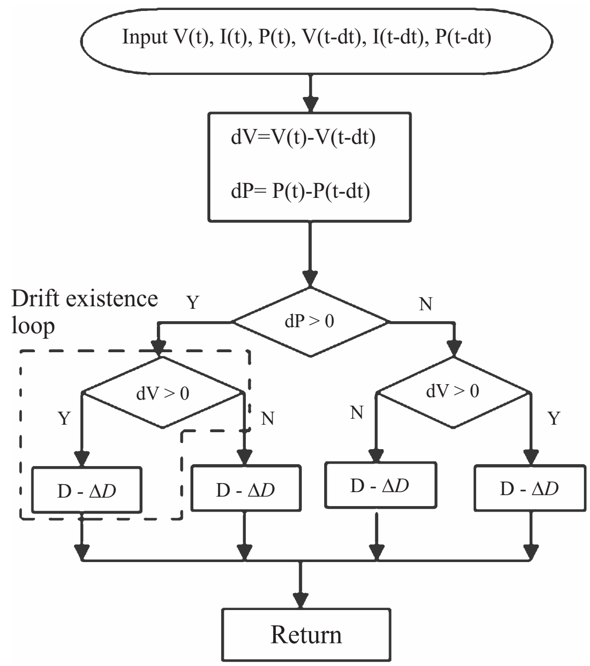

Fig. 3. Flowchart for conventional P&O algorithm

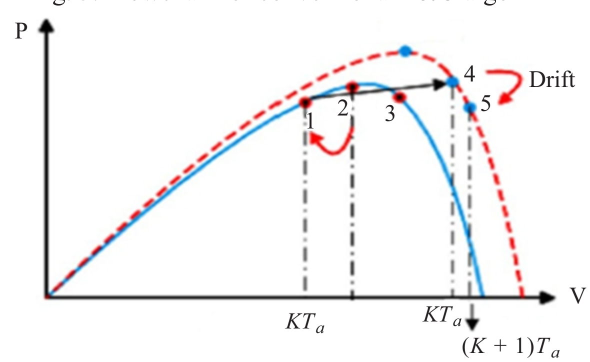

Fig. 4. Drift in MPP due to changes in irradiance

The flow chart for modified P&O used in this paper is presented in Fig. 5. In algorithm; first measure the panel voltage, current and power. Then a undersized perturbation is applied to system to vary the PV module parameters. The module voltage is prearranged a perturbation and output voltage, current and power is changed. Now, compare these parameters with the previous perturbation cycle. If power is increased then voltage is checked either as increased or decreased. If voltage is increased then check for current whether it has been increased or decreased as shown in flowchart in Fig. 5.

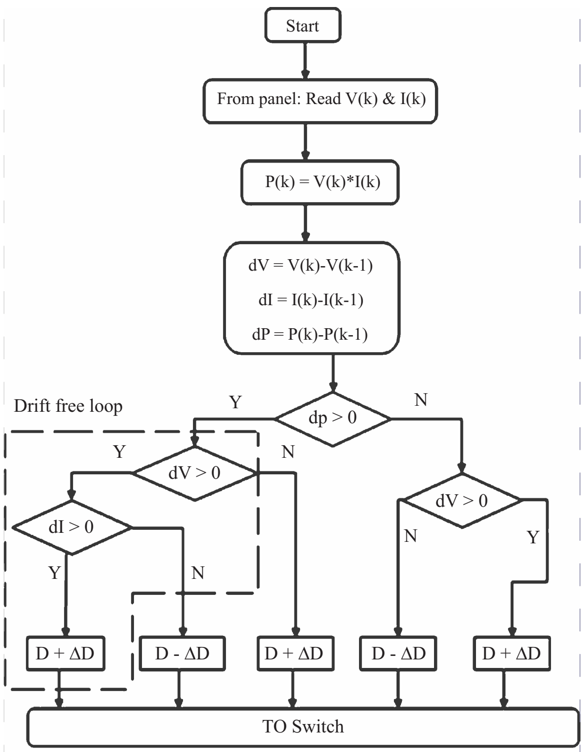

Fig. 5. Flow chart for drift free modified P&O algorithm

If current is increased then perturbation is made in same direction until MPP is obtained. After MPP has reached the perturbation applied results in decreased power then voltage condition is checked; now the perturbation is reversed as made known in Fig. 6.

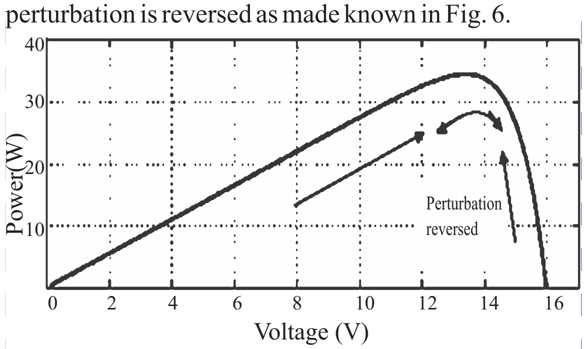

Fig. 6. Power versus voltage graph for P&O perturbation

III. ACO BASED PI CONTROLLER

A. PI Controller

PI controllers are commonly used for industrial applications. They are simple structured with robust performance. In PI controller, the proportional component is responsible for following the desired set point while integral component sums the error term for specified time span so it derives error towards zero. PI controller expression is defined in Eq. 1.

$$u(t) = K_p\, e(t) + \frac{K_p}{T_i}\int_0^t e(t)dt \qquad (1)$$

Where $e(t)$ shows error between input & output of system, $U(t)$ is the control action, K_p and T_i are proportional gain and integral time constant respectively.

B. ACO

The ant system is introduced by in [xxvi]. This technique is simple to implement and based on the behavior of real ants. ACO is specifically acceptable for finding answers to special optimization problems. To find true answers a colony of artificial ants work together, which is developing belongings of the ant's interaction. ACO algorithms are adaptive and sturdy, because of their resemblance with natural ant colonies. It can be implemented to exceptional variations of the identical problems as well as to exclusive optimization problems. The primary tendencies of artificial ants are taken from their usual behavior. Those most important trends are (1) Artificial ants are present in colonies of collaborate individuals, (2) They indirectly communicate by means of deposited pheromone (3) They use a chain of nearby moves to discover shortest route from starting point to destination point.

They practice a decision policy by using nearby data, only to locate the quality solution. If a good way is necessary to resolve a particular optimization problem then artificial ants are improved with a few extra abilities which no longer present in actual ants.

C. ACO Based PI Optimization

In Fig. 7 a plant G(s) has to be controlled. Now searching best possible parameters K_p and K_i for PI controller with ACO using technique in [xxvii]. Each of the parameter has a decimal value between 0 and 10. So a matrix of all possible nodes is generated. It has 10000 rows and 2 columns. 1st column represents K_p 2nd column represents K_i with rows same for both. They start from 0.1 and go up to 10 in equal increments. Each generated ant will have a combination of K_p and K_i values from these possible values 10000*2.

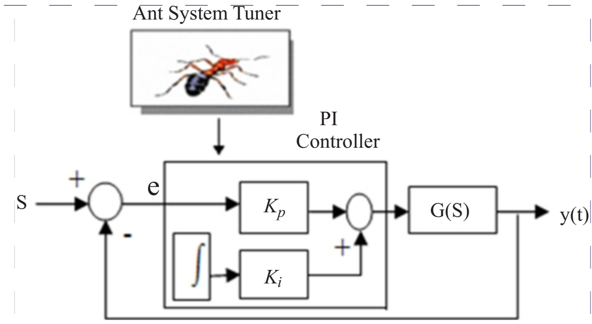

Fig. 7. ACO tuned PI

III. PROPOSED MPPT TECHNIQUE

The proposed MPPT technique used modified P&O algorithm that is drift free as contrasted to conventional P&O, proposed block diagram for MPPT is presented in Fig. 8.

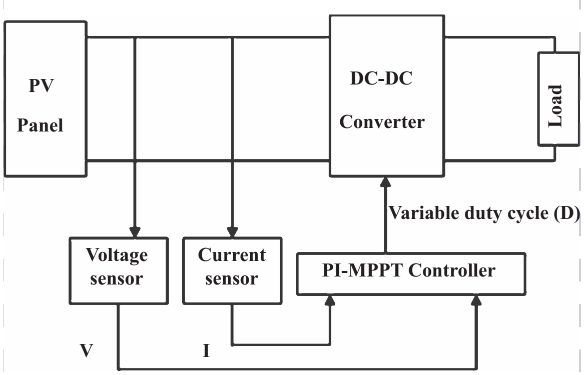

Fig. 8. Proposed Flow diagram for PV system

The algorithm also responds well at higher irradiance levels. This technique using PI controller was capable to attain MPP quickly and oscillations are close to zero. Due to slow transient response an optimized PI controller is used that based on optimization algorithm recognized as ACO.

A DC-DC buck boost converter having variable duty cycle is used as an interface between load and PV output to track MPP efficiently. The technique is applied to BP SX 150S series PV panel to verify the validity of proposed technique.

IV. RESULTS AND DISCUSSION

The technique is used for PV system connected with PI MPPT controller, DC-DC converter and load as shown in Fig. 8. The goal is to get maximum power from PV system. In this section, simulation experiment is performed by MATLAB/SIMULINK for evaluating performance of PV system. Simulation results are find at Temperature T = 25∘C and Irradiance S = 400 W/m^2-1000 W/m^2. The simulation experiment is divided into 3 cases.

<u>*Case 1:*</u> Ordinary P&O.

<u>*Case 2:*</u> Modified P&O with PI controller.

<u>*Case 3:*</u> Modified P&O with ACO based PI controller.

<u>In case 1</u>, the PV system output is shown in Fig's. 9 - 11 for conventional P&O MPPT. The settling time and output calculated values are shown in Table 1. This technique cannot track MPP efficiently and produces oscillations at higher irradiance levels. No current change is considered in this algorithm as shown in Fig. 3; this is the main reason behind drifting of conventional P&O. The most important differences in the algorithms which will explore for the MPP are speed, overshoot and tracking efficiency. To achieve MPP efficiently these three parameters are necessary.

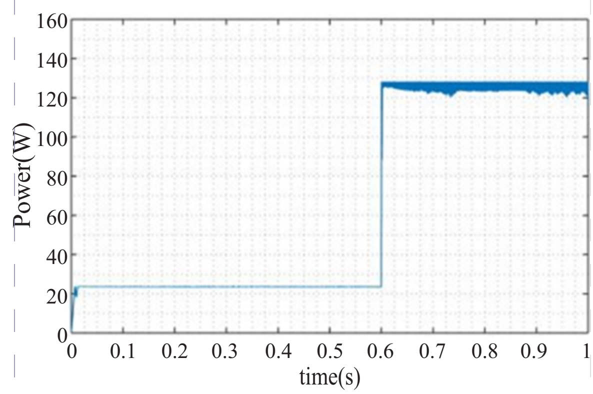

Fig. 9. PV output power of ordinary P&O

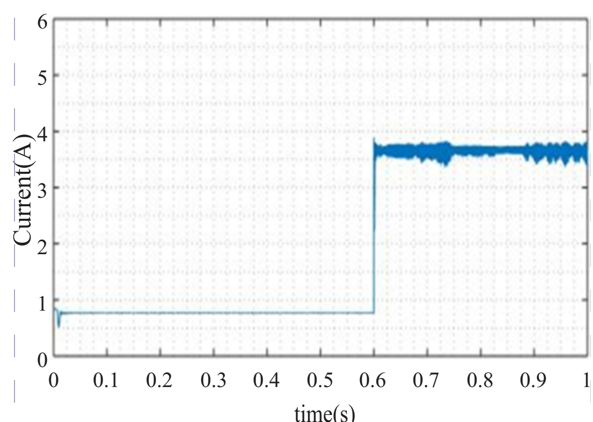

Fig. 10. PV output current of ordinary P&O

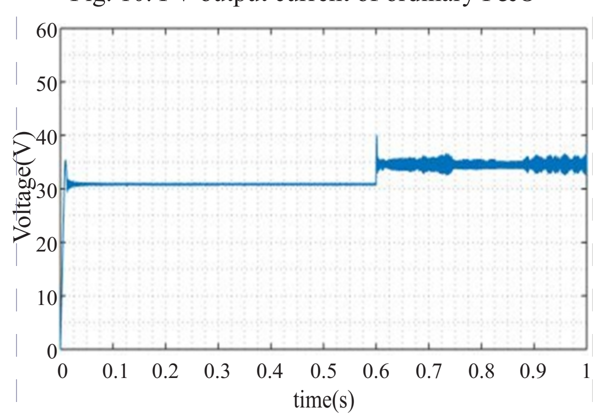

Fig. 11. PV output voltage of ordinary P&O

In case 2, the PV system output is shown in Fig's. 12 - 14 for modified P&O with PI controller. The settling time and output calculated values are shown in Table I. This technique can track MPP efficiently and also has no oscillations at higher irradiance level. But PI controller requires enough time to attain steady state operation. Moreover, it also has inherited nonlinearities that degrade the performance. Overall the expected outcome algorithm is quite good. The algorithm can be optimized to meet certain timing requirements.

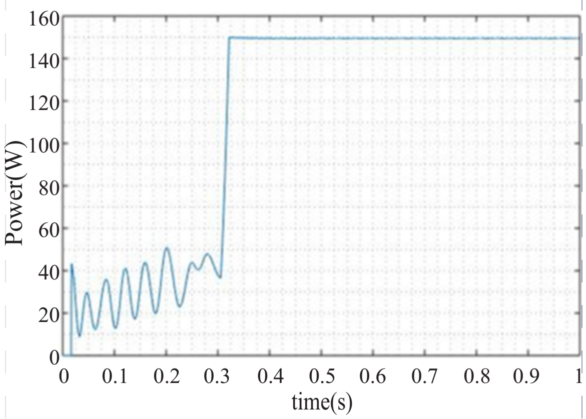

Fig. 12. PV output power of modified P&O with PI controller

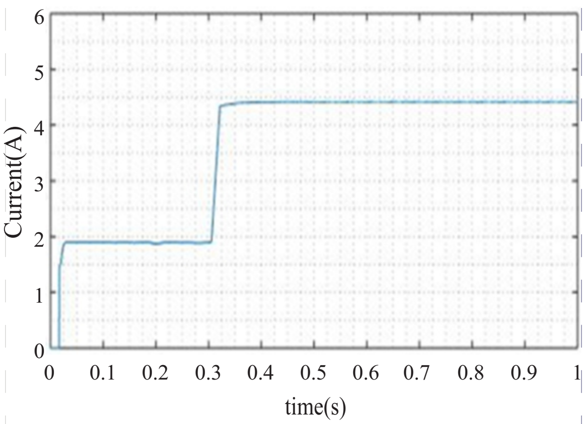

Fig. 13. PV output current of modified P&O with PI controller

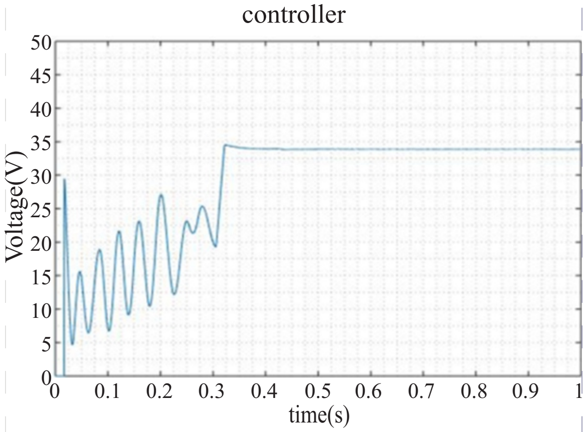

Fig. 14. PV output voltage of modified P&O with PI controller

In case 3, the PV system output is shown in Fig's. 15 - 17 for modified P&O with ACO based PI controller. The settling time and output calculated values are shown in Table I. The anticipated technique transfer MPP after very short transient time with steady state error approximately equal to zero. ACO is used to devise gains of PI MPPT controller. The goal of ACO is enhancing equally the configuration proficiency of PI control frameworks and execution to find ideal PI parameters. The feasibility of the presented system is confirmed with changing irradiance.

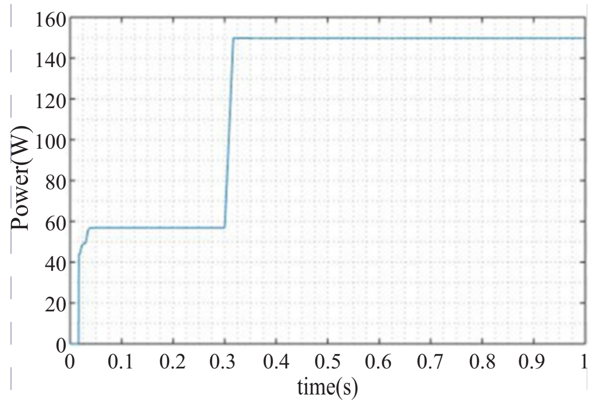

Fig. 15. PV output power of proposed MPPT algorithm

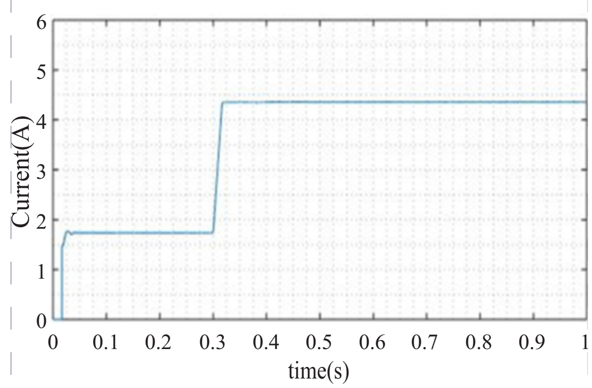

Fig. 16. PV output current of proposed MPPT algorithm

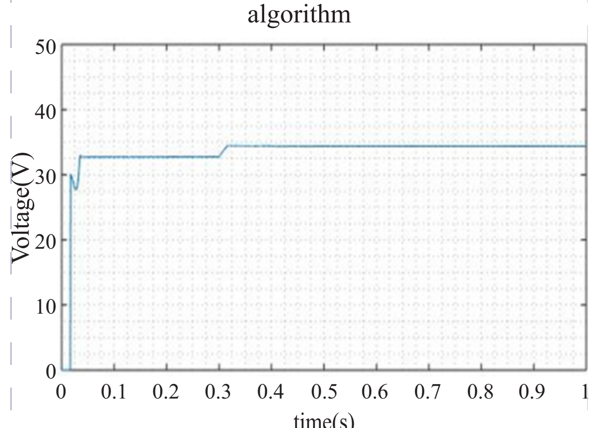

Fig. 17. PV output voltage of proposed MPPT algorithm

TABLE I
PERFORMANCE INDEXES OF DIFFERENT CASES

Case	Voltage (V)	Current (A)	Power (W)	Settling Time(ms)
1	37.5	3.7	138	50
2	34	4.2	142.8	0.3
3	35	4.3	150	0.05

V. CONCLUSION

In this paper, a drift free modified P&O algorithm is utilized with ACO based PI controller. The proposed technique is modeled using MATLAB software. The technique increases the efficiency of PV system by avoiding drift due to utilization of drift free modified P&O algorithm. This algorithm uses an extra condition; change in current (dI) as compared to conventional P&O. With ACO based PI it is capable to reach MPP efficiently and oscillations are approximately zero. The proposed technique has fine convergence, easy to implement, respond well at high levels of irradiance and transfer maximum power with no overshoot after very short transient time. The proposed technique is different as compared to [xxi], [xxviii], [xxiii] and [xxix] as following:

- A reduced computational exertion than [xxi].
- Oscillations and settling time is better as compared to [xxviii].
- A simple to actualize procedure with no additional expense for the extra control loop [xxiii] is accomplished.
- A quick transient reaction without swaying around the MPP is performed.
- Settling time and oscillations overcome as compared to [xxix].

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