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Control Enhancement of Maximum Power Extraction for Inverter Fed Two-Diode Photovoltaic System

Visvanathan K.* and V. Krishna Murthi**

ABSTRACT

The renewable energy is in crucial growth in present era of power generation because this is having pollution free in nature. In that, photovoltaic system is great attention in renewable power generation. Noise less, less maintenance, high efficiency and pollution free are the unique merits of photovoltaic system compared with wind generation system. In this paper proposed that modeling and development of two diode photovoltaic system and control and analyses with three different MPPT topology (P&O, incremental conductance and hybrid control). Aim to find a suitable control law for photovoltaic system and fed with inverter system for three phase AC motor power supply application. In order to reduce computation time, two-diode photovoltaic system is proposed in this control analysis. The voltage source inverter system is fed with present enhanced control of photovoltaic system is applied for AC motor power supply. The present and control scheme was analysis with MATLAB/Simulink results and verified performance of photovoltaic power source.

Keywords: PV (Photovoltaic system), Two-diode PV system, MPPT (Maximum Power Point Tracking), P&O (Perturb and Observer), IC (Incremental Conductance), Hybrid MPPT (both P&O and IC), VSI (Voltage Source Inverter).

1. INTRODUCTION

Increasing of energy demand in a world, renewable power generation is a best and suitable alternative power source. So many analyses are carried out to development of renewable source in literatures [1]-[3]. Photovoltaic system is a suitable system in renewable generation which wind power source and fuel cell power sources [4]. The photovoltaic system is having notable unique merits which pollution free in nature, less maintenance is compared with wind power source, high efficient power delivery and noise less power generation. The most common photovoltaic system is single diode photovoltaic system [5], [6] because it has a perfect relationship between voltage and current and simplified structure. Even though the single diode based photovoltaic module is having merits but computation time is large and iteration speed of parameters is been considered.

The two diode scheme is implemented for increasing efficiency, processing of iteration speed and reducing of computation time while comparison with single diode based photovoltaic system [7], [8]. The topology is proposed that two diode photovoltaic system with having high efficiency, simplified structure and neglecting series/ parallel resistor. Photovoltaic performance and its characteristic is varied by temperature variation, solar irradiation and output power so parameters of saturation current (I_0), series resistance (R_S), shunt resistance (R_{SH}), photovoltaic current (I_{PV}) and ideality constant (A).

* Research scholar, Department of EEE, North East Frontier Technical University, Sipu Puyi, Aalo (P.O), Arunachal Pradesh, *Email: visvanathanphd16@gmail.com*

** Professor, Department of EEE, North East Frontier Technical University, Sipu Puyi, Aalo (P.O), Arunachal Pradesh, *Email: krishnamurthieee16@gmail.com*

A maximum power point tracking is introduces to extract power from photovoltaic system by varying condition of irradiation and temperatures. The most common significant extraction method is P&O (perturb and observer) method because simplicity of structure and less maintenance. But we obtaining significant demerits such as low efficiency by so many iteration levels, we cannot determine MPP (maximum power point) [9]. Incremental conductance methods is introduces to improve efficiency over P&O (perturb and observer) method. Most of cases like MPP (maximum power point), efficiency and irradiation level but quite high in efficiency. A suitable maximum power point tracking scheme is finalized in this paper by comparing P&O and IC method for presented two-diode photovoltaic system.

This paper is presented a two-diode photovoltaic system is fed with three-phase voltage source inverter for AC motor application. The development of two diode photovoltaic model and finding a suitable maximum power point tracking scheme is applied to photovoltaic system by comparing of P&O (Perturb and Observer) method and IC (Incremental Conductance). Aim to develop and extracting of maximum power and increasing generation capacity of photovoltaic system for three-phase AC power supply application or AC Motor drive application.

2. PHOTOVOLTAIC SYSTEM

From the Fig. 2, two-diode model the current equation can be represented in equation (1) accordingly;

$$I = I_{PV} - \left[\exp\left(\frac{q(V+IR_S)}{N_S KTA_1}\right) - 1\right] - I_{02}\left[\exp\left(\frac{q(V+IR_S)}{N_S KTA_2}\right) - 1\right] - (V+IR_S)/R_{sh} \tag{1}$$

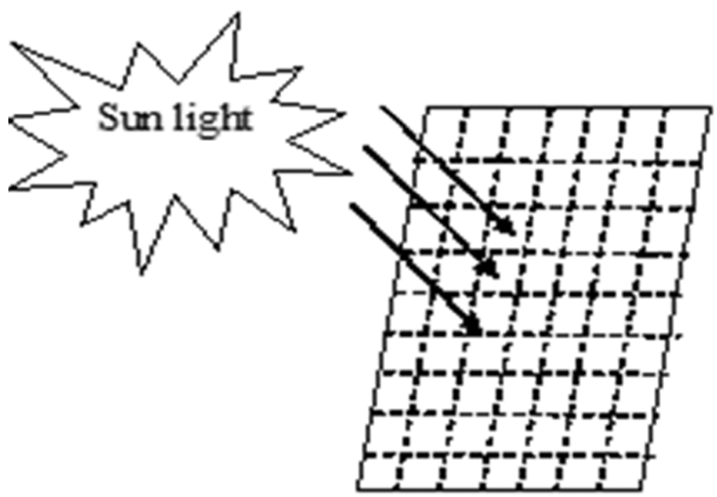


Figure 1: Generalized diagram of Photovoltaic system

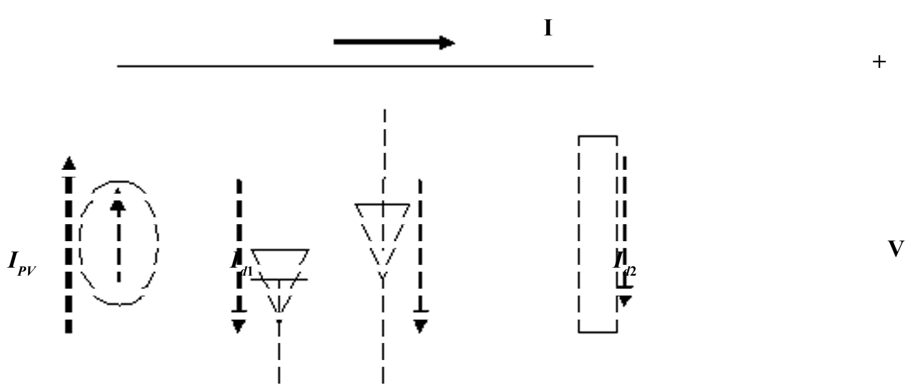


Figure 2: equivalent circuit for two diode photovoltaic system

Where,

q – Electron charge (1.6 × 10–19C)

K – Boltzmann constant (1.38 × 10–23 Nm/K)

T – PV module temperature in Kelvin

I_{01} – reverse saturation current of diode 1

I_{02} – reverse saturation current of diode 2

A_1 – diode ideality constant of diode 1

A_2 – Diode ideality constant of diode 2

I_{PV} – Light generated current of PV module in amperes

R_s – series resistance of PV module

R_{sh} – parallel resistance of PV module

N_s – Number of PV cells connected in series.

I – current of PV in ampere.

A mathematical model of the PV module is constructed by using five parameters, such as reverse saturation current (I_0), photoelectric current (I_{PV}), series resistance (R_S), shunt resistance (R_{sh}), and ideality constant (A), are required to be calculated its magnitude of I_{02} is found that nonlinear equations (5) and some of the parameters are assumed arbitrarily, since required to reduce the number of unknowns. A two diode model is attempt to reduce mathematical computation time and complexity, the proposed model has reduces the series and parallel resistances [10], the equivalent circuit is shown in fig: 3

$$I = I_{PV} - I_{01}\left[\exp\left(\frac{q(V)}{N_S KTA_1}\right)-1\right] - I_{02}\left[\exp\left(\frac{q(V)}{N_S KTA_2}\right)-1\right] \tag{2}$$

I_{PV}, I_{01}, I_{02}, A_1, A_2 are unknown parameters to be found in pv model respectively. I_{02} is derived from I_{01}; however the further unknown parameters are estimated. Those are determined from the constructed datasheet, which is obtained below. PV current (I_{PV}) can be derived from in terms of a short-circuit current under well standard test conditions (STC) in which the PV cell surface irradiation and temperature are 900W/m2 and 300 K by (3), consider variation of temperature and irradiation. Has a linear relationship to irradiation (G) and short-circuit current (I_{SC}) [11], and which can be follows as

$$I_{PV} = (I_{SC} + K_I \Delta T)\frac{G}{G_{STC}} \tag{3}$$

Where I_{SC} is the short-circuit current under STC, ΔT is the temperature difference between module temperature (T) and the STC temperature, K_I is called the short-circuit current constant and this is preferred from the datasheet, G is surface irradiation, and GSTC is the surface irradiation under short-circuit current. The equation to describe the saturation current is taken by

$$I_{01} = \frac{(I_{SC} + K_I \Delta T)}{\exp\left[(V_{oc} + K_v \Delta T) * \frac{q}{(N_S KTA_1)}\right] - 1} \tag{4}$$

Where K_v is called voltage temperature constant and the value is taken from data sheet, and V_{oc} is the open-circuit voltage. it can be describes as equation (5)

$$I_{02} = \left(\frac{T\frac{2}{5}}{3.77} \right) I_{01} \tag{5}$$

Finally find A_1, A_2 values by using simple and fast iterative method, by following two conditions are considered:

a) open-circuit condition with V_{oc};

b) Maximum power point (MPP) condition with V_m and I_m.

Under open-circuit condition, $V = V_{oc}$, $I = I_{oc} = 0$; $V = V_{oc}$

$$0 = \left| I_{PV} - I_{01}\left[\exp\left(\frac{q(V_{oc})}{N_S KTA_1}\right) - 1\right] - I_{02}\left[\exp\left(\frac{q(V_{oc})}{N_S KTA_2}\right) - 1\right]\right| \tag{6}$$

A_2 Can be obtained from A_1,

$$A_2 = \frac{(qV_{oc})}{N_S TK \ln\left(\frac{I_{PV} - I_{01}\left(\exp\left(qv/(N_S KTA_1 T)\right) - 1\right)}{} + 1\right)} \tag{7}$$

At high voltage condition the single diode equation assumes a constant value for the ideality factor. But the two diode estimation of ideality constants A_1 and A_2 varied based on the iterative matching algorithm. The calculated ideality values A_1 and A_2 for the PV modelling matching algorithm is given [7] and the validated estimation parameters (voltage, current, temperature and irradiation) are given in Table I.

Table 1
Estimated Parameters of the Proposed Model

	S = 1000 W/m2		T = 250C		
Parameters	I(A)	V(V)	T(0C)	V(V)	S(W/m2)
1	3.1	21.5	00	24.6	400
2	3.2	22.9	250	24.7	600
3	3.3	24.8	500	24.8	800
4	3.4	26.5	750	24.9	1000

The calculation of ideality factors A1 and A2 values and drawing in I–V curves and the model is simulated in the MATLAB environment. The intelligent and simplified two-diode model of PV array I–V curves and p-v curve should be validated for different temperature(°C) and irradiate value. The calculation of ideality factors A1 and A2 values and drawing in I–V curves and the model is simulated in the MATLAB environment. The intelligent and simplified two-diode model of pv array I–V curves and p-v curve should be validated for different temperature(°C) and irradiate value.

From Fig.3, performance of the two diode modeling I-V curve should draw between different temperature variations, constant irradiation S=1000W/m2 illustrated. The temperatures are examined by consider the

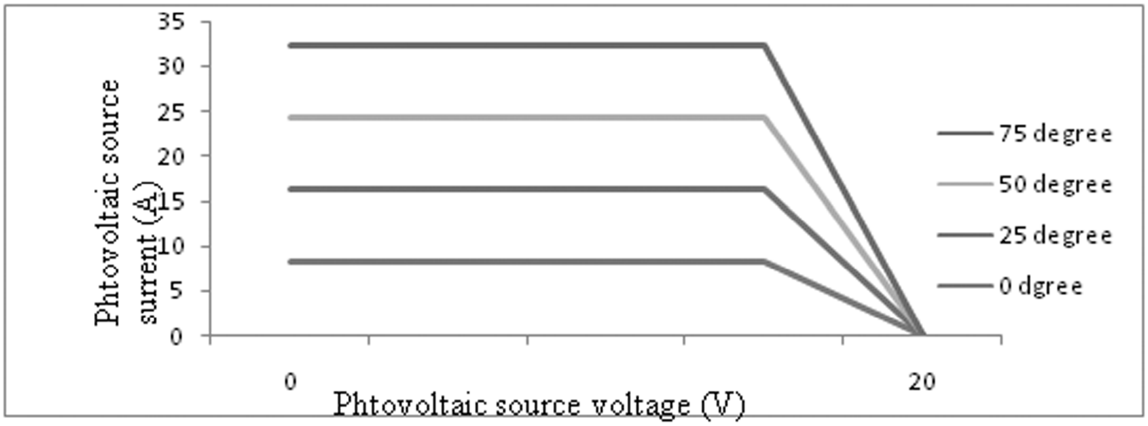


Figure 9: voltage and current relationship for three-types of MPPT topology

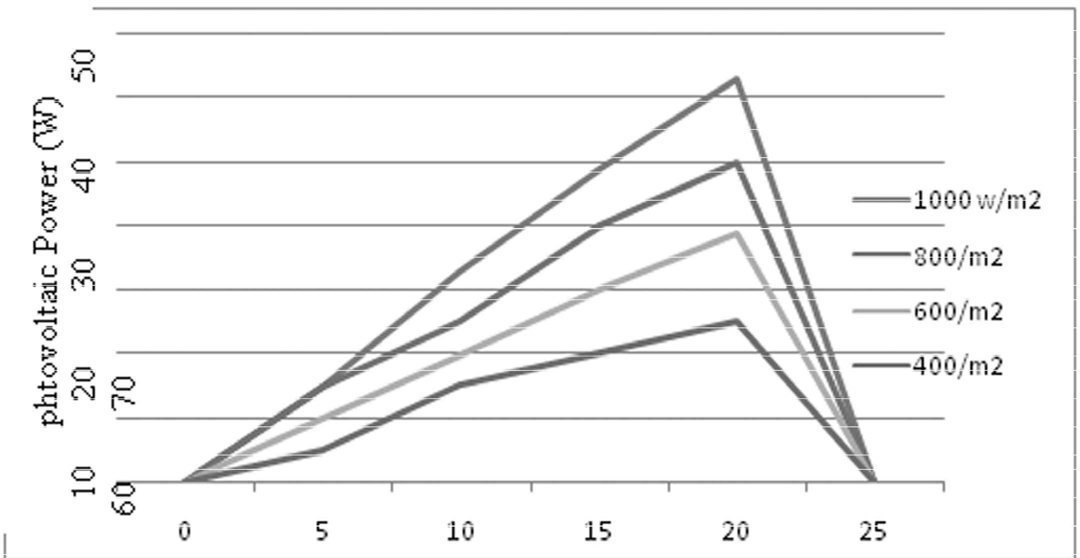


Figure4: P–V curves of two-diode model for constant temperature T=25C, different irradiation level S=1000W/m2.

range 25°C, 50°C, and 75°C, respectively. Ideality factor constants are major parameters that can able to affects the performance of a PV setup. Ideality constant factors are calculated by using a simple iterative matching algorithm, which is shown in Fig.3.Short-circuit current of the PV module is not changed by constant Ideality factor(A_1 A_2) whereas, the open-circuit voltage varies linearly with ideality constant [12]-[13].

A typical P–V characteristic for different irradiation level with respect to constant temperature for two-diode PV modeling is shown in Fig. 4. According to the result, which is compared with ideal single-diode model, the two-diode model significantly improved. Furthermore, it can produce more accuracy.

3. MPPT (MAXIMUM POWER POINT TRACKING) ALGORITHM

In this chapter, an analysis about three types of Maximum Power Point Tracking (MPPT) technique is presented for improving photovoltaic generation. Two popularly known techniques are P&O (Perturb and Observer) and IC (Incremental Conductance) method. Also fuzzy logic based MPPT topology is presented as third comparison approach for two-diode photovoltaic system.

3.1. P&O (Perturb and Observer)

The most suitable and common algorithm for maximum power extraction is P&O (Perturb and Observer) method is shown in Fig. 5. The amount of voltage is been changed with respect to irradiation level and finally measured derivative form of voltage (ΔV) at MPP (Maximum Power Point). The measuring voltage (ΔV) is move to positive with respect to irradiation, and then curve shown power vs voltage comparison becomes high which is shown in Fig. 6. Derivative form of voltage at MPP is negative and then curve shown power vs voltage comparison becomes low which is shown in Fig. 6. The low irradiation level, light and cloudy condition, efficiency becomes low compared with light conditions and oscillation occur during MPP level. Those are the demerits about perturb and observer method for performing photovoltaic system.

The procedure and flow of control for perturb and observer method is applied to two-diode photovoltaic system and verified the performance of photovoltaic system. The power, voltage and current are measured for various irradiance conditions with interfacing of three-phase inverter system.

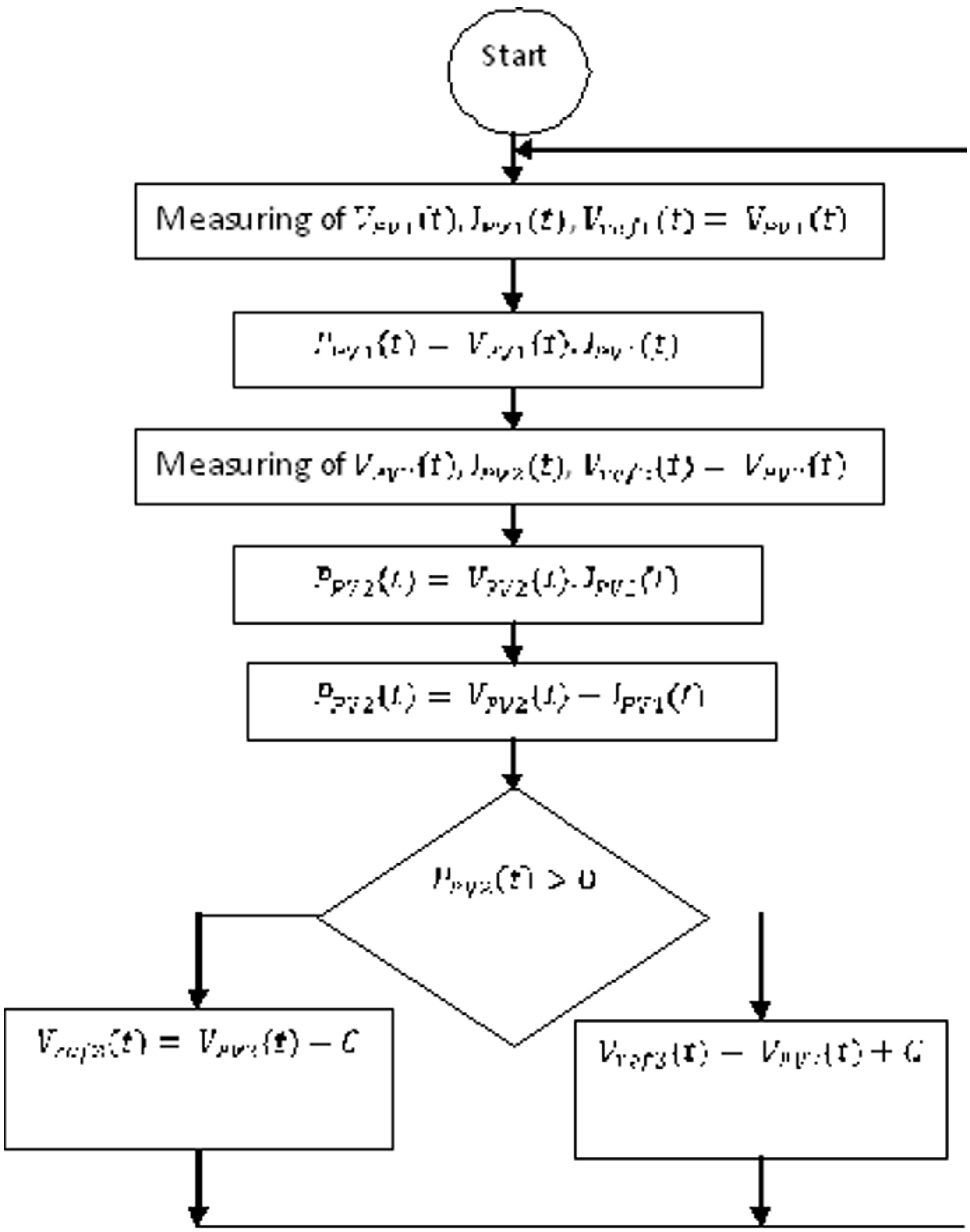


Figure 5: flow chart for process of perturb and observer algorithm

3.2. IC (Incremental Conductance method)

The implementation of incremental conductance method is form of photovoltaic power by calculating voltage and initiating to zero which equation bellow

$$\frac{\Delta P}{\Delta V} = \frac{\Delta (VI)}{\Delta V} = I + V\frac{\Delta I}{\Delta V} = 0 \ \textit{at MPP} \text{ (Maximum Peak Power)} \tag{8}$$

The equation (8) is rearranged by bellow equation

$$-\frac{I}{V} = \frac{\Delta I}{\Delta V} \tag{9}$$

In equation (9), shows an instantaneous conductance which is given left hand side of equation whereas right hand side shows an incremental conductance. The amount of positive and negative variation is clearly rectifying by using equation (9). The above equation is described by condition basis is bellow.

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V}\left(\frac{\Delta P}{\Delta V} = 0\right) \tag{10}$$

$$\frac{\Delta I}{\Delta V} < -\frac{I}{V}\left(\frac{\Delta P}{\Delta V} < 0\right) \tag{11}$$

$$\frac{\Delta I}{\Delta V} > -\frac{I}{V}\left(\frac{\Delta P}{\Delta V} < 0\right) \tag{12}$$

If condition occurs as equation (10), there is no chance of decrease or increase in ΔI and also ΔV, process remains continues in MPP (maximum peak power). Array voltage is purely depends on irradiation

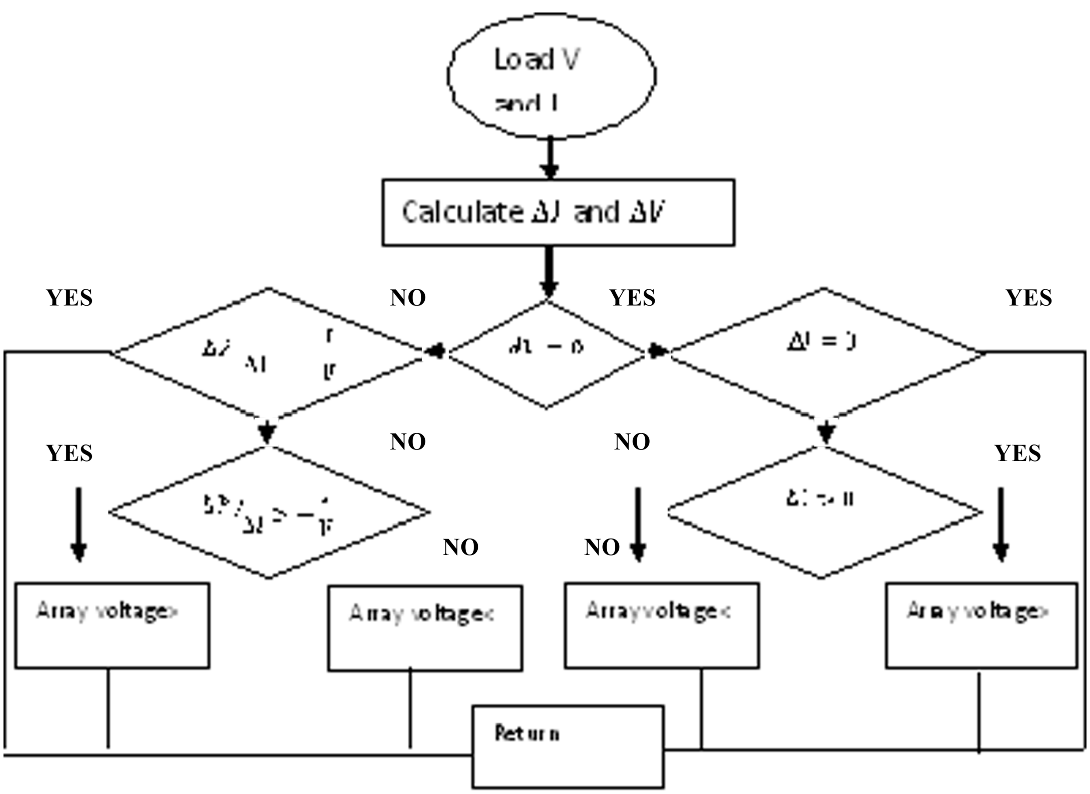


Figure 6: Flow chart for processing of incremental conductance algorithm

level and simultaneously current is measured at every cycle for this condition. If changes occur in ΔV or ΔI as equation (11) whether it is positive or negative, corresponding current or voltage should be increase or decrease to compensate performance of photovoltaic system. Similarly (12) is been deriving as per the irradiation level so solution to compensate voltage or current will be decrease or increase at current level. The detailed flow of incremental conductance algorithms is shown in Fig. 6. The merits of incremental conductance algorithm are suitable for finding MPP (Maximum Peak Power) accurately, no oscillation happen while on peak value, capable of deriving high efficiency while comparison with P&O (Perturb and Observer) and can capable of tract right direction about performance.

3.4. MPPT (Maximum power point tracking) using fuzzy logic scheme

The maximum power point tracking is implemented using fuzzy logic scheme to introducing an advancement of maximum power point tracking control. The photovoltaic system was tested under different irradiation level (100/m^2 to 1200/m^2). Maximum peak power is located at particular region alone but in voltage of optimal working is classified into four types (N for N string level). The old approach of perturb and observer method and incremental conductance method is track or perform with in local area or region.

The given enhancement of fuzzy logic based MPPT (Maximum Power Point Tracking) is presented in this approach for improving photovoltaic power generation over P&O (Perturb and Observer) and IC (Incremental Conductance method).Aim to achieve good performance in generation a fuzzy logic scheme is been initiated in incremental conductance algorithm to increase in performance. Control system is tested in two-diode photovoltaic system. The rules derivation is based voltage, current under various irradiations, temperature in average (40^o) and data given in data sheet. The buck boost converter is used to implement MPPT (Maximum Power Point Tracking) using fuzzy logic approach is shown in Fig. 7.

The duty cycle is calculated for present MPPT approach is given as

$$V_{ref} = (C - 0.5)\ V_{OC}.STC \tag{13}$$

$$D_{ref} = V_{out}/V_{ref} \tag{14}$$

The flow chart given for proposed MPPT scheme given in Fig. 7 for two-diode photovoltaic system as follow by

Initialization: initiate value calculated duty cycles references (D_{ref}) and old and sudden changed value of power for (P_{old}) and (P_{sudden}) respectively.

Fuzzy rules generation: drive a V-I curve for each irradiation level condition and calculate MPPT for each irradiation and temperature level, output of this applied to fuzzy logic control to generated rules for this scheme with respect photovoltaic system power conditions.

Input data measurement: read about irradiance of each photovoltaic module (I_{Irr} (t) where i = 1, 2, 3, 4. Calculated power ($P(k)$) by ($I(k)$) and ($V(k)$) through photovoltaic string.

Category prediction: measuring of present and end terms of power with base value so we can get error between them i.e. $P - P_{old} > P_{sudden}$, this is called sudden change in voltage. Calculated optimal voltage, duty cycles using equation given (13) and (14).

Region control: on the other hand, duty cycle is controlled in limits as ($0.05 < D_{ref} < 0.95$) to buck-boost converter effectively for improving photovoltaic power generation.

Duty cycle calculation: initiate power value of old to present value ($P = P_{old}$) and MPPT is calculated by 3rd steps of algorithm

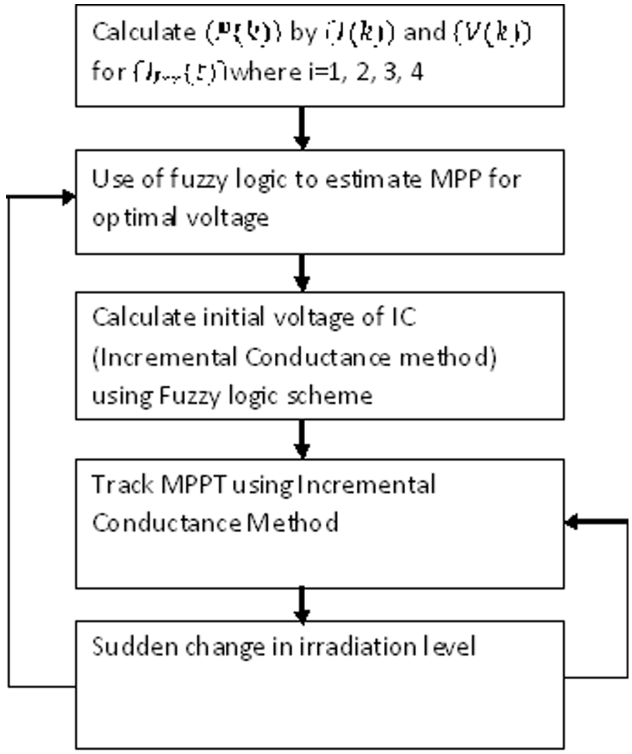


Figure 7: proposed MPPT (Maximum Power Point Tracking) method using Fuzzy Logic scheme

4. SIMULATION RESULT AND DISCUSSION

The presented scheme of two-diode photovoltaic system is tested using three-types of MPPT (Maximum Power Point Tracking scheme) to verify about suitable and efficient extraction scheme for two-diode module and its developed to apply three-phase voltage source inverter for AC power supply or Three-phase AC motor operation. The scheme of proposed approach is implemented using MATLAB/simulink result is shown in Fig.8 and performance is verified in form of power generation capacity with respect time. The parameter used for two-diode photovoltaic system is given in Table I. entire system parameter is given in Table II. Voltage and current variation with respect to irradiation level for three-MPPT technique is shown in Fig. 9. The voltage performance for solar power generation using three-MPPT method is shown in Fig. 10. The inverter output voltage performance for three-MPPT topology is given Fig. 11. Current variation performance for three MPPT methods is shown in Fig. 12.

Table 2
Parameters for Two-Diode photovoltaic system

Kyocera KC200GT for Two-Diode photovoltaic system	
Parameters	*Value*
$I_{sc}(A)$	8.20
$V_{oc}(V)$	32.90
$I_{mp}(A)$	7.61
$V_{mp}(V)$	26.3
$I_{01}(A)$	5.0122×10^{-4}
$I_{02}(A)$	1.298×10^{-5}
$I_{PV}(A)$	17
A1	1.7
A2	2.5

Table 3
Parameters for proposed system

Parameters	*Value*
PV(V)	200
MPPT(V)	600
INV(*V*)*AC*	600
RL	300
Inverter frequency (*f*)	1kHz
Load Power	500W
duty cycle for buck-boost	0.5
Buck-boost converter frequency (*f*)	25kHz

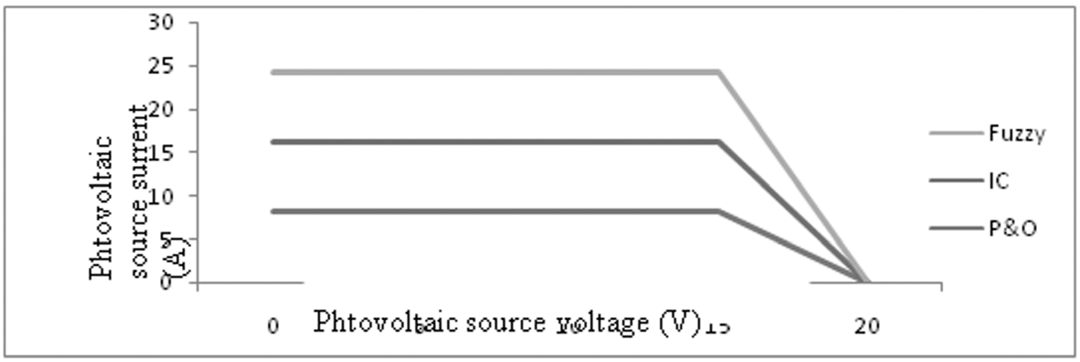


Figure 8: voltage and current relationship for three-types of MPPT topology

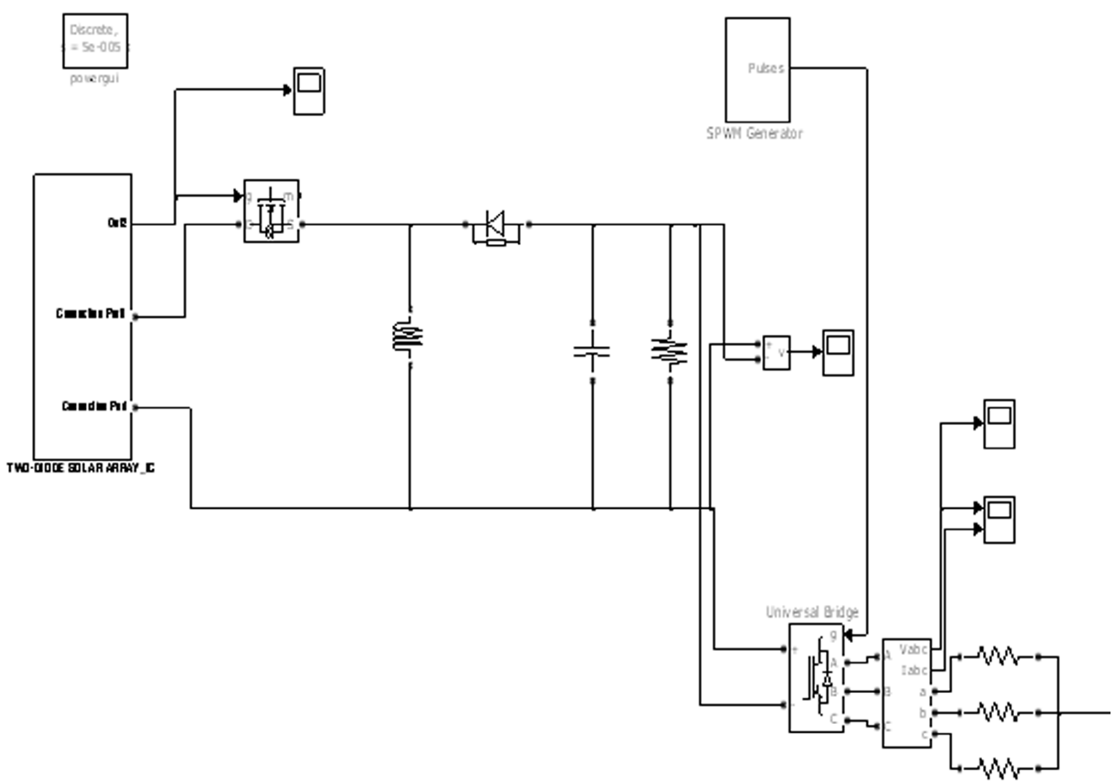
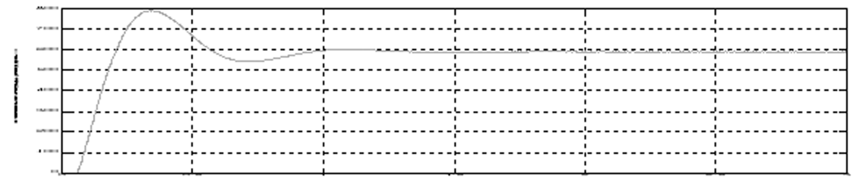
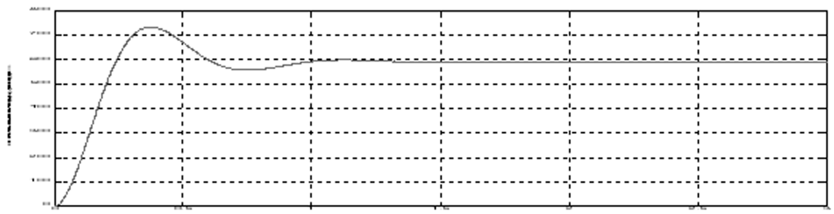


Figure 9: simulation implementation circuit for proposed configuration



(a)



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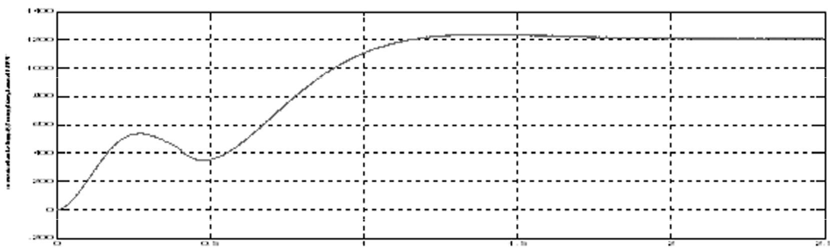
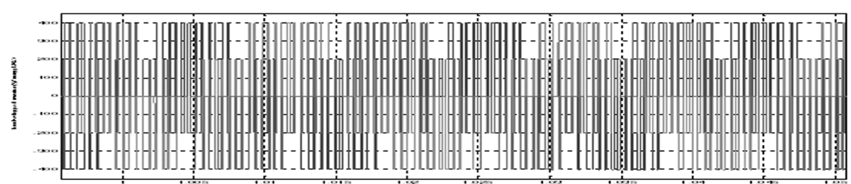


(c)

Figure 10: converter output voltage for three-types of MPPT topology



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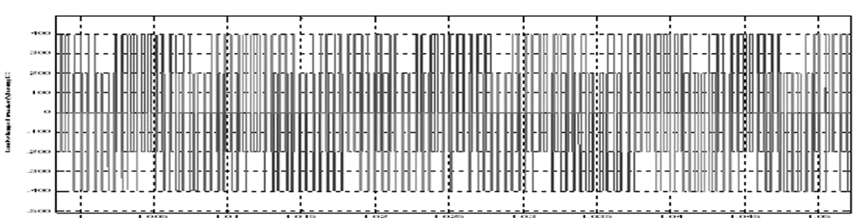

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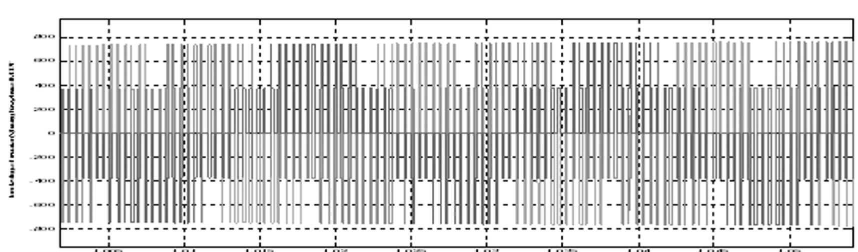
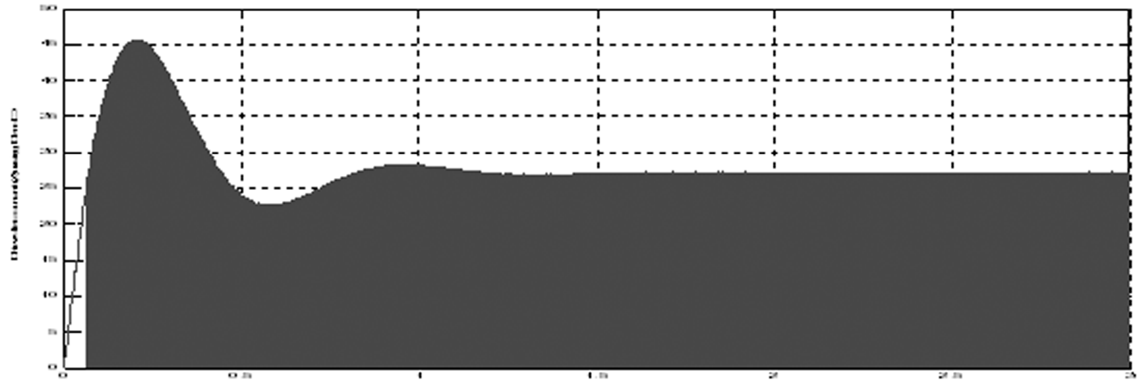
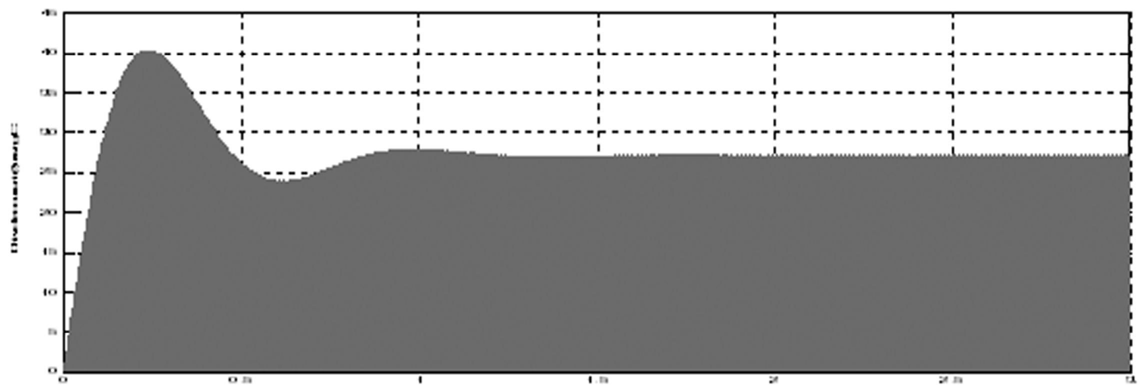


(c)

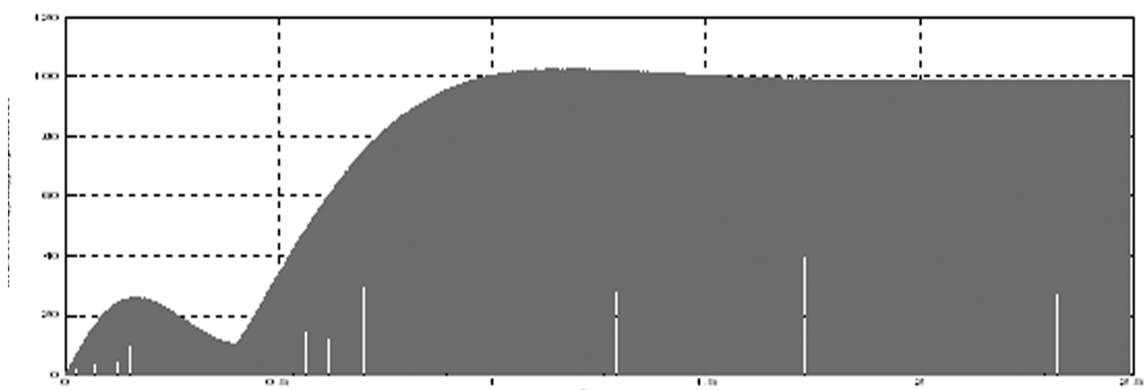
Figure 11: converter output voltage for three-types of MPPT topology



(a)



(a)



(a)

Figure 12: solar current performance for three-types of MPPT topology

5. CONCLUSION

The enhancement of control scheme is initiated in this paper for two-diode photovoltaic system. Three different maximum power point tracking scheme was analyses in this paper for finding a suitable extraction scheme for Two-diode photovoltaic system. The buck-boost converter is presented to verifying performance and extraction of photovoltaic system using MPPT techniques. The system power applied to three phase voltage source inverter for AC power generation and motor application. Aim of presented scheme that developing and efficient extraction of photovoltaic power using suitable MPPT scheme and it's promoted for AC motor power supply application. The fuzzy based MPPT scheme is initiated for proposed two-diode photovoltaic system and performance of voltage and current are verified using MTALAB/ simulink result. The present approach is capable delivering continuous power to three phase AC motor by proposed control and development of photovoltaic system.

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