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Adaptive Fuzzy Pid Controller Based Maximum Power Point Tracking For PV Fed DC Motor Drive

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Abstract : The PV characteristics of a photovoltaic generator is a non linear one. Hence it is necessary to develop an algorithm for a Maximum Power Point Tracking (MPPT) in order to optimize the photovoltaic(PV) system performance. An adaptive fuzzy proportional integral derivate (AFPID) control based MPPT method is suggested in this paper which uses the two level control mechanism. This method combines the privileges of both traditional PID control and Fuzzy logic control. The results of simulation infers that the proposed controller guarantees confluence to the maximum power point at varying climatic conditions and yields better response under varying load conditions. The designed AFPID control algorithm simultaneously improves both dynamic as well as steady state performance of PV system when compared to traditional P&O approach.

Keywords : PV system, MPPT, P&O, DC-DC boost converter, Adaptive fuzzy PID controller.

1. INTRODUCTION

The essential and important sources for satisfying human needs are water resources. These are also essential for ensuring protective health, food production as well as economic and social development. This essential need can be met by a solution *i.e.*, Remote Water pumping system. In the world, day- by- day increasing population leads to increased energy demand. These days, generation of electricity is majorly dependent on non-renewable energy resources. The alternative for these resources are renewable energy resources like fuel cells, biomass, solar and wind. The renewable energy sources like wind, solar PV, biomass and fuel cells seems to be the alternate option to conventional non renewable energy resources. In particular, solar energy seems to be the finest recourse for generating electricity as it is indefinitely renewable as well as noise and pollution free. A photovoltaic (PV) system transforms sunlight into electricity at once and is best known for inexhaustibility and sustainable environment. The major drawback of these systems is that the PV systems exhibits poor efficiency and the power generated changes with varying climatic conditions. The efficiency of solar PV arrays is dependent on irradiance, temperature and the non-linear characteristics exhibited by PV cell. So, we need a tracker which extracts a point at which the power of the system is maximum. The maximum power point tracking (MPPT) is one approach which extracts maximum output power from the PV array and the output power can be increased by varying the voltage current ratio.

Many MPPT algorithms are put forward to extract maximum power of the PV system. The commonly used methods are Perturb and Observe (P&O) and Incremental conductance(IC). The P&O technique is widely used because of its ease of implementation, but the major drawback is that there are much

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power oscillations around MPP which leads to reduced efficiency. The other MPPT strategies Employing artificial intelligence such as Genetic algorithms, artificial Neural networks have their own disadvantages like energy losses particularly in large PV systems. An adaptive fuzzy PID controller based MPPT method is suggested here to achieve maximum output power. The proposed technique constitutes the advantages of both conventional PID controller and fuzzy logic controller. Here, the gains of PID controller are tuned using fuzzy logic controller and this method guarantees maximum power operation under different conditions such as varying irradiance and at various levels of load.

2. THE PROPOSED SYSTEM

The synoptic scheme of the proposed PV stand-alone system is as shown in the figure1.

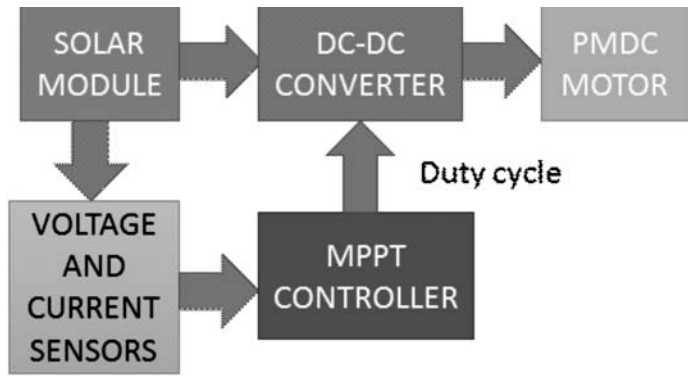

Fig. 1. Scheme of proposed system.

The proposed PV stand-alone system consists of a solar PV module of 250W, a DC-DC boost converter, MPPT controller and a DC motor as load. Usually DC motors are more preferable compared to other motors as they yield high efficiency and the advantage that they can be directly connected to a PV module.

3. MODELLING OF DEVICES

The single diode model of an ideal PV cell and practical model of PV cell is shown in figure 2.

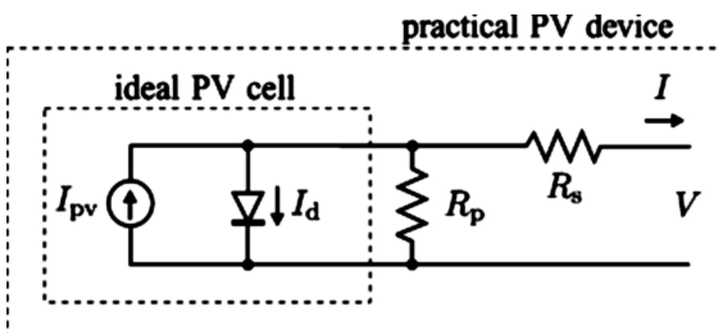

Fig. 2. Single-diode theoretical model of PV cell and equivalent circuitof a practical PV device with parasitic resistances.

The mathematical expression that describes the I-V characteristics of a PV cell is as follows.

$$I = I_{pv,\,cell} - I_{0,\,cell}\left\{e^{\frac{qV}{akT}} - 1\right\} \tag{1}$$

Where,

$I_{pv,\,cell}$ is current due to incidence of light,

I^d is diode current,

$I_{0,\,cell}$ is diode reverse saturation current,

q is the electron charge whose value is $1.60217646 \times 10^{-19}$ °C ,

k is Boltzmann constant having a value $1.3806503 \times 10^{-23}$ J/K,

T represents the p-n junction temperature and

a is diode ideality factor.

Equation (1) cannot be taken as a specimen for I-V characteristics of a practical PV array. PV arrays in practical consists of several series or parallel connected individual PV cells. Hence the characteristic equation of PV array is obtained by including additional parameters into the basic equation.

$$I = I_{pv} - I_0 \{ e^{\frac{V + IR_s}{V_t a}} - 1 \} - \frac{(V + IR_s)}{R_p} \tag{2}$$

Where I_{pv} and I_0 represent array current and reverse saturation current, $V_t = \frac{N_s k T}{q}$ gives the cell thermal voltage. N_s represents number of series cells. Figure 3 shows the I–V characteristics of PV cell.

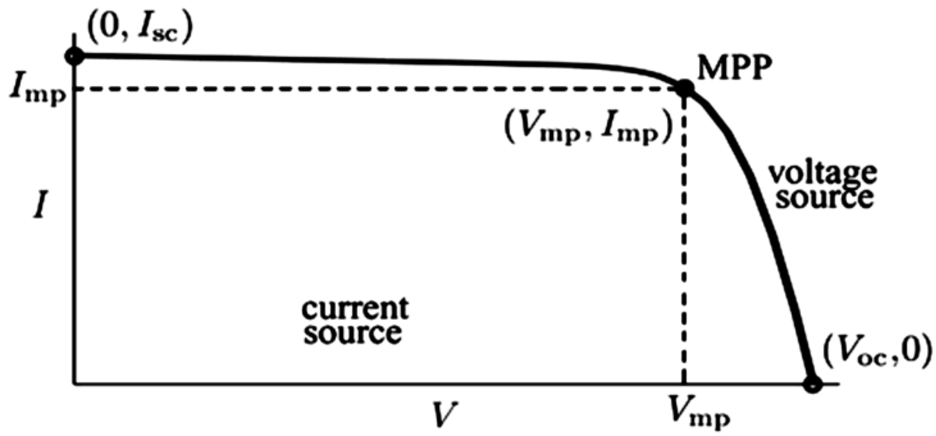

Fig. 3. I–V characteristic of a practical PV device.

The short circuit current I_{SC} is first calculated at a given temperature (T) where I_{SC} at T_{ref} is given in the datasheet (measured at irradiance of 1000W/m^2). T_{ref} is the reference temperature. The diode reverse saturation current I_0 is dependent on temperature and at a given temperature the mathematical expression for I_0 is

$$I_0|_T = I_0|_{T_{ref}} \left(\frac{T}{T_{ref}} \right)^{\frac{3}{n}} e^{\left(\frac{-qE_g}{nk} \right) \left(\frac{1}{T} - \frac{1}{T_{ref}} \right)} \tag{3}$$

The parameters of PV module of the proposed system are tabulated as follows.

Table 1. Electrical characteristics of the PV module

Parameter (at STC)	Value
Maximum Power	250W
Voltage at Pmax (Vmpp)	30.69V
Current at Pmax (Impp)	8.15A
Open circuit Voltage (Voc)	37.98V
Short circuit current (Isc)	8.67A
No. of cells in series	60

The PV and IV characteristics of PV module are shown in figure 4 and figure 5.

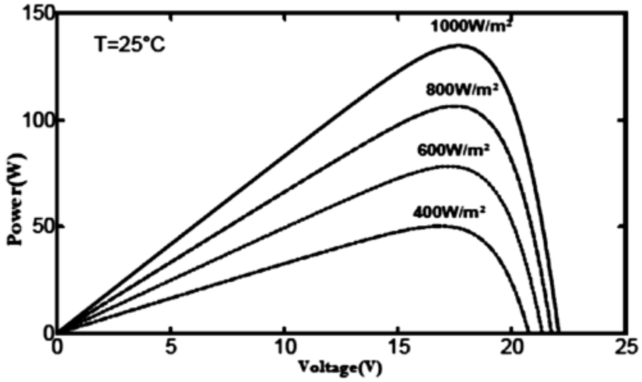

Fig. 4. Characteristic PV curve of P-V array at 250°C.

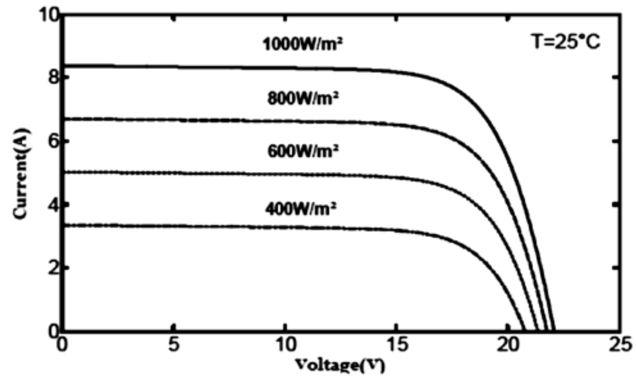

Fig. 5. Characteristic I-V curve of PV array at 25°C.

The PV systems widely use DC-DC power converters as an intermediate between the PV generator and the load in order to operate the PV system at its MPP.

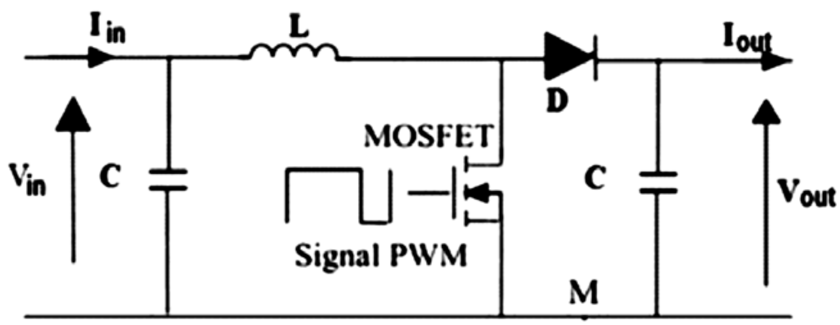

Fig. 6. Schematic circuit of DC –DC boost converter.

Figure.6 shows a DC-DC boost converter which includes an inductor, capacitor and MOSFET. In ideal situation, these components do not consume power and have good yields. The switching times of the MOSFET is controlled by the duty cycle obtained from the MPPT controller.

The input-output voltage relation which is also the gain of the converter in terms of duty cycle *d* , is given as

$$\frac{V_{out}}{V_{in}} = \frac{1}{1-d} \quad (5)$$

Generally, DC motors are employed in most of the PV water pumping systems because direct coupling with PV module is possible and as a result the system becomes simple. Of all types of DC motors, PMDC motor is best suitable as it provides high starting torque.

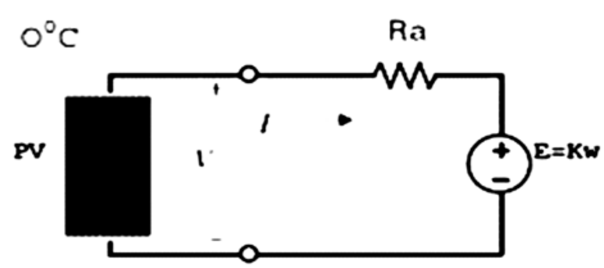

Fig. 7. Equivalent circuit of PV fed permanent magnet DC motor.

$$V = I_a R_a + k\omega \quad (6)$$

Figure. 7 represents an equivalent circuit of a PMDC motor fed from PV source. The dynamic equation governing the DC motor armature circuit is given as

The I-V curve of a PMDC motor with respect to varying irradiance is represented in figure.8

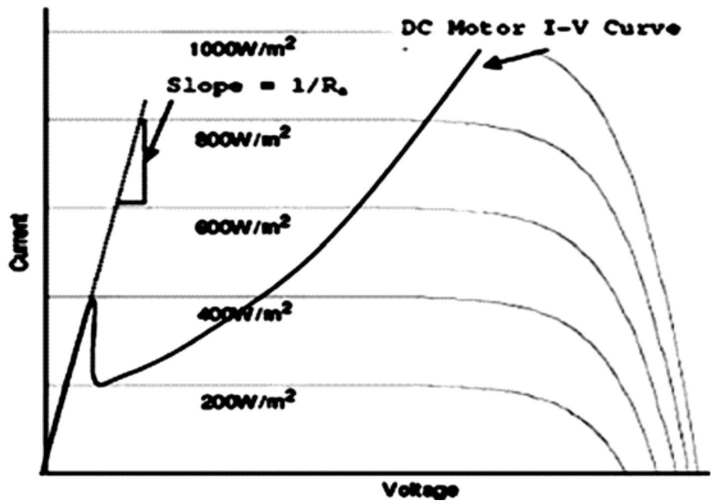

Fig. 8. I-V curve of a DC motor at different irradiance.

In the available MPPT techniques, the Perturb and Observe (P&O) method is frequently used as it is simple and easy to implement. The flowchart explaining the basic P&O MPPT method is shown in figure.9

This method works on principle that perturbing(increase/ decrease) duty cycle and observing the PV system output power. If the output power is augmented due to the perturbation, the operating point moves towards the maximum power and hence the perturbation is continued in same direction. If the output power reduces, a new perturbation is made in opposite direction. The main drawback of this method id deviation of MPP during varying climatic conditions.

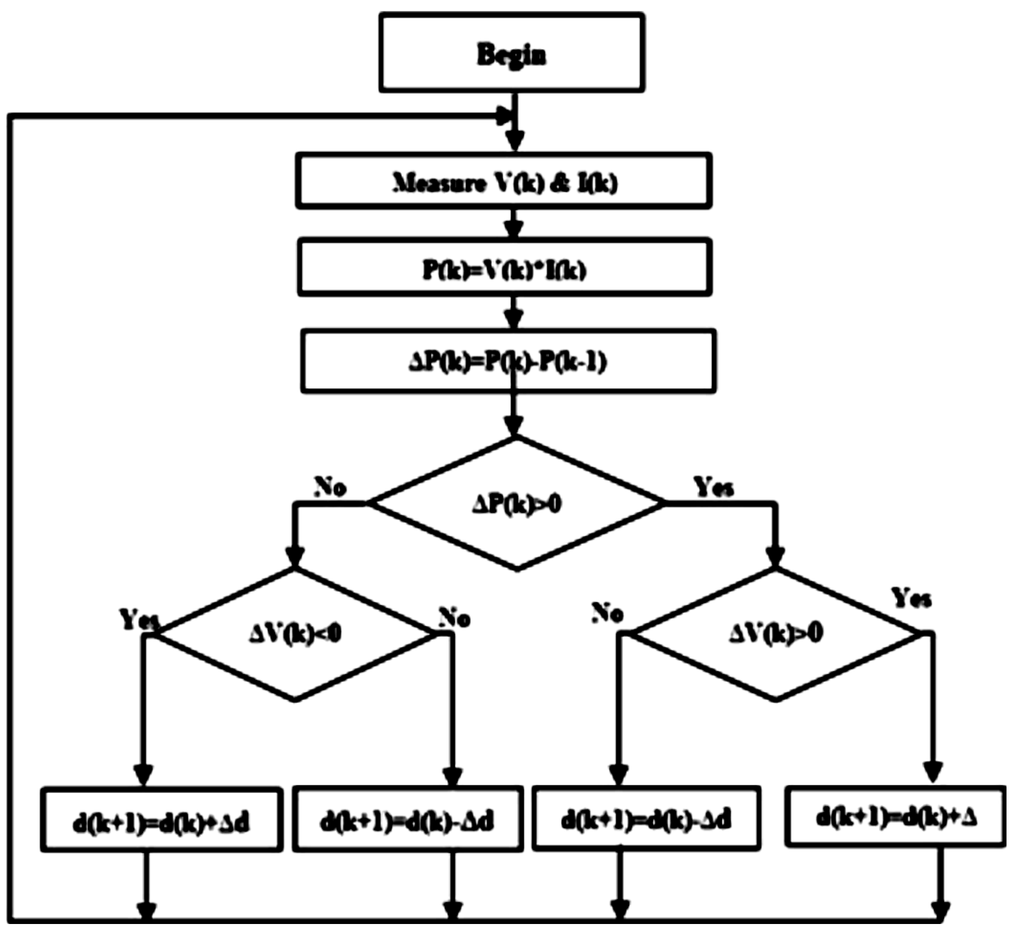

Fig. 9. Flowchart of the P&O MPPT algorithm.

4. PROPOSED AFPID MPPT CONTROLLER

The schematic representation of the suggested AFPID controller is as shown in figure.10

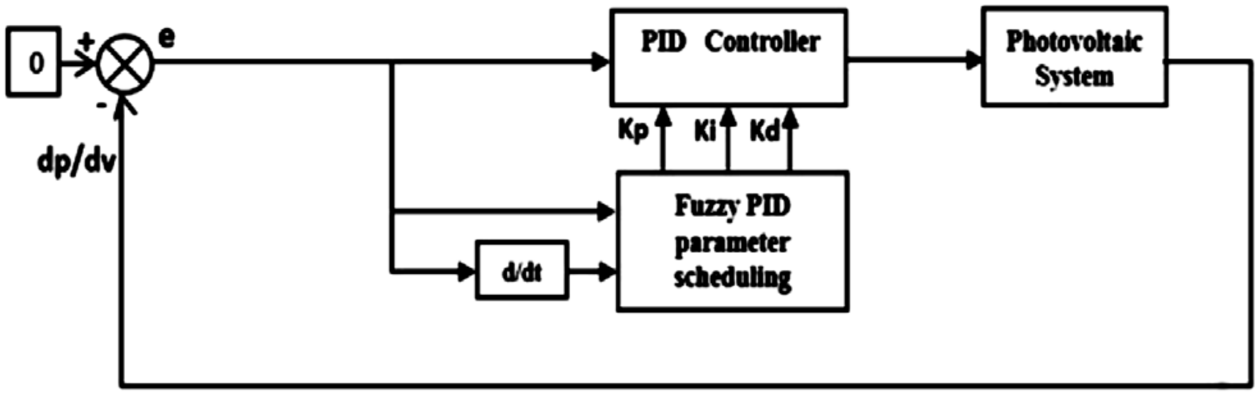

Fig. 10. Block Diagram of proposed fuzzy adaptive PID controller.

This proposed adaptive fuzzy PID controller based MPPT technique consists of two stages of control which includes adjusting gains of PID controller using fuzzy inference mechanism. The output expression of the conventional PID is given by

$$u(t) = K_p \left\{ e(t) + \frac{1}{T_i}\int_0^t e(\tau)\, d\tau + T_d \frac{de(t)}{dt} \right\}$$

$$u(t) = K_p\, e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{de(t)}{dt} \tag{7}$$

Where $e(t)$ is input error,

T_i represents integral time constant,

T_d represents derivative time constant,

K_p the proportional gain,

$K_i = \frac{K_p}{T_i}$ is the integral gain and

$Kd = K_p T_d$ is the derivative gain.

The P-V characteristics of PV generator change with climatic conditions which makes the traditional PID incapable to maintain at its MPP. Therefore, tuning of PID gains is necessary for real MPPT. So here a fuzzy inference mechanism is added to modify the parameters of the PID controller. The proposed Adaptive fuzzy PID controller produces three gains (the proportional gain Kp, the integral gain Ki, the derivative gain Kd) as outputs with error and rate of change of error as two inputs. The fuzzy subsets of input and output linguistic variables are denoted as negative big (NB), negative small (NS), zero (Z), positive small (PS), positive big (PB). The proposed Adaptive fuzzy PID controller makes use of a triangle membership function, and the Mamdani Max-Min fuzzy reasoning. The optimal values of the fuzzy tuned PID parameters are obtained from the following equation.

$$K_p = K_{p,\text{ initial}} + \Delta K_p \tag{8}$$

$$K_i = K_{i,\text{ initial}} + \Delta K_i$$

$$K_d = K_{d,\text{ initial}} + \Delta K_d$$

where $K_{p,\ initial}$, $K_{i,\ initial}$, $K_{d,\ initial}$ are the existing values of the PID gains.

The fuzzy rule base for proportional, integral and derivative gains obtained in following tables 2,3 and 4.

Table 2: Rules for proportional modification gain

Error(e)	Change of error(ce)				
	NB	NS	Z	PS	PB
NB	PB	PB	PB	PS	Z
NS	PB	PB	PS	Z	NS
Z	PB	PS	Z	NS	NB
PS	PS	PS	Z	NS	NB
PB	Z	NS	NB	NB	NB

Table 3: Rules for integralmodification gain

Error(e)	Change of error(ce)				
	NB	NS	Z	PS	PB
NB	Z	Z	Z	NS	NS
NS	NS	NS	NS	Z	PS
Z	NB	NS	Z	PS	PB
PS	NS	NS	Z	PS	PS
PB	Z	Z	PS	Z	Z

Table 4: Rules for derivative modification gain

Error(e)	Change of error(ce)				
	NB	NS	Z	PS	PB
NB	PS	NB	NB	NB	PS
NS	Z	NS	NS	NS	Z
Z	Z	NS	NS	NS	Z
PS	Z	Z	Z	Z	Z
PB	PB	PB	PS	PS	PB

5. SIMULATION RESULTS

The simulated model of proposed PV system with AFPID controller is shown in figure.11 and figure 12. The AFPID controller employed to achieve MPP according to varying irradiance and changing load conditions and to improve the effectiveness of MPPT technique.

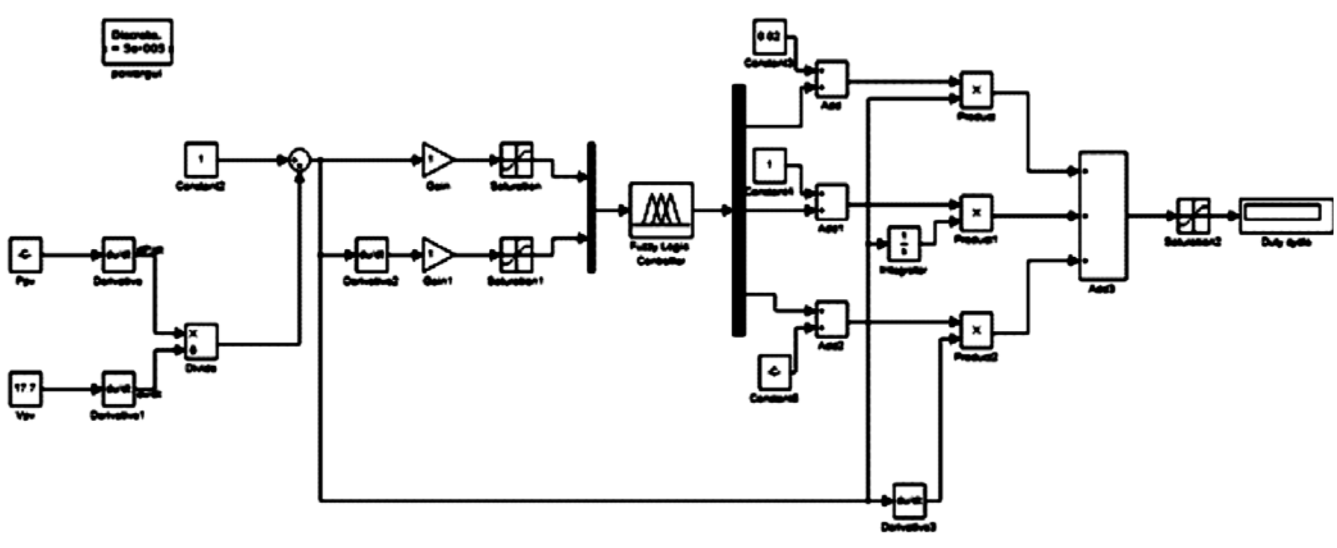

Fig. 11. MATLAB/Simulink model of AFPID controller.

The output power and voltage of the PV system with AFPID controller are compaperd with the results of PV system with P&O method are shown in figures 13 and 14 .

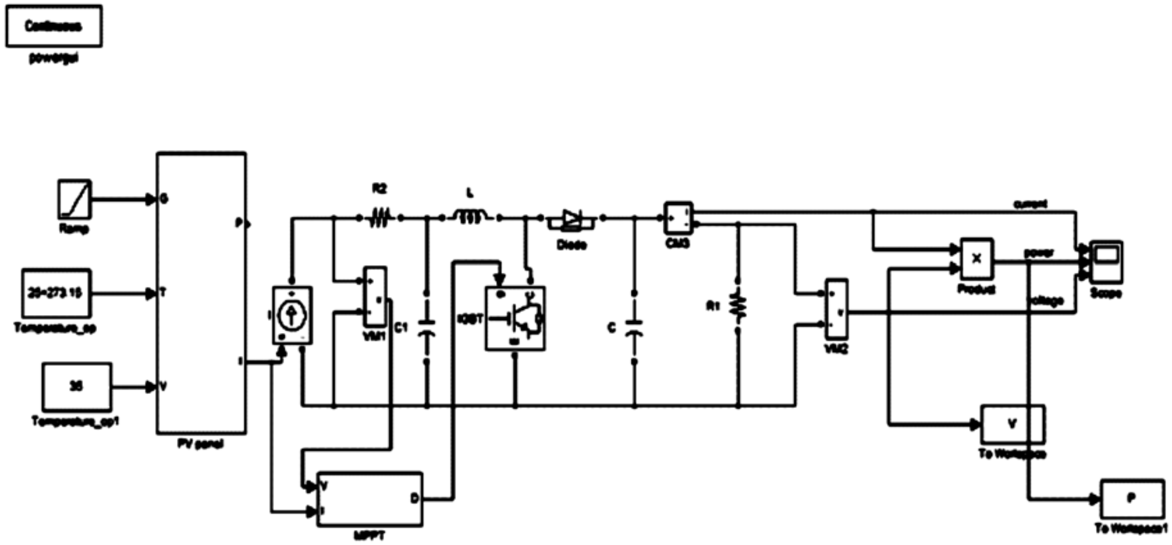

Fig. 12. MATLAB/Simulink model of overall AFPID controller for DC motor drive.

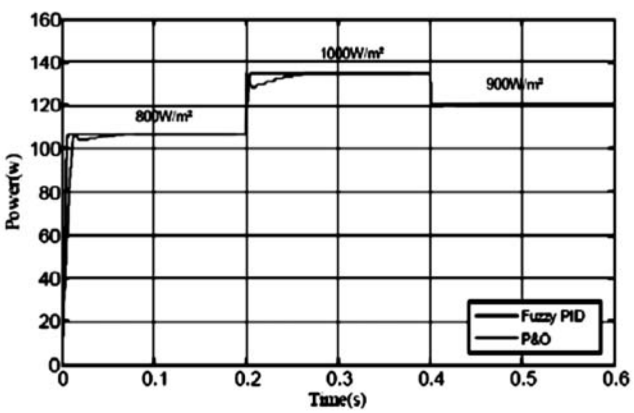

Fig. 13. Output power curve of PV array.

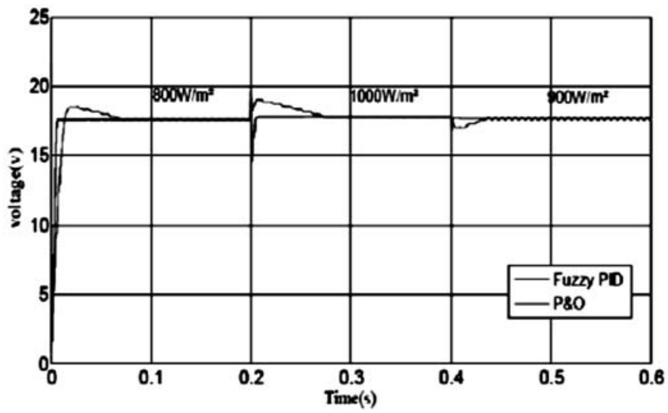

Fig. 14. Output voltage curve of PV array.

From the simulation results a rapid increase in irradiance from 800W/m^2 to 1000W/m^2 and a reduction from 1000W/m^2 to 900W/m^2 with a time period of 0.2 sec is observed. The temperature of PV module is maintained at 250C. And also it can be inferred that the AFPID controller yields more effective response time, less oscillation and more accuracy.

6. CONCLUSION

In this paper, an adaptive PID controller based MPPT technique is proposed. The modelling and simulation of this controller is obtained by combining the advantages of both FLC and PID. As a result more accurate MPP is extracted in less time. The simulation results determine that the controller yields better results by tracking MPP during various weather conditions compared to P&O approach.

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