ISSN: 2278-0181
NCIETM - 2017 Conference Proceedings

# MPPT of PV array in MATLAB

Amit Sharma[1]
Assistant Professor in Mechanical Engineering Department
Geeta Engineering College (Panipat)[1]

***Abstract*-Governments around the world are facing a steadily rising demand on global electric power. To face this challenge, they are striving to put in place regulatory guidelines to aid the adoption of best practices by utilities in terms of the Smart Grid and renewable energy applications. Smart Grid organization provides the consumers with the ability to monitor and control energy consumption.Solar electric or photovoltaic technology is one of the biggest renewable energy resources to generate electrical power. There are many methods for maximum power point tracking like on line methods and off line methods but hybrid methods proved to be more efficient than them. Recently fuzzy logic controllers are also used to track the maximum power point in PV connected grids. But these suffer from a drawback of static membership function's range which must be changed with change in input irradiance. We have worked to overcome this limitation and achieved higher maximum power point. The tuning of membership function values is done by a hybrid bio inspired algorithm- bacterial foraging optimisation (BFO) and particle swarm optimisation (PSO). BFO is offline method and PSO is online method, so a combination of both is used in our work to control the duty cycle of boost converter which boosts the dc voltage produced form PV array, to pass to grid.**

***Keywords: Photovoltaic system, Maximum power point, BFO, PSO.***

## 1. INTRODUCTION

The word photovoltaic is derived from "photo" meaning light and "voltaic" which refers to production of electricity. Hence photovoltaic means "production of electricity directly from sunlight". PV system is composed of one or more solar PV panels, an AC/DC power converter and a rack system that holds the solar panels, and the mountings and connections for the other parts. A small PV system can provide energy to a single consumer or to isolated devices like a lamp or a weather device. Large grid-connected PV systems can provide the energy needed to serve multiple customers. A single individual solar cell has a very low voltage. Hence, several cells are wired together in series giving rise to a "laminate". The laminate is then assembled into a protective weatherproof casing thus creating a photovoltaic module or a solar panel. Modules may be then strung together to form a photovoltaic array. The electricity generated can either be stored to put into direct use to fed into a big electricity grid powered essentially by central generation plants (grid-connected/grid-tied plant) or fed into a small grid after combining with one or many domestic electricity generators (hybrid plant). Depending on the application type, the rest of the system known as balance of system. PV energy conversion systems can either be off-grid (stand-alone) or grid-connected.

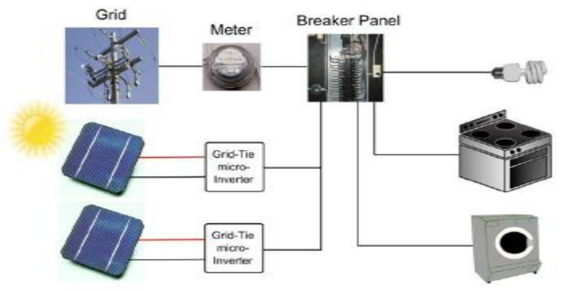


Fig 1.1: Schematic diagram of a simple photovoltaic system

To Calculate various MPP tracking methods have been proposed. The most popular technique is the Fuzzy logic control is used to adapt the duty cycle of boost converter with change in irradiation. But the performance can be improved further if membership functions of fuzzy logic control are tuned at each instant rather than keeping them fixed for whole simulation.

Given below will be key objectives which will be chased during the work:

- During this work my objective will be to develop the algorithm which can sense external changes in PV array and as modify the fuzzy logic control for MPPT control.
- Bacterial foraging optimisation (BFO) will be used as tuning algorithm for membership functions of fuzzy logic.

In this prescribed work we have tracked the maximum power point to gain maximum power and PV grid simulation. A PV array and utility grid are interconnected with a voltage to source converter so that DC can be transferred to utility grid.

### *1.2 Fuzzy logic control for MPPT*

The tracking of MPP is divided into two steps: first will increase the response of MPP and other will increase the stability after MPP. The fuzzy controller consists of three sub-blocks: fuzzyfication in which real environment variable is converted to fuzzy variables, inference model which inherits the rule set or decision variables and last one is defuzzyfication which reverse the fuzzy variables to environment variables. The fuzzy logic controller for the MPPT has two real time inputs measured at every sampling time, named 'E' and 'CE' and one output named 'Duty' for each of the phases. The 'E' stands for error and 'CE' is the change in error. The error at sample time k is calculated by

$$E(k) = \frac{\partial P}{\partial V} = \frac{[P(k) - P(k-1)]}{[V(k) - V(k-1)]} \quad \text{..................(1)}$$

$$CE = E(k) - E(k-1) \quad \text{....................(2)}$$

Where P(k)= output power of PV panel at time instant k

P(k-1)= output power of PV panel at time instant (k-1)

V(k)= output voltage of PV panel at time instant k

V(k-1)= output voltage of PV panel at time instant (k-1)

The input signals are fuzzified and represented in fuzzy set notations by membership functions. The defined 'if … then …' rules produce the linguistic variables and these variables are defuzzified into control signals for comparison. Fuzzy logic control involves three steps: fuzzification, decision-making and defuzzification. Fuzzification transforms the non-fuzzy (numeric) input variable measurements into the fuzzy set (linguistic) variable that is a clearly defined boundary. In the proposed controller, the 'E' and 'CE' are defined by linguistic variables such as NB, NS, ZE, PS, PB characterized by memberships. The memberships are curves that define how each point in the input space is mapped to a membership value between -0.032 to 0.032 and -100 to 100 for 'E' and 'CE' respectively. The membership functions belonging to the other phases are identical Membership functions for the inputs are shown in Fig.1.2 and Fig.1.3. The membership function of output variable is shown in Fig.1.4.

The surface viewer of our fuzzy logic is shown in figure 1.5. It is a three dimensional representation of mapping of error and output of fuzzy logic. Because this curve represents a two-input one-output case, you can see the entire mapping in one plot. SNR is along x axis and mod is drawn along y axis.

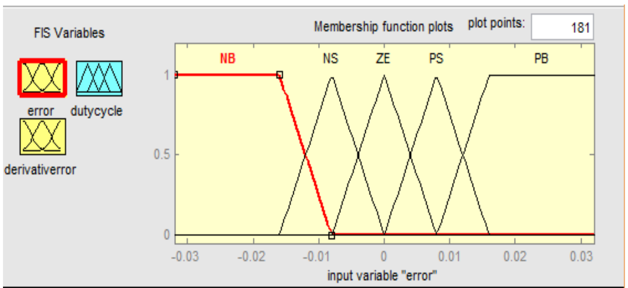


Figure 1.2: Membership function of input 'SNR'

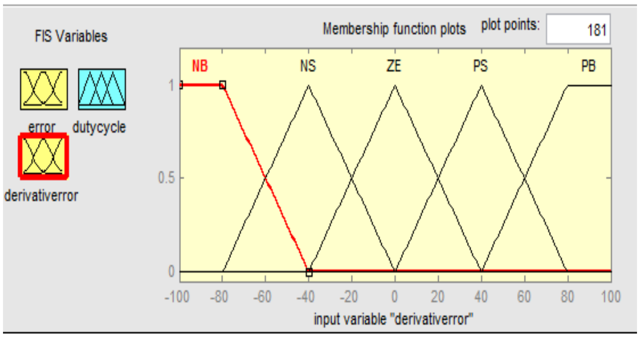


Figure 1.3: Membership function of input 'mod'

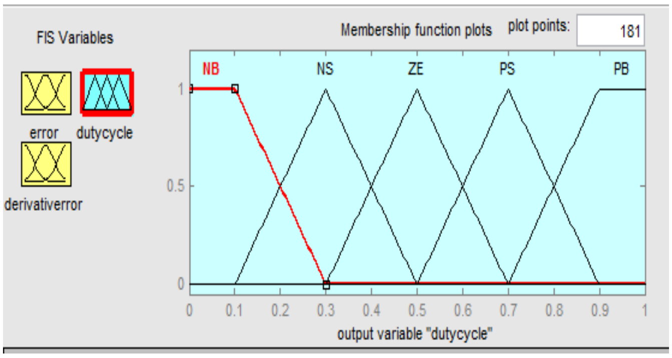


Figure 1.4: Membership function of output modulation technique

Z axis represents the output modulation technique. Defining only membership function doesn't complete fuzzy logic designing. Rule sets for taking decision have to be designed also. A set of 25 rules in our case is designed and table 1.1 represents that along with the representation of rules in rule viewer in figure 1.6. The Rule Viewer displays a roadmap of the whole fuzzy inference process. It is based on the fuzzy inference diagram. You see a single figure window with 25 plots nested in it. The three column plots represent rules of SNR, mod and output. Each rule is a row of plots, and each column is a variable. The rule numbers are displayed on the left of each row. You can click on a rule number to view the rule in the status line.

- The first two columns of plots (the six yellow plots) show the membership functions referenced by the antecedent, or the if-part of each rule.
- The third column of plots (the three blue plots) shows the membership functions referenced by the consequent or the then-part of each rule.

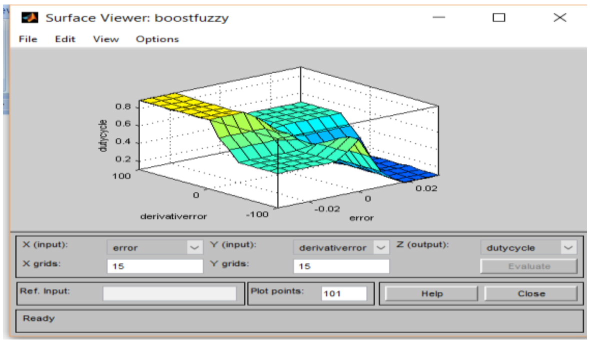


Figure 1.5: Surface viewer plot of fuzzy logic

This decision will depend on the input values for the system. The defuzzified output is displayed as a bold vertical line on this plot. The Rule Viewer allows you to interpret the entire fuzzy inference process at once. The Rule Viewer also shows how the shape of certain membership functions influences the overall result. Based on these rules output duty cycle range is decided.

Table 1.1: Fuzzy logic rules sets

| E/CE | NB | NS | ZE | PS | PB |
|---|---|---|---|---|---|
| NB | ZE | ZE | PB | PB | PB |
| NS | ZE | ZE | PS | PS | PS |
| ZE | PS | ZE | ZE | ZE | NS |
| PS | NS | NS | NS | ZE | ZE |
| PB | NB | NB | NB | ZE | ZE |

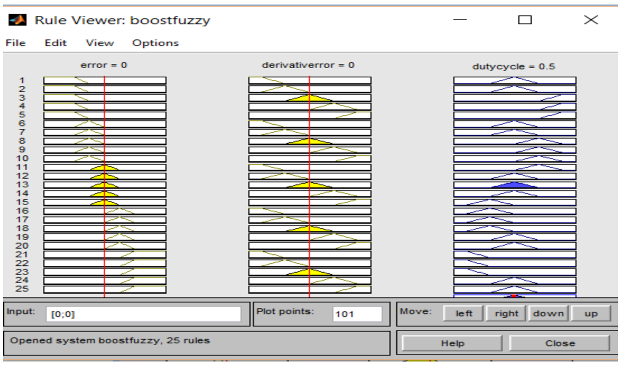


Figure 1.6: Rule viewer of membership functions

### *1.3 Fuzzy Logic tuned with PSO*

#### *1.3.1 Description*

We have already discussed the fuzzy logic decided duty cycle output. In figures 1.2-1.4 membership range of two inputs and one output is defined. These ranges are fixed once and are not changes during the simulation. Values of range in membership function is finalised after several testing results and these may give undesired or poor results if conditions are changed for which these were tested. For example in our case, the intensity of sun radiations is not constant every time. Even after the prediction based on previous data, the prediction accuracy is very less, due to which fixing the fuzzy logic membership function's value is obsolete. So we picked this problem and suggested an optimization solution for it. We tuned the membership function range based on the input conditions and a hybrid bio inspired algorithm is proposed. We combined bacterial foraging optimization (BFO) and particle swarm optimization (PSO) for this work. Both have overcome each other's advantages and disadvantages. PSO is local searching algorithm and sometimes trapped into local minima which doesn't guarantee an optimum solution whereas BFO is a global optimization which doesn't trap into local minima but convergence time is high as compared to PSO. So we combined BFO with PSO so that it converges in less time. The combination takes place to give the tuned direction of bacteria rather than random as in conventional BFO. Bacteria move in random direction in search of its food which takes time into convergence of BFO. We have controlled this random direction with help of PSO. The velocity calculated in PSO is now the direction of BFO. The positions of bacteria are the initial position of particles in PSO and velocity updated on these positions constitute the direction of bacteria in BFO which is now tuned rather than random. For every bacteria and its updated position, PSO is called for updated velocity as direction. Detailed description of BFO and PSO is given in previous chapter. The soil of each optimisation algorithm is its objective function which differs for each application and all constraints are defined there. In our case to the objective function is the 'error' which is calculated by equation (1). We need to tune the range values of membership functions of fuzzy logic. We have five membership functions for each input and output making a total of 15 membership function. Trapezoidal and triangular functions are used in our case so a total of 51 values should be tuned but in actual these are just 12 values which requires tuning as per change in initial conditions. Figure 1.2-1.4 depicts the answer to this. The initial and final range of trapezoidal function is fixed which is at –infinity to +infinity. Moreover, two points of each membership function are common to others. It can be clearly shown in table 1.2.

Table 1.2: range values for input 'E' to fuzzy controller

| Membership functions | Range parameters |
|---|---|
| Trapezoidal | [-inf -0.032 x(1) x(2)] |
| Triangular | [x(1) x(2) 0] |
| Triangular | [x(2) 0 x(3)] |
| Triangular | 0 x(3) x(4) |
| Trapezoidal | x(3) x(4) 0.032 inf |

Common values can be easily predicted form table 1.2. So for a single variable we have to tune only four values and for three variables, a total of 12 values are too tuned. There are some constraints which should be considered while tuning these values.

*Constraints:*

1. Every value should satisfy the following inequality criteria
   x(1)<x(2)<x(3)<x(4)
2. For input ‘E’
   -0.032<x<0.032
   For input ‘CE’
   -100<x<100
   For output ‘DE(duty cycle)’
   0<x<1
   $x_i = +ve\ for\ i = 1,2,5,6\ and\ x_i = -ve\ for\ i = 3,4,7,8,9,10,11,12$

For these constraints the membership function values of fuzzy controller is changed and model is executed for these values. The error form equation 4.1 will be the target to be minimised and it is the objective function value.

$$objective\ function = \min mean(error)$$

*1.3.2 Significance of BFO-PSO terms in fuzzy logic controller*

Since BFO and PSO are bio inspired algorithms .In this case tuning variables are 12 so each bacteria’s positions will be defined by 12 co-ordinates. Table 1.3 shows the equivalent terms of BFO and PSO with fuzzy logic.

Table 1.3: Bio inspired algorithm’s equivalent terms to fuzzy logic tuning

| | BFO & PSO terms | Fuzzy Logic tuning terms |
|---|---|---|
| 1 | Search space Dimension | Number of tuning variables |
| 2 | Objective function value | Mean of error |
| 3 | Positions of bacteria | Values of tuning variables |

*1.3.3 Algorithm Used*

Initialize the random positions and directions of bacteria.

$$new\ pos = old\ pos + step\ size \times \frac{direction}{\sqrt{direction * direction}}$$

PSO Starting:

$$new\ velocity = 0.9 * old\ velocity + c1 * R1(local\ best\ position - current\ posiiton) + c2 * R2(global\ best\ position - current\ posiiton)$$

Where c1, c2 and R1, R2 are initialized initially.

This new velocity is the direction of bacteria in BFO as

$$direction = velocity$$

PSO ends

RESULTS

In the above work We have used MATLAB simulink’s power system toolbox to convert the idea into simulation. We used MATLAB 2013 version for the implementation with simpower toolbox. A sample time of $10^{-4}$ seconds is considered for model simulation. To check the results, initially the V-I curve and P-V curve of PV array is plotted for different radiation intensity. Figure 1.7 shows the curve for that and nonlinear characteristics of PV array are depicted from these. Every curve has a unique maximum point which is called maximum power point. We worked towards raising the value of this point. Note that with decrease in radiation intensity MPP point also reduces.

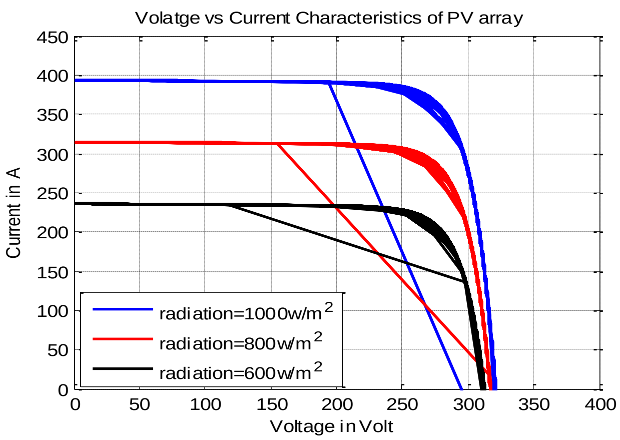


Figure 1.7: I-V curve of PV array with 66 parallel strings and 5 strings in series

Varying intensity radiations are used as the input in the model and the stability of model is analyzed by the constant DC voltage. For a given input if proposed model is executed than comparative curve between three methods P&O, fuzzy P&O and BFO-PSO fuzzy P&O; is obtained. Fuzzy controller’s parameters are tuned with BFO and PSO and after tuning the values are changed from the original once and shape too. Figure 1.8 . shows the new fuzzy logic membership functions with new range for which our optimization algorithm finds the minimum error.

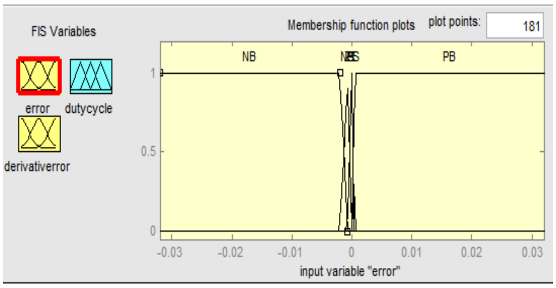


Figure 1.8: optimised membership function for input error

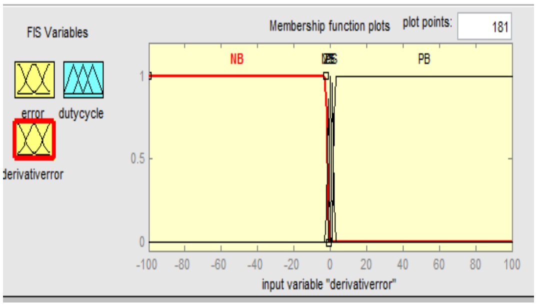


Figure 1.9: optimised membership function Change in error

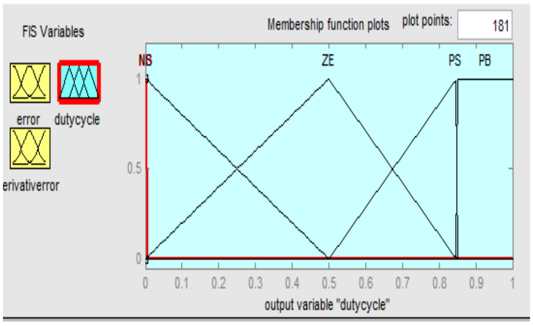


Figure 2.0: optimised membership function for output duty cycle

For testing purpose we have applied an input radiations of intensity 1000 w/m^2 for 4 seconds and 800 w/m^2 for next 1 second. Since DC voltage is the evaluation parameter for the stability of the PV grid model so a comparative graph of DC voltage is shown in figure 1.11. As can be seen the variation in DC voltage by proposed wok is less as compared to rest two and a sharp decrease after 4 seconds is also visible in all three.

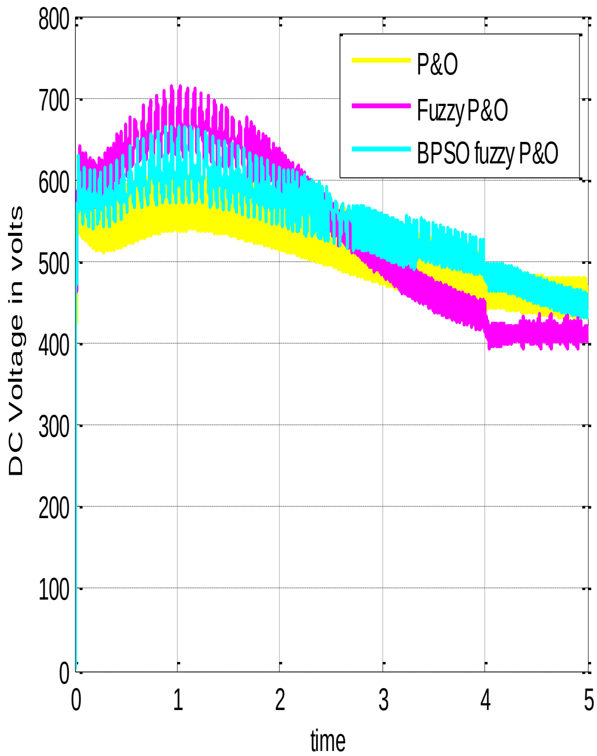


Figure 1.11: DC voltage output of boost converter by three methods

In table 1.3 output power of PV array is given and clearly analysed that proposed method gives the maximum power. The proposed method generated 43.4820 MW more than conventional P&O method and 150 KW more than fuzzy P&O method.

Table 1.3: Output of PV array

| | P&O | Fuzzy P&O | BPSO Fuzzy P&O |
|---|---|---|---|
| PV array output power | 56.228 MW | 99.56 MW | 99.71 MW |

Since whole change in power and voltage is based on change in duty cycle of boost converter. The BPSO tuned fuzzy logic controller graph is more stable and have highest magnitude than rest is shown in figure 1.12. A three phase voltage and current of grid output is shown in figure 1.13.

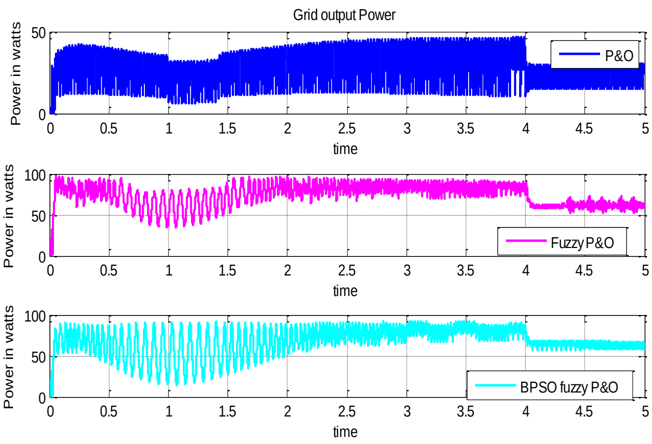


Figure 1.12: grid Output power for P&O, fuzzy P&O and BPSO fuzzy P&O controller

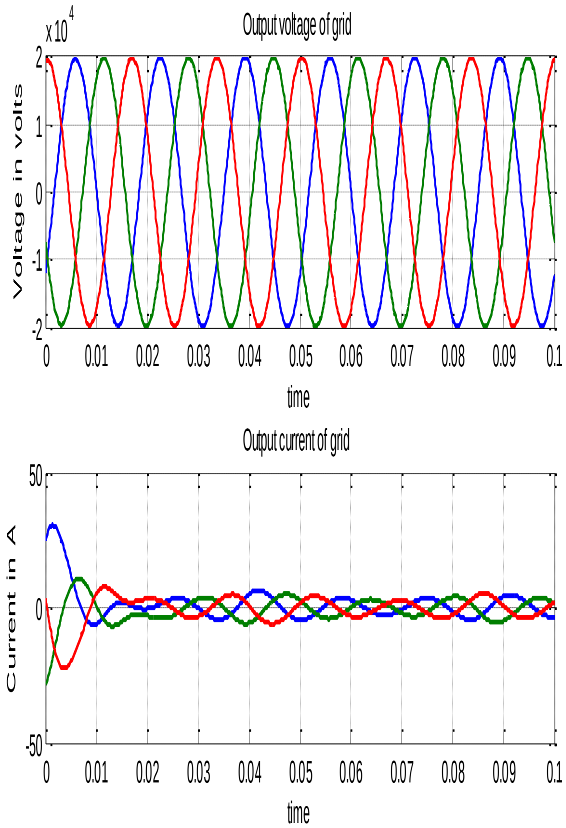


Figure 1.13: Output current and voltage of grid in case of proposed method

CONCLUSION

We have considered in present research work the simulation of two methods of control: fuzzy controllers and BFO-PSO tuned fuzzy controller. All of them were applied on a chain of energy conversion supplied by DC-DC boost converter. We compared the obtained simulation results, by subjecting the controlled system to the same environmental conditions. The simulations have shown that the use of fuzzy logic controller can improve the efficiency of the overall system algorithm as in our proposed case then the efficiency of system increases more. We have achieved the generation of 99.71 MW of power from 66 parallel connected and 5 series connected PV. We conclude that the MPPT fuzzy controller which is based on the experience of the operator, has a very good performance. It reduces the time responses of the photovoltaic system to perturbations and insures the continuity of the operation at the time in response to the continued maximum power point and it also eliminates the fluctuations around this point. This quality shows the effectiveness of the proposed fuzzy controller for photovoltaic systems as well in standard as in variable environmental conditions.

REFERENCES

[1]. Mouhanned Brahim, Jamel Belhadj," Performance of PV Grid-Connected System Under Grid Failure" International Journal Of Renewable Energy Research Mouhanned Brahim et al., Vol.3, No.4, 2013

[2]. Zameer Ahmad, S.N. Singh," Modeling and Control of Grid Connected Photovoltaic System- A Review" International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 3, March 2013

[3]. Debendra Bahadur Raut, Ajay Bhattrai," Performance Analysis of Grid Connected Solar PV System Using Matlab/Simulink", Rente Symposium Compendium, Volume 3, September 2013, pp 48-54

[4]. K.Manohar, P.Sobha Rani," Mppt and Simulation for a Grid-Connected Photovoltaic System and Fault Analysis" The International Journal of Engineering And Science (IJES), Volume 1 Issue 2|Pages 158-166 2012

[5]. Ayaz Ahmad, Rajaji Loganathan, " Real-Time Implementation of Solar Inverter with Novel MPPT Control Algorithm for Residential Applications" *Energy and Power Engineering*, 2013, 5, 427-435

[6]. Riad Kadri, Jean-Paul Gaubert, *Member, IEEE*, and Gerard Champenois, *Member, IEEE,"* An Improved Maximum Power Point Tracking for Photovoltaic Grid-Connected Inverter Based on Voltage-Oriented Control*"* Ieee Transactions On Industrial Electronics, Vol. 58, No. 1, January 2011

[7]. Takayoshi Kamejima1, Vanxay Phimmasone1, Yuta Kondo1, Masafumi Miyatake," The Optimization of Control Parametersof PSObased MPPT for Photovoltaics" IEEE PEDS 2011, Singapore, 5 - 8 December 2011

[8]. Ali RezaReisi, MohammadHassanMoradi , ShahriarJamas," Classification and comparison of maximum power point tracking techniques for photovoltaic system: A review" Renewable and Sustainable Energy Reviews 19 (2013) 433–443

[9]. Pritam Chowdhury, Indrajit Koley, Sougata Sen, Dr.Pradip Kumar Saha, Dr.Gautam Kumar Panda," Modelling, Simulation And Control Of A Grid Connected Non Conventional Solar Power Generation System Using Matlab" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 4, April 2013

[10]. Takayoshi Kamejima1, Vanxay Phimmasone," The Optimization of Control Parametersof PSObased MPPT for Photovoltaics" IEEE PEDS 2011, Singapore, 5 - 8 December 2011
[11]. Neng Cao, Yajun Cao," Modeling and Analysis of Grid-Connected Inverter for PV Generation" Proceedings of the 2nd International Conference on Computer Science and Electronics Engineering (ICCSEE 2013)
[12]. C. Liu, B. Wu and R. Cheung," Advanced Algorithm For MPPT Control Of Photovoltaic Systems" Canadian Solar Buildings Conference Montreal, August 20-24, 2004
[13]. Pongsakor Takun, Somyot Kaitwanidvilai and Chaiyan Jettanasen," Maximum Power Point Tracking using Fuzzy Logic Control for Photovoltaic Systems"IMECS 2011, Hong Kong
[14]. Abdullah M. Noman, Khaled E. Addoweesh," A Fuzzy Logic Control Method for MPPT of PV Systems" IEEE 2012.