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Design and Investigation of Adaptive Fixed Duty Cycle MPPT algorithm for Photovoltaic Systems

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As the usage of fossil fuel and generation has required the available resources, there was great boom for renewable energy sources. The most abundant solar energy is one of the most familiar sources of energy in the present world. In solar system, the photovoltaic array depends on the climatic variations, solar intensity and temperature of the atmosphere. The effect can be minimized. Though many MPPT techniques are described in the literature, sufficient comparative analysis with proper environmental condition is not addressed. In this paper, a novel Adaptive Fixed Step Size (AFDC) AFDC technique is designed and is evaluated that can adaptively adjusts to reference step size and hysteresis bandwidth, AFDC is also promises to result in improved efficiency with automatic self-tuning perturbations.

Keywords: Photovoltaic system, Modeling of PV arrays, Adaptive fixed step sized algorithm, Variable adaptive step size algorithm

Introduction

In the present world, huge increses in the population is observed since two decades. In order to satisfy the huge electrical demand it is essential to generate the electrical energy as per the demand. The conventional electricity producing methods based on fossil fuels is not appropriate solution for future because of several limitations. Due to limited available resources and the growing demand for the energy, the need for an alterntive renewable sources. The solar energy is one of the most abundant alternate energy resources.For improving the output of PV system, AFDC MPP tracking method is proposed in this paper. The proposed AFDC technique attains perturb value according to system changes, no oscillations produced for the period of tracking and steady-state operations and reduced computational trouble. To meet these requirements fast tracking is required which is achieved by using digital controllers[1-2]. The block diagram of proposed AFDC mppt algorithm based photovoltaic system is shown in figure.1.

Photovoltaic System

The most commonly used MPPT technique is a PV cell with a diode that undergoes photoelectric effect which convert electromagnetic radiation into elecrical current. A PV cell is fundamentally p-n junction diode which converts incident solar irradiation into electrical energy.The electrical energy obatained from one single cell is very low. Soin order to obtain desired output, number of PV cells are connected in series or parallel[2].

Influence of variation of solar irradiation

Irradiance is a measure of power density of sunlight. So, when sunlight falls on the junction, the electron hole pair will be created. The electrons travel towards n-type semiconductor and holes towards the n-type semiconductor. When the load is connected between the both layers, the current is flowing from p-type to n-type semiconductor. Whenever irradiance increases, the electron hole pair generated also increases. Therefore, the short circuit current increases proportionally w.r.t

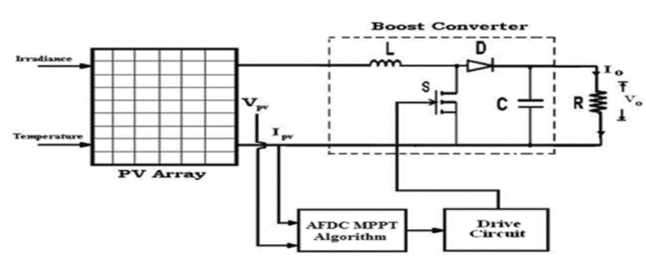

Fig. 1 — Schematic Diagram of Proposed AFDC MPPT

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solar irradiance and open circuit voltage slightly increases with the irradiance; due to arithmetically log proportional to the irradiance. When the irradiation increases, both the current and voltages increases, this has an impact on the power. The more the irradiation, the more power is generated[2-3].

Influence of variation of temperature

When the temperature of the PV array increases, the depletion layer width decreases. The electrons and holes will have the capability to cross the junction, so the short circuit current slightly increases. When temperature is increased, the intrinsic carrier concentration increases which is proportional to reverse saturation current**.** So, the open circuit voltage significantly decreases with the increase in reverse saturation current. When the temperature increases, the output voltage is decreased. The current increases with the temperature but too small to balance the decrease in the voltage caused by a given temperature rise. So that the power also decreases. Therefore the efficiency of solar cell is lowered[2-3].

Boost Converter

A boost converter is integrated with PV array to boost the output voltage under varying cell temperature and solar irradiance conditions. The low amount voltage output is not appropriate and useful for industrial application. Where the requirement of electrical energy is higher. To improve the magnitude of low output voltage, a boost converter should be utilised with high efficiency and low cost. In order to increase the voltage gain, the boost converter is required. In boost converter, the output voltage can be boosted in significant level[4].

Methods of MPPT Control

MPPTis one of the most essential technique to maximize efficiency of PV systems, and it is efficient technique for extracting maximum power from PV- system, as it is fuel free and requires low maintainance[1].

Several MPPT techniquies can be adopted for improving the performance of PV- system. MPPT techniques a*ften used are*

Fractional voltage feedback

Fractional current feedback

Incremental Conductance

Fixed step size P& O

Fractional voltage feedback MPPT technique

The fractional voltage feedback MPPT technique is the most simple MPPT method well identified as costant – volatge method. In this method,it is observed that the PV module maximum output power is around 0.76 times that of the open- circuit technique, hence known as 76 percent technique. The main drawback is to change the optimal point (0.6 – 0.75) of the constant $Z_{v.}$ This technique however has low efficiency comparatively[5].

Fractional current feedback MPPT technique

The short circuit current algorithm is one of the simplest control algorithm and aften designated as costant – current technique. In this technique, the factor ($k < 1$) lies in the range 0.78 - 0.92. In this MPP technique, the the output current of PV module should operate around 90 % of the short circuit current[5].

Incremental Conductance MPPT technique

The perturbations is the operating point can be stopped with incremental conductance MPPT technique.The direction of perturbation can be obatained from the fact it is negative when it is towards right of MPP and positive when it is toward left of MPP[5-7].

Fixed step size P& O MPPT technique

This technique is also called as hill climbing technique in which by periadically increasing or decreseing the array volatage, the operating point transverse towords MPP.This technique is software based with self tuning adjusting the reference - volatge and step size to reach maximum power tracking under dynamically varying changes[7].

Proposed AFDC MPPT Control

Different MPPT techniques are Fractional voltage feedback MPPT technique, Fractional current feedback MPPT technique, P&O algorithm and Incremental Conductance MPPT techniques arestandard because these are all simplest MPPT techniques and implementation is simple when compared with other methods. Nevertheless, these methods does not perform good because of existing noise and current change threshold due sudden change of the reference voltage. Because of PV source non-linearity the noise factor exists in addition to contollers and sensors. The above mentioned noise problem has an effect on the entire PV system such as slow tracking of MPP and the output voltage of DC-DC converter or inverter[8-10]. In view of all the limitations in the earlier MPPT methods, this paper has proposed a highly digital control using adaptive perturb and observe (AP&O) MPP technique. The highlights of this technique are summarized as follows: firstly, quick to reach the maximum power point. Secondly, work well with of noise existence that occurs due to the nonlinearity of PV source. Third being, tracking efficiency is better as previous MPPT methods[11-12].

The output power of the PV array depends upon the solar irradiance and cell temperature. The output power of PV module is given to the grid through the DC-DC boost converter and inverter. The PV output voltage and current is given to adaptive perturb and observe MPPT controller. The adaptive perturb and observe MPPT controller generates duty ratio based on the fixed step-size perturb. In this method, the duty cycle is varied accordingly to maximum operating point oscillates around the MPPs. By changing duty ratio, it can match the characteristic impedance of the PV array to the load impedance. Therefore, it quickly transferred the maximum power to the load[13-15].

AFDC MPPT Algorithm:

The relationship of ‘P’ and ‘D’ in the photovoltaic system with boost converter as power conditioner show in fig 2(b). Here ‘P’ is represents the photovoltaic output power and ‘D’ is the duty cycle of DC-DC boost converter.

$$d(k) = d(k-1) \pm \frac{dP/dD}{P/D} \quad \ldots (1)$$

If dP/dD>0 be able to access maximum power point, then the equation (1) as modified as

$$d(k) = d(k-1) + \frac{dP/dD}{P/D} \quad \ldots (2)$$

Similarly, for dP/dD<0, then the expression is

$$d(k) = d(k-1) - \frac{dP/dD}{P/D} \quad \ldots (3)$$

The operation of P-D curve start with left area, if dP/dD>0 be capable of access maximum power point (MPP). However, the actual operating point is in the right-hand area, to keep dP/dD<0 to reach maximum power delivery. When the tracking system of dP/dD=0, then, the power reaches maximum point. The flowchart of AFDC MPPT control algorithm is presented in fig. 2(a).

The algorithm steps are :

Step 1: start

Step 2: initialize the value of duty cycle between 0 and 1.

Step 3: measure the values of photovoltaic array voltage and current at kth and k-1th Instants and compare powers at kth and k-1th instants.

Step 4: if dP > 0 , slope = 1 and duty cycle is increased by D + c * slope.

Step 5: if dP < 0, slope = -1 and duty cycle is decreases by D + c * slope.

Step 6: save present power as previous power (k-1) value.

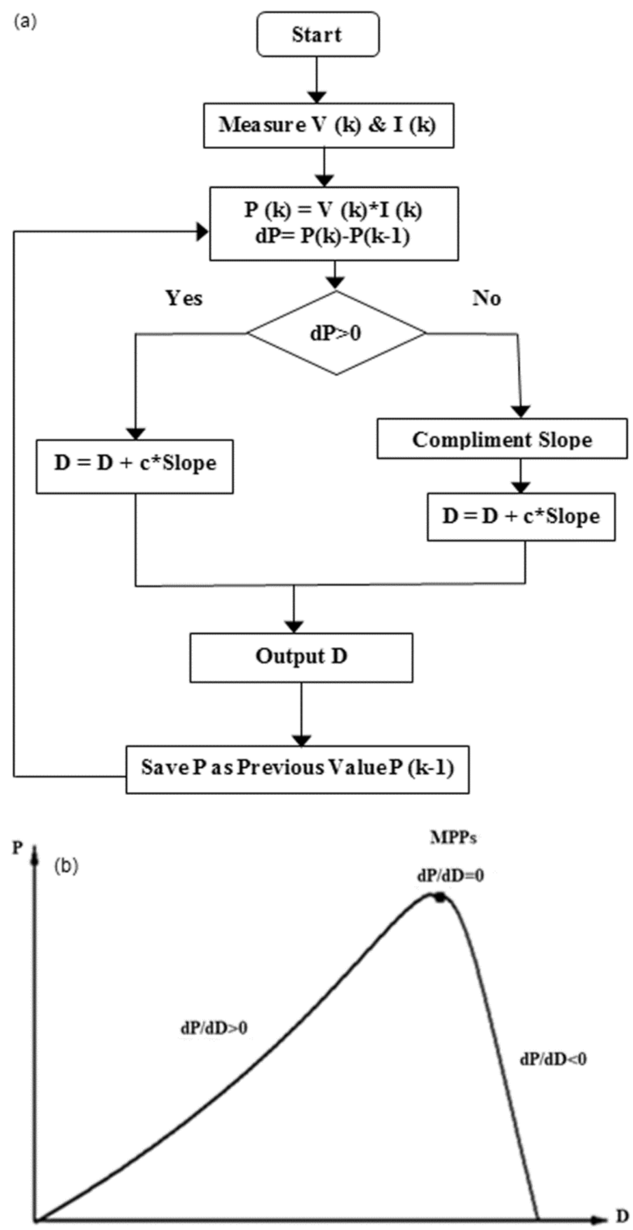

Fig. 2(a) — Flowchart of AFDC MPPT control algorithm, (b): Relationship of P and D

Step 7: Go to Step 3 and repeat the above steps until reaching the Maximum power point

Step 8: stop.

Results and Discussion

To show the effectiveness of adaptive perturb and observe MPPT control PV system, mathematical simulation has been carried out by using MATLAB/Simulink. The specification parameters of the photovoltaic module and boost converter are presented in Table 1

Variation of Irradiance

From Table 2, it is concluded that, adaptive perturb and observe MPPT algorithm method gives optimal performance by increasing the tracking efficiency, (86.29%) of the photovoltaic module. Hence, the proposed MPPT algorithm with PV system to give optimal performance when the system operating low/medium/high temperature at irradiance is 1000W/m2. It is observed that, when the cell irradiance decreases the photovoltaic output power also decreases. Similarly, when the irradiance decreases the output voltage is decreased. Whereas, the output current of the photovoltaic system is increased.

Variation of Load

Figure. 3(a) and Figure.3(b) shows the recital of ADFC and proposed MPPT algorithm at various load conditions. It is clear that from Table 3, if the duty cycle is constant, the variation of load resistance is increase (decrease) the voltage and decrease (increase) in current of the photovoltaic system. Though, variation in the voltage and current are alwys in the opposite direction under load variation.

Table 1 — Specification Parameters of the Photovoltaic Module and Boost Converter

Photovoltaic Module	
Maximum Power ($P_{max.}$)	100W
Open Circuit Voltage(V_{OC})	21.75V
Maximum Power Point Voltage(V_{MPP})	17.1V
Short Circuit Current(I_{SC})	6.43A
Maximum Power Point Current(I_{MPP})	5.85A
DC-DC Boost Converter	
Input Voltage	25V
Output Voltage	100V
Output Power	100W
Boost Inductor	2.3mH
Boost Capacitor	1200µF
Switching Frequency	20kHz
Load Resistance	5-100 ohms

Table 2 — Evaluation of PV Output Voltage, Current, Power and Tracking efficiency at different Load Resistance

Load Resistance (Ohms)	Proposed AFDC MPPT Algorithm			
	I_{PV}	V_{PV}	P_{PV}	Tracking Efficiency (%)
9	4.548	18.97	86.29	86.29
12	4.21	18.16	76.49	76.49
15	3.23	19.81	66.24	66.24
20	2.66	19.88	52.93	52.93
50	1.149	20.10	23.10	23.10
75	0.85	20.24	17.23	17.23
150	0.342	20.51	7.03	7.03
200	0.273	20.59	5.64	5.64

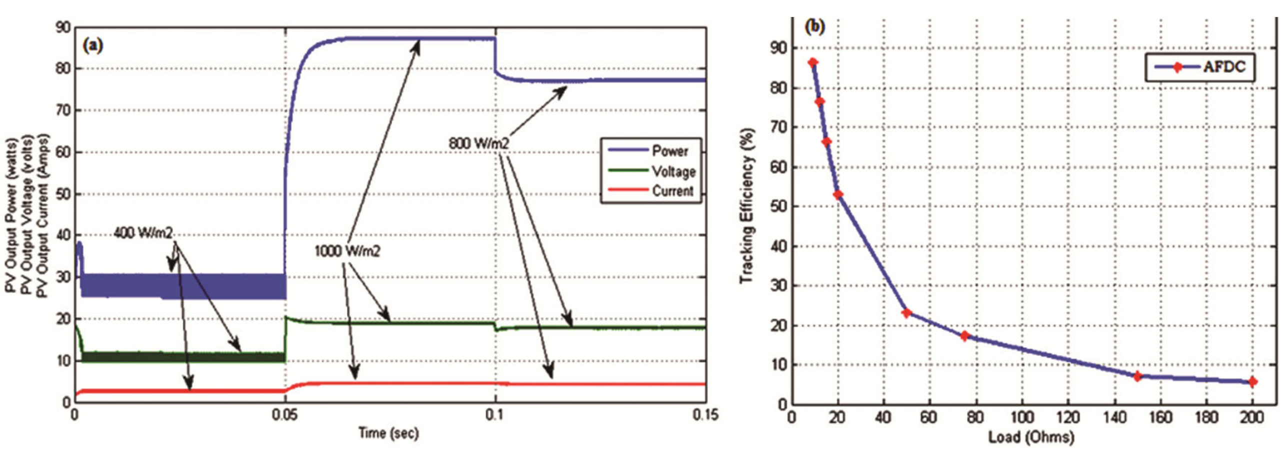

Fig. 3.AFDC — (a) Measured Waveforms of PV Output Voltage, Current and Power with Different Irradiance at Fixed Temperature is 25° C and (b) Analytical evaluation of Tracking efficiency at various Load Resistance.

Table 3 — PV Output Voltage, Current and Power with different Irradiance at Constant Temperature condition

Irradiance (W/m^2)	Temperature (^{o}C)	AFDC MPPT Method		
		PV Output Voltage (V_{mp})	PV Output Current (I_{mp})	PV Output Power (P_{mp})
1000	25	18.97	4.548	86.29
800		17.70	4.120	72.92
600		15.18	3.524	53.49
400		11.87	2.580	30.62
200		9.985	1.293	12.91

Conclusion

The proposed adaptive P & O MPPT algorithm is tested on a closed loop system. The concept of maximum power tracking in proposed algorithm is adapted thereby reducing the oscillation around the MPPs and fast dynamic response involved in the all previous MPPT control techniques. Simulation results conclude that, the proposed MPPT control algorithm gives improved performance as compared to all control techniques. Hence, to improve the PV system, in terms of increased tracking efficiency and reduced oscillation around MPPs in the output of the PV power during low/medium/high temperature and irradiance regions, AFDC MPPT is suits well.

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