iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** IV **Month of publication:** April 2016

DOI:

www.ijraset.com
IC Value: 13.98

Volume 4 Issue IV, April 2016
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

An overview of some modifications proposed in Perturbation & Observation Maximum power point Tracking

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Abstract--Solar energy is one of the most important form of renewable energy in the present time because of rapid depletion of non renewable sources of energy. Solar energy is clean, safe and abundant in nature. Photo voltaic or PV technology is used to harness solar energy. Solar energy in form of sun rays are collected via solar or PV panels. The PV panels/arrays have high initial cost and less efficiency. Now in order to maximize the power output and thus justify the high initial cost, there is a need of optimization algorithm which can be called as maximum power point tracking (MPPT). MPPT is an efficient technique used these days to optimize the performance of a PV panel so that maximum power can be drawn from the panel. There are many MPPTs which have been developed all these years. Of which perturbation & observation (P&O) method is most popular because of its simplicity, easy implementation, robustness. It is efficient but suffers with trade off problem of oscillations which are to be minimized. In this paper, different modifications in P&O technique for reducing the trade off problem are discussed which are proposed earlier and a comparative analysis is being done. Also the technique also has significant effect of irradiance and temperature on its performance. Paper also discussess the modifications which reduce the dependence of P&O algorithm on the irradiance and temperature also.

Keywords: Converters, Maximum power point tracking (MPPT), Perturbation & observation (P&O) algorithm, PV array, Solar energy.

I. INTRODUCTION

Day by day as the earth is aging, its resources are depleting and getting exhausted. These include the conventional energy resources which are the base of world's energy requirement are depleting at very fast pace. This is a well established fact in this present scenario of energy resources. It is needed that some other sources should discovered or developed so that they can be used for tackling the, day-by-day increasing demands of energy. Photovoltaic or PV technology has evolved as an efficient source of energy in recent times and can provide vast amount of power if controlled properly [1], [2] .But it has serious disadvantages of high installation costs and low conversion efficiency. The commercial success & viability of PV technology has great dependency on improvement of conversion efficiency from solar energy to electrical energy and cost reduction. The power generated by a PV array is a factor of solar irradiance level falling on the array and the temperature, primarily. Clouding, local surface reflectivity etc are other secondary factors. The characteristics of PV array are highly non- linear in nature and also the non –continuous nature of sunlight, makes it difficult to properly utilize the PV array. For a particular value of irradiance, there is particular point on power versus voltage (P-V) curve of PV array called maximum power point (MPP). MPP keeps on changing with solar irradiance and temperature. For extracting, maximum power from the array, array is made to operate on this MPP with help of maximum power point tracking technique (MPPT).

All over these years various MPPTs have been developed [3] for obtaining maximum power from the PV array. These methods differ each other in tracking speed, sensors used, complexity, cost and hardware implementation. Many MPPTs have been developed so far. Of all these perturb & observe method [4] and incremental conductance method are most popular. Both are efficient than almost all other MPPTs [5] Here in this paper we are going to discuss about perturb and observe method. As it is easy to implement and is quite simple. But there are certain disadvantages of the technique which hamper its performance effectively [6]. There are oscillations existing in the system due to perturbations and these are proportional to the perturbation step size i.e. larger the step size, higher are the oscillations and vice versa. A good amount of energy is wasted in these oscillations. Smaller step size, do reduce the oscillations and energy but it also brings a slower response to the system. This is termed as trade off which is existing in the system between steady state and tracking speed.

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II. PERTURABTION &OBSERVATION MPPT

The P-V curve below, in fig 1, gives a brief idea about performance level of the PV array. The P-V characteristics show the MPP is located in upper right corner of the curve and it shows the point of operation of highest power which can be drawn from the array. Maximum power is generated only at single point of the power curve, that point is MPP [7]. The slope $\partial P/\partial V$ at the MPP is zero. The area on the left of the MPP is a region of constant current and the area on right is the region of constant voltage. Since MPP is dependent on sun rays falling on the array and temperature of array, so it is not constant and changes with time. Therefore, it is necessary for a MPPT to track the changes occurring in the MPP, for better performance. Now MPP changes throughout the day, throughout the year. So it is essential for a MPPT keep the track of the successively changing MPP. Also because MPP changes continuously, an effective power plan must be planned continuously by the connecting converters between PV array and load/grid, setting the working/operating point in a way which makes panel to produce the maximum power they are capable of. Then, a tracking algorithm then developed which follows the MPP of PV field, which is here P&O algorithm

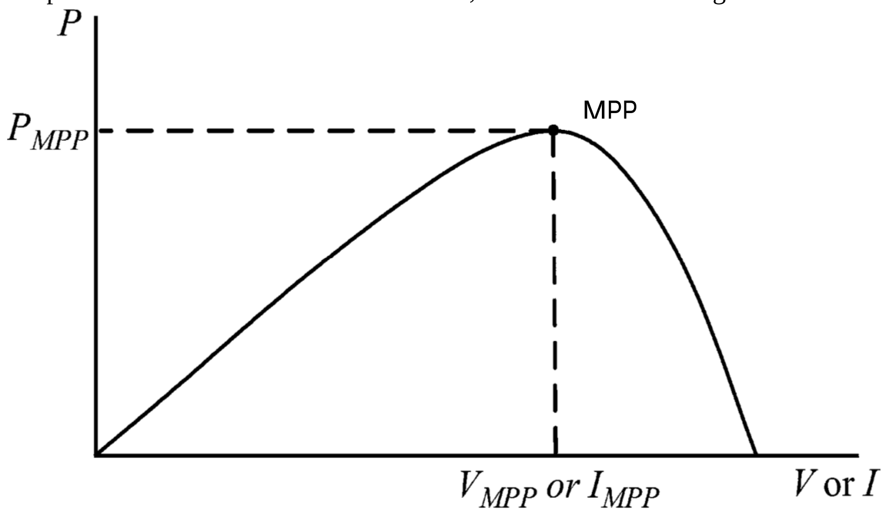

Fig 1 Typical P-V characteristics of PV array showing MPP

P&O algorithm uses the operating the voltage and current of PV panel i.e. I_{PV} & V_{PV}, to detect the MPP, by scanning the P-V curve. The scanning of the P-V curve is carried out by changing the operating point, which is called perturbation step and then measuring the change in power, which is called as observation step. The resulting changes in power are observed as follows:

In the fig 1,when operating point lies on the left of MPP, power increases when voltage is incremented and vice versa and when operating point lies on the right of the MPP power decreases when voltage is decremented and vice versa. Now in case of power increase, the perturbation should be kept same to reach the MPPT. However in case of power decrease, in order to reach MPP the perturbation should be reversed. Here it is noted that perturbation step size is constant. This procedure can be summarized in the table as:

Table 1: Summary of Perturb and Observe algorithm

Perturbation	ΔP	Next Perturbation
Increasing	Positive	Increasing
Increasing	Negetive	Decreasing
Decreasing	Positive	Decreasing
Decreasing	Negetive	Increasing

This process of perturbation is repeated until MPP is reached. So the system just oscillates about the MPP. Thus results in loss of energy. Now here as the perturbation size is fixed, the reference signal can be generated either by perturbing array reference voltage [8] or current [9]. Usually a P-I or hysteresis controller is used for controlling the power. The oscillations which are produced can be reduced by lowering the perturbation size, however that also decreases the tracking speed and vice versa. A solution to this problem can be done employing variable step size and as MPP is approaching the step size gets smaller. *Al-A.Amoudi et al* [10] proposed a method for applying P&O method with variable step-size such that the perturbation step size gradually decreases when operating point is approaching towards MPP. But this method is not truly adaptive as the steps applied are varied in a predetermined way. A similar approach was also proposed in [11]. Here the perturbation value is varied according to output power. But again, it is not a truly adaptive technique. Nevertheless both [10], [11] exhibit a better performance than their fixed step counterparts. P&O method has also has a serious disadvantage of dependency on atmospheric conditions like change in temperature and irradiance. As the output characteristics of PV panel are itself dependent on operating conditions of irradiance level and temperature working [12] – [15]. Any change in these two variables changes the location of operating point on the P-V curve [16] and decreases the efficiency of the algorithm and slows down the tracking speed along with loss of energy. Several improvements on the P&O algorithm have been proposed in order to reduce the oscillations around then MPP in steady-state, but almost all of them slow down the response speed of the algorithm when atmospheric conditions change and hence the efficiency decreases during cloudy days. [17]

As mentioned above in the process of, locating MPP on P-V curve, there are oscillations developed in the system which make system somewhat unstable. Also the changing atmospheric conditions affect the efficiency and performance of the system. To reduce oscillations and decrease the dependency on weather and atmospheric conditions many modified P&O methods have been developed. *Femia M. et al* [18] have proposed to apply a constraint on the perturbation size that is, change in duty cycle of the coupled converter such that the classic P&O is free from the problem of deviation from MPP and instability due to rapid weather changes. Proposed method does successfully tracks MPP under fast change of weather, but due to application of higher step size, there is high power loss in the steady state. *Pandey A et al* [19] worked on setting the minimum and maximum threshold value of power change(perturbation) [20] to overcome the problem in [18] but no optimal solutions are obtained as power change is dependent on weather conditions. So they suggested an entire trend of P-V curve. But it was not again practical to implement, in case of rapid weather changes as the working operating point moves entirely into a new place on the corresponding P-V curve for each value of radiation change. Variety of modifications in conventional P&O techniques have been proposed so far. These are efficient but have some drawbacks. Talking about the recent times, with the advent of technology and demand some more new techniques have been prospered .Our objective in the paper ,is to analyze some of these modifications and thus can have an idea about the working of these methods, also we can have an idea about their efficiencies. We can observe while discussing about the different modifications, we have variety converters coupled to PV array.

A. *Adaptive Step Size With Adaptive-Perturbation- Frequency Digital MPPT Controller for a Single-Sensor Photovoltaic Solar system*

Normally the all MPPTs developed, require sensing of PV voltage and current both and then obtain the power value. Although there are methods reported for realizing MPPT by sensing the load current only, with fixed step size[21]-[23]. This eliminates the requirement of a multiplier for measuring the power of PV array. The present technique deals with adaptive perturbation step size algorithm [24]-[25] which fetches rapid dynamic convergence speed and high efficiency in steady state. The trade off existing between rapid dynamic response and efficient performance in steady state with less oscillations, is discussed with an adaptive step size and perturbation frequency MPPT. This proposed load – current adaptive step –size and perturbation – frequency (LCASF) MPPT algorithm [26] generates larger perturbations with longer perturbation time during transients for fast and dynamic response and generates smaller perturbations with short perturbation time for lower oscillations during steady state, for high efficiency. In PV systems, settling time is proportional to the perturbation. Longer the perturbation, longer is the settling time and vice versa if the perturbation step size is fixed. Now that means, the settling time of MPP controller is longer too when operating time is near the MPP, which should be avoided. The LCASF takes care of this issue by keeping lower perturbation frequency when the perturbation is higher and vice versa.

The LCASF algorithm uses duty cycle perturbations like conventional methods only. It continuously adjusts duty cycle perturbation size values and adjusts the perturbation frequency while taking into account the load current values. The algorithm is implemented into two component schemes- adaptive determination of perturbation values in duty cycle ΔD and adaptive determination of perturbation period T.

1) *Adaptive perturbation step size determination:* let the current perturbation values of duty cycle of converter are denoted as D(k) and load current as I(k). The previous perturbation values are D(k-1) and I(K-1). Hence the changes in the load current and duty cycle from one cycle to the next are defined as:

$$I_{diff} = I(k) - I(k-1) \qquad (1)$$
$$D_{diff} = D(k) - D(k-1) \qquad (2)$$

If the signs of I_{diff} , D_{diff} are same , the duty cycle is incremented by ΔD and a count variable X is set to '1' ,so that algorithm can

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remember the last perturbation direction of the duty cycle. If the signs of I_{diff} , D_{diff} are opposite ,the duty cycle is decremented by ΔD and the variable 'X' is set to '0'. If in case $I_{diff} = 0$, the duty cycle is perturbed in same direction as previous iteration and current values are not swapped. This step is equivalent to increasing the duty cycle perturbation size. The duty cycle of next iteration is given by:

$$D(k+1) = D(k) \pm C.\left|\frac{I\ diff}{Ddiff}\right| = D(k) \pm \Delta D \qquad (3)$$

Where C is the scaling factor used in designing of adaptive steps.

In above equation, smaller perturbation step size in steady state and larger perturbation step size in dynamic state are applied. So there are less oscillations and greater efficiency and fast and rapid convergence speed to MPP is there.

2) *Adaptive perturbation frequency determination*: for fixed step size algorithms as well as for variable step size techniques the perturbation period is always kept constant. For instance in [27], perturbation time T = 0.25s .But here perturbation time is not taken constant and accordingly the perturbation frequency is also not constant. This perturbation period is usually selected for max perturbation step size in duty cycle i.e. ΔD_{max} in adaptive step size algorithms. This is basically a worst case selection (ΔD_{max}) for perturbation time period, which results in slower dynamic response of MPPT controller.

The settling time for this stage design, can be computed from output current-to-duty cycle transfer function G_{cd} (s) which is for buck converter is given as :

$$G_{cd} = \frac{(1+R_{esr}C_0\,s).V_{pv}}{1+\left(L.\frac{V_0}{I_0}+R_{esr}.C_0\right)s+L.C_0.s^2}\frac{I_0}{V_0} \qquad (4)$$

where V_{pv} is the PV panel voltage which is the power stage input voltage, *Co* is the dc–dc buck converter output capacitor Lo is the dc–dc buck converter output inductor, R_{esr} is the output capacitor equivalent series resistance, *Vo* is the dc–dc buck converter output voltage, and *Io* is the dc–dc buck converter load current.

In the proposed LCASF algorithm, the perturbation period is varied as a function of the perturbation step size (which is also variable) as:

$$T\text{mppt} = f(|\Delta D|). \qquad (5)$$

Different step sizes in Δ*D* result in different output voltage settling times that determine the adaptive perturbation time period so the transfer function can be used to determine the settling time theoretically from above equation.

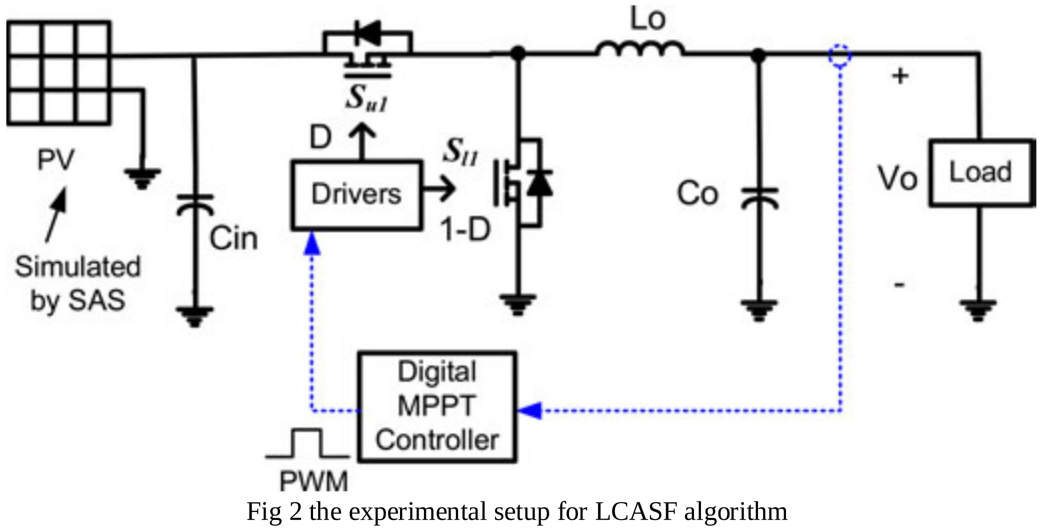

Fig 2 the experimental setup for LCASF algorithm

Fig 2 shows the experimental setup for the algorithm which utilizes buck converter. The control unit of the algorithm is implemented using TMSF28335 MCU which is having an analog to digital converter (ADC). There is a sensor which senses the load current value. An average value of around 100 samples of load current is taken as one perturbation value in algorithm as I (k).Both the schemes- adaptive duty cycle scheme and adaptive perturbation scheme are activated together in the system the convergence speed is improved further and significantly improved about 40 ms better than adaptive perturbation scheme acting

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ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

alone.

Thus the LCASF MPPT controller results in faster convergence speed which is almost equal to speed with 5% fixed duty cycle along with achievement of smaller oscillations and better efficiency

B. Modified Perturb and Observe Maximum Power Point Tracking Technique for Single-Stage Grid-Connected Photovoltaic Inverter

As mentioned above there are inherent oscillations, trade off problem existing in conventional P&O technique as the perturbation step size is fixed. Authors in [28] propose a modification in conventional P&O by setting an initial perturbation value. Whenever there is a change on irradiance value and continuing the tracking process with adaptive perturbation step size. For the application of the modification a grid connected photovoltaic (GCPV) system is used as shown in fig 3. To the PV system there connected a transformer for stepping up the voltage which is obtained from the PV panel. It is single stage topology in which phase angle (inverter) control controlling technique [29] for tracking MPP is applied, keeping modulation index constant. Fig 3 represents the scheme

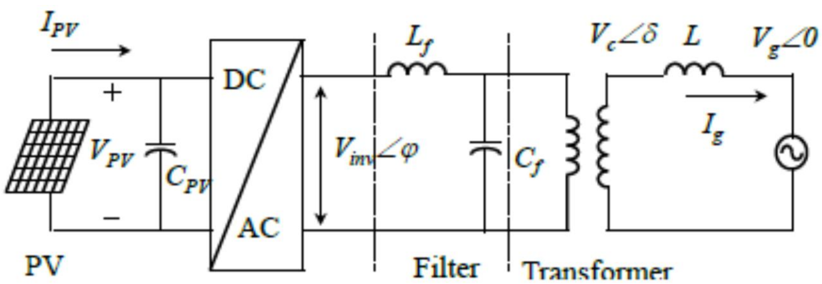

Fig 3 single stage grid connected PV system

If clearly observed it can be noticed that whenever there is change in irradiance, the operating point before getting settled around MPP on P-V characteristic of PV array, crosses a point on curve where the value of power is equivalent to the value of maximum power corresponding to changed irradiance. This point occurs as soon as there is irradiance change. And can be referred to as $P_{max\text{-}intial}$ .soon after that operating point settles around the MPP which is stable. Now this knowledge about power can be useful to determine an approximate value of the phase angle corresponding to MPP, which is used to set an initial value of phase angle. This is worked out as under:

For a certain value of irradiance G_n , the approximate value phase angle corresponding to MPP can be computed as

$$\phi_{nmax} = \phi_{Gmax}(P_{Gmax} - P_{nmax}) \times \beta \qquad (6)$$

where ϕ_{nmax} is corresponding phase angle ,P_{nmax} is the value of power generated at an irradiance G_n, P_{Gmax} is the max power value at initial irradiance G, $\beta = \frac{d\phi nmax}{dPnmax}$

From ϕ_{nmax} , perturbation step size in phase angle ϕ can be computed as:

$$\Delta\phi_n = (\phi_{nmax} - \phi_) / \alpha \qquad \text{,where } \alpha \text{ is a constant}$$

Now, $(\phi_{nmax} - \phi_)$ decreases as operating point approaches MPP and the step size gradually decreases. Thus this helps in fast convergence and less oscillations near MPP

We can see that the step size of perturbations is adaptive in nature and it adjusts according to the location of operating point from MPP. When far the operating point perturbations are large for fast tracking and when it is near the MPP, step size is small. That helps in fast tracking as well as reducing the oscillations and efficiency is thus good.

C. Variable Perturbation Size Adaptive P&O MPPT Algorithm for Sudden Changes in Irradiance

This also deals with variable size perturbation algorithm which consists of three component algorithms -current perturbation,

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adaptive control, and variable perturbation. Further, the proposed algorithm offers the tuning of variable perturbation size in two stages, which are coarse and fine tuning. In the coarse tuning, the perturbation size is estimated on the basis of irradiance level. In the fine tuning, the perturbation size is computed on the basis of operating point oscillations around MPP. By proposing these algorithms [30], authors try to remove the oscillations as well as dependence of algorithm on irradiation and temperature. The three algorithms are briefly explained as under:

D. Current perturbation algorithm (CPA)

This utilizes the conventional P&O algorithm and perturbs the current values of PV array. The reference value of the current is generated as:

$$I_{ref} = I_{pv}(k) + \mathrm{sign}(I_{pv}(k) - I_{pv}(k-1)) * \mathrm{sign}(\Delta P_{pv}) * \Delta I(k) \qquad (7)$$

Where sign(.) has +1 or -1 values depending upon the positive or negative values inside the function, all current values are computed at kth iteration. $I_{pv}(k)$ is operating current

Let us examine the I-V characteristics the PV array, which is shown in fig 4. In the figure, it can be seen that on the LHS of the MPP the output current of the PV array is almost constant and on RHS, the PV current changes rapidly. Therefore even if we apply small perturbations in current of when operating point is on LHS of MPP then system reaches the MPP rapidly and if the point on RHS of MPP operating current $I_{pv}(k)$ is less than (I_{MPP} –(I_{SC}-I_{MPP}) then the current perturbation gives slower response. To rectify this ACA is proposed.

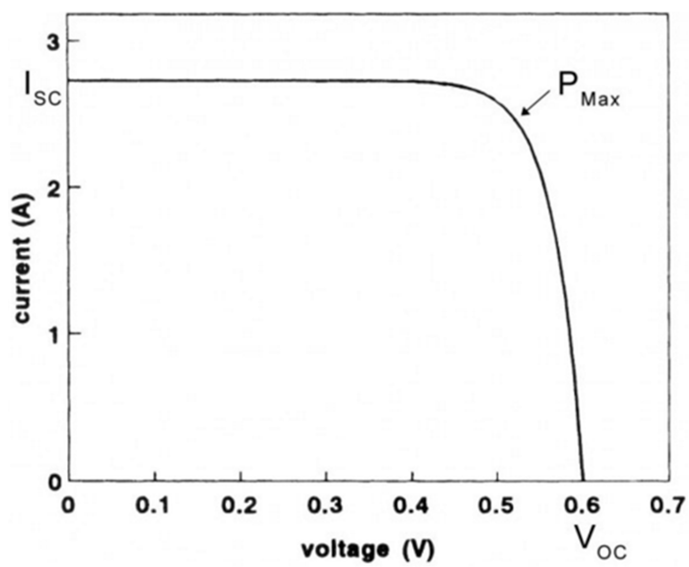

Fig 4 I-V characteristics of PV array

E. Adaptive control algorithm (ACA)

It always tries to keep the operating point within the operating range which is given as:

$$2I_{MPP} - ISC < I_{pv}(k) < I_{SC} \qquad (8)$$

Once MPP is reached, then V_{MPP} and I_{MPP} oscillate around MPP depending on the perturbation size. If the operating point doesn’t follow the range in (8) due to sudden change in the value of irradiance, then I_{pv} is to be controlled so that the operating point satisfied in (8). This can be done by estimating the short circuit current Once I_{SC} is estimated, the new operating point is calculated using FSCC (fractional short circuit current) method. In this, the MPP current I_{MPP} is continuously monitored with respect to the short circuit current I_{SC} [31]-[33].

According to FSCC, IMPP is approximately linearly related to I_{SC} as :

$$I_{MPP} \cong ksc\, I_{SC}; \quad ksc \text{ is a constant.}$$

The ACA basically moves operating point near MPP by multiplying short circuit current with an optimal proportionality constant. It provides coarse tuning of the perturbation size, based on the irradiance level.

F. Variable Perturbation Algorithm (VPA)

This algorithm reduces the perturbation size dynamically whenever the operating point crosses the MPP such that the oscillations are reduced around MPP. This provides the fine tuning of perturbation size. The fine perturbation size (ΔI_F) is expressed as:

$$\Delta I_F = (m_1 + m_2 \frac{|M|}{2} \Delta I_k)$$

where m_1 is the reduction factor of perturbation size and $m_2 = 1 - m_1$. The variable M represents the oscillations of operating point around MPP and defined as:

$$M = \text{sign}(\Delta P_{pv1}) + \text{sign}(\Delta P_{pv0}) \quad (9)$$

$$\text{Where, } \Delta P_{pv1} = P_{pv}(k) – P_{pv}(k\text{-}1) \quad (10)$$

$$\Delta P_{pv0} = -P_{pv}(k) + P_{pv}(k\text{-}1) \quad (11)$$

Now sign(ΔP_{pv1}) and sign(ΔP_{pv0}) can have values of +1,-1. And hence M can have values of -2,+2 or 0

The proposed MPPT algorithm is implemented using a boost converter as shown in fig 5. And it is realized using by dSPACE real - time control. The data acquisition process and control system are implemented using it. It is verified for sudden changes in irradiance with help of digital simulations. Successive sudden changes in irradiance value (both increasing and decreasing) are applied for a constant value of temperature. Iterations are taken and it can be inferred that proposed algorithm takes fewer iterations for reaching the MPP, if comparison is done with the case of conventional P&O and any adaptive P&O. It is further observed that oscillations are also minimized compared to both.

The given algorithm effectively tracks MPP at fast pace, whether there is increase or decrease in irradiance. It steadily tracks MPP under normal conditions and paces up dynamic performance if there is sudden change in operating conditions and thus decreases oscillations around MPP.

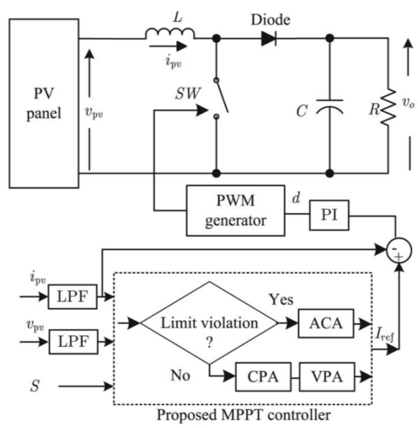

Fig 5 circuit diagram of PV system with MPPT controller

G. Optimization of Perturbative PV MPPT Methods Through Online System Identification[34]

It has been observed that the efficiency of MPPT algorithm is mainly factor of the amplitude of perturbation amplitude and the perturbation time period, i.e. the time for which the perturbation is applied. It is shown in [35] that the value of these two parameters should be selected in a proper way for better efficiency of the algorithm. Authors in [34] propose an online optimization of perturbation time in conventional P&O technique. They propose to estimate the min value of perturbation period in real time for operating PV conditions, Tp. This value of perturbation time is dependent on type of PV array, irradiance, temperature as well on

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ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

power circuit parameters. The whole technique uses frequency domain analysis and is implemented in a field programmable gate array [36].

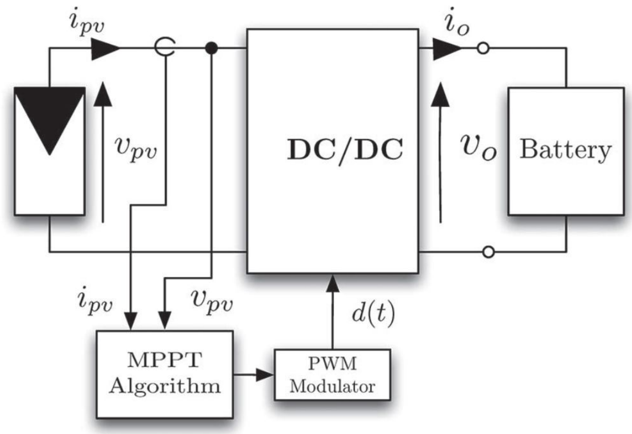

Fig 6 Typical PV with implemented by means of a switching converter

The perturbation step size in duty cycle i.e. ΔD must be greater than a min value ΔD_{min} and the perturbation period must not be less than Tp. There is a lower threshold value for ΔD which is taken from [35] in which some preliminary results are given about the proposed method. It is given as:

$$\Delta D_{min} = \frac{1}{G_0}\sqrt{\frac{V_{MPP} * K_{ph} * |\dot{G}| * T}{H * V_{MPP} + \frac{1}{R_{MPP}}}}$$

Where, $\dot{G}$ is the average rate of change of the irradiance level in the time interval T between two consecutive perturbation and G_0 is the dc gain of the transfer function between the PV voltage and the control variable D. V_{MPP}, I_{MPP}, and R_{MPP} are the PV voltage, current, and differential resistance at the MPP, respectively. K_{ph} and H are variable quantities dependent upon G , V_{MPP}, I_{MPP}
A small perturbation in duty cycle ΔD can used for determining the settling time T_p, which is the time taken by the response before getting settled around a steady state value. Smaller the value of perturbation period T, the MPPT is more efficient in tracking the MPP which changes due to abrupt changes in environment. Thus this method basically aims at computing the min value of the perturbation period of MPPT controller, which is an important affecting the performance of MPPT. The technique then applies the Cross –correlation method (CCM) [37] which is based on injection on pseudorandom binary sequence (PRBS) superimposed on duty cycle of converter. The CCM then is used for defining a transfer function $G_{vp,D}$. Then after that the system impulse response is computed such that Fast Fourier Transform (FFT) can be applied for estimating the frequency response.
Method aims at estimating the power response settling time by considering dynamic response of converter, operating conditions at PV array. The FPGA is used to implement the designed MPPT controller. The method is quite adaptive for any set of operating conditions. hence is accurate and gives better results

H. Optimized Adaptive Perturb and Observe Maximum Power Point Tracking Control for Photovoltaic Generation [38]

Authors in [38] propose a criterion for designing, which involves choosing an adaptive perturbation step such that most suitable perturbation step size is selected for different operating conditions, for a better dynamic response of the system. The proposed technique employs dual input inductor push-pull converter (DIIPPC) [39] and a perturbation function is proposed like in [40]. The basic configuration of a DIIPPC is shown in fig 7

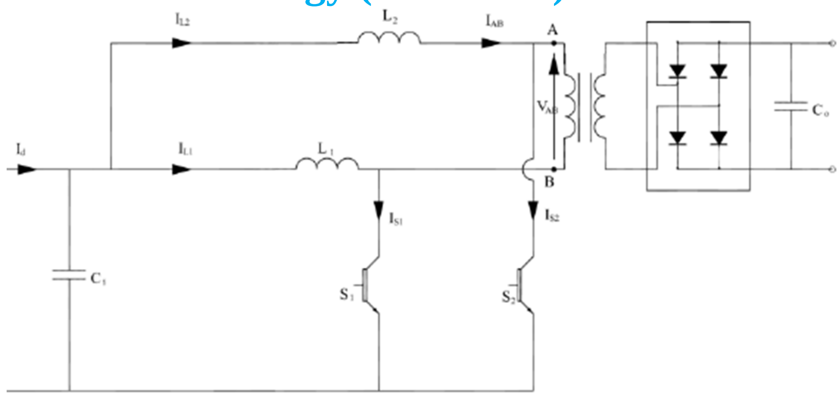

Fig 7 circuit diagram of DPPIIC

As we have learnt earlier the perturbation step size affects the tracking speed of the algorithm and hence the efficiency of the perturbation step. So it is needed that an optimal perturbation step should be found which is factor of PV array characteristics, working conditions and topology of converter. This method proposes an adaptive P&O technique which operates with variable perturbation size which is adapted to actual working conditions.

When operating is far large perturbations are chosen and vice versa and hence algorithm needs to know the position of MPP. In this the perturbation step in form of function, is defined as:

$$\Delta V\ (V) = f(V_{M,est} - V) + \Delta V_{min} \quad (12)$$

Where, ΔV is the perturbation step; $V_{M,est}$ is the estimated voltage at MPP; V is the measured voltage; ΔV_{min} is the minimum value of the perturbation. Now if voltage which is estimated is most accurate ,i.e. $V_{M,est} \equiv V_{MPP}$ and the DC-DC converter does not introduce any delays then the perturbation function is defined as

$$f(V_{M,est} - V) = |V_{M,est} - V| \quad (13)$$

$$\Delta V_{min} = 0$$

Ideally, MPP is attained after one perturbation only but MPP voltage estimation introduces an error in the value. So for algorithm to estimate the actual MPP , $\Delta V_{min} \neq 0$. Also, when the measured voltage V is close to V_{MPP}, the function f should yield a value lower than ΔV_{min} when $V \equiv V_M$:

$$f(V_{M,est} - V) < \Delta V_{min} \quad (14)$$

After V_{MPP} is estimated, the theoretical position of V_{MPP} can be computed by mathematical model of PV array. With the proposed algorithm, an error in the estimation of the theoretical maximum is compensated by the P&O function. Also irradiation and temperature are measured for estimating the MPP.

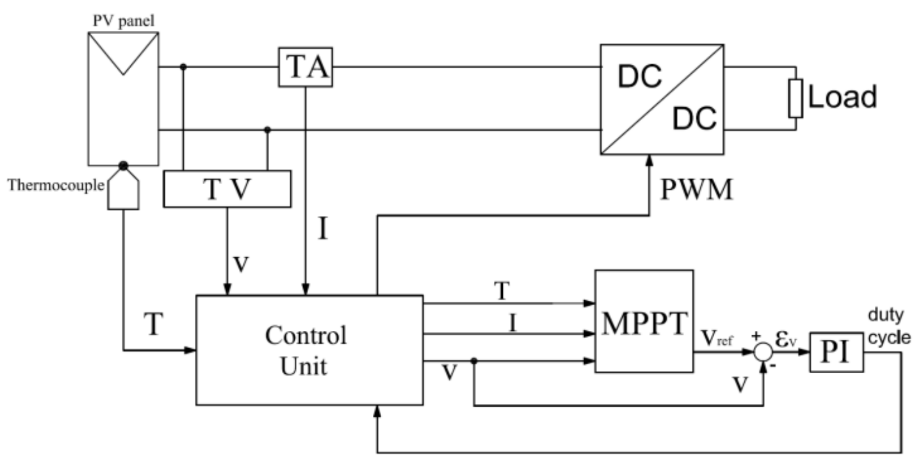

Fig 6 block diagram for system

The MPPT algorithm is implemented by changing the duty-cycle of the DIIPPC via a proportional-integral regulator. Result show that the modified P&O is better than conventional one and shows comparable reactivity during transients even if there is no adjustment applied on perturbation step size for different operating conditions. This is due to adaptive nature of algorithm. Overall

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ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

system shows better efficiency

The experimental results have demonstrated clearly that the proposed modified perturb & observe algorithm is better than the conventional P&O and IC in steady-state and shows comparable reactivity during transients, even if no adjustment is operated on the perturbation voltage step for different operating conditions. This is due to the intrinsic adaptive characteristic of the algorithm. The perturbation step is set in a way that it is higher when the irradiation changes suddenly and is lower when the operating point is close to the maximum power point. From the analysis of the results, it is evident that the proposed perturb & observe algorithm has higher efficiencies than the algorithms already proposed in the technical literature.

III. CONCLUSION

In the present paper, the various modifications proposed in recent times for conventional perturbation and observation MPPT algorithm. We can see almost all modifications aimed at reducing the oscillations which are inherent in the system. Also, they try to reduce the effect of temperature and irradiance on the performance of the MPPT.

Table 2 below establishes the comparison between all the modifications discussed on different parameters

Approach	Converter involved	Implementation	Effect on oscillations	Dependency on Irradiance and temperature	Performance
A	Buck converter	Difficult	The oscillations are greatly reduced	The technique does not takes into account the effect of radiation falling on PV panel and changing temperature	A good trade-off between convergence speed & tracking efficiency is yielded. Also faster convergence speed is obtained
B	Inverter	Easy	Oscillations are reduced	Performs well under the effect of sudden irradiance changes	The efficiency is greatly increased as oscillations are decreased & effect of irradiance is taken in account
C	Boost Converter	Difficult	Oscillations are reduced	It takes into account the effect of sudden changes in the radiation	The tracking of MPP is good in steady as well as in dynamic state when the operating conditions are changed. Tracking speed is also improved
D	DC-DC converter	Difficult	Oscillations are less	It considers the effect of sudden working conditions on PV system which includes the changing environmental conditions.	The dynamic response of system is improved
E	DPPIIC	Easy	Oscillations are less	Does not take into account the effect of irradiance	The dynamic response of the system is greatly improved. Algorithm adapts itself for different operating conditions. The efficiency is increased as well

Volume 4 Issue IV, April 2016
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Table 2 comparison of different modified P&O techniques

The paper aims at studying and discussing the important features of different modifications proposed in perturbation and observation MPPT by different authors/researchers. Paper discusses the salient points of the modifications developed. Paper also does a comparative analysis of all the techniques on the basis of different parameters. It can be seen from the table 2 that each approach has its own advantage and disadvantage. Each technique can be applied as per the demand of the situation. Also there is plenty scope of applying further modifications in existing as well as proposed algorithm.

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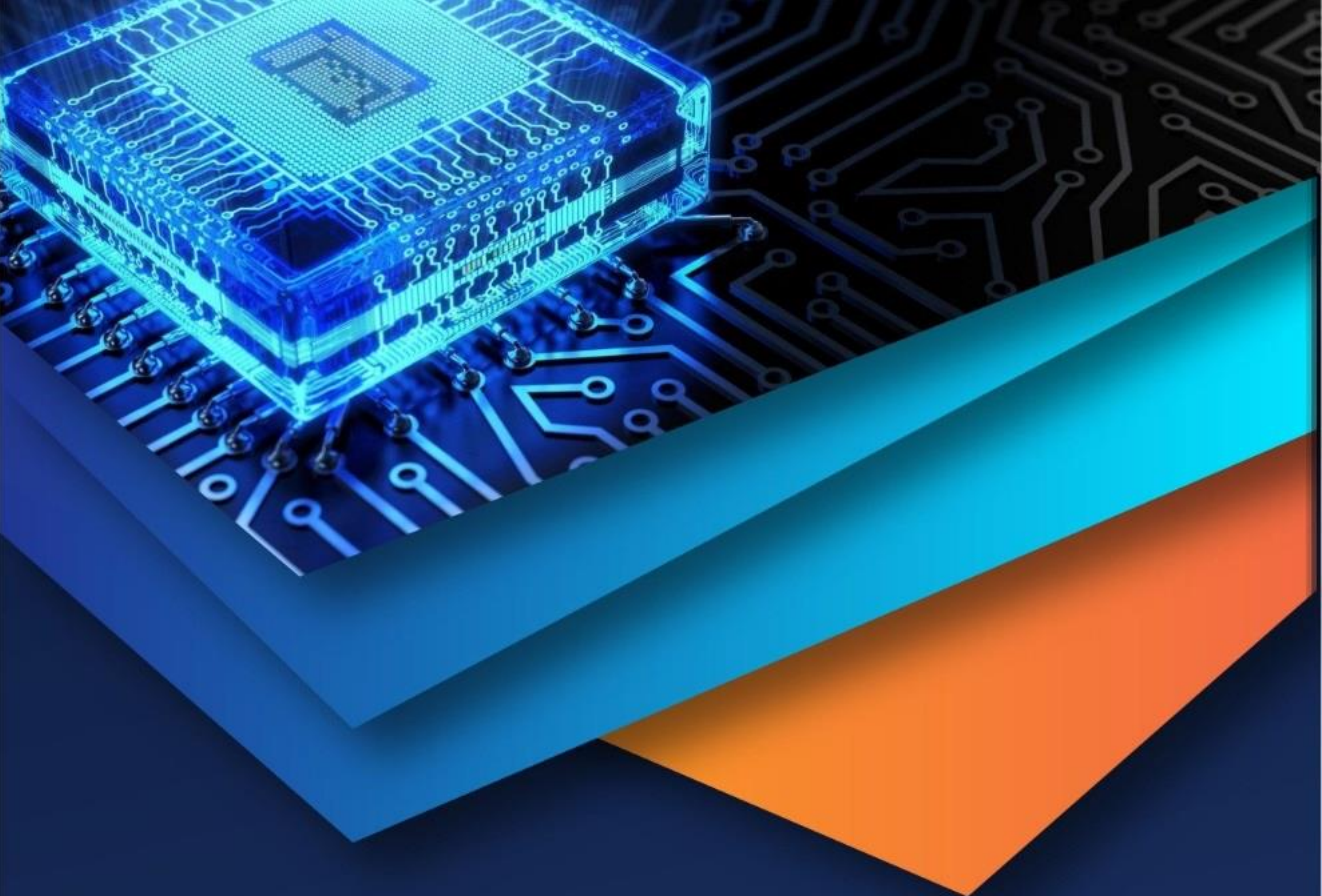

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