



ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 7, Issue 5, May 2018

MPPT of PV Array Using Fuzzy Logic Controller Based LUO Converter

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ABSTRACT: The solar power extracted using a solar array varies mainly depending on the weather conditions. Thus, many new algorithms have been projected to track the maximum power point (MPP) of the solar PV system. This paper, presents a comparative study between two of the most intelligent control methods used in order to optimize the efficiency of the solar PV system, the Incremental conductance algorithm and fuzzy logic controller algorithm applied to a Luo converter. The Luo converter increases the output voltage depending on the duty cycle of switching device. The proposed controller adjusts the duty cycle of the Luo converter switch to track the maximum power out of the solar PV array. Finally the performance comparison is done between Incremental conductance and Fuzzy logic controller method, in which Fuzzy logic controller method has the merit of improved efficiency. Both these controller has been simulated using MATLAB version (R2015a).

KEYWORDS: Solar PV array; Maximum Power Point; Incremental conductance algorithm; fuzzy logic controller algorithm; Luo converter.

I. INTRODUCTION

Taking the current global trend into consideration, the need for effective systems to efficiently extract renewable energy from various sources is on very high demand and thus incomparable amount of money and human resources are being invested towards achieving the required goal. This field has been continuously monitored by various public and private organisations, making it highly competitive. The overall quality of the product produced and services offered have been increased dramatically due to the competition held within this renewable energy market. Renewable energy comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished, hence energy extracted from all such sources are called as Renewable Energy. Therefore, for all practical purposes, these resources can be considered inexhaustible, unlike dwindling conventional fossil fuels. The global energy crunch has provided a renewed Impetus to the growth and development of Clean and Renewable Energy sources. Clean Development Mechanisms (CDMs) are being adopted by organizations all across the globe. Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their use. Renewable energy sources are known to be much cleaner and produce energy without the harmful side effects like pollution unlike their conventional counterparts. Extraction of solar energy using a PV array is the most reliable and highly preferred renewable energy source, hence the operation and modelling of a stand-alone power system with PV power generators operating in the slave-and-master modes is applied to system development process to balance the energy and supply good power quality by the controlling the voltage and frequency of the power system in stand-alone application [1]. By initial approximation the maximum power point (MPP) is quickly achieved using a variable step-size. Thus, the drawback of a fixed small step-size over the entire tracking range is removed, resulting in reduced number of iterations and much faster tracking compared to conventional methods. For faster changing environment, faster tracking of maximum power point has resulted in improved efficiency [2]. The modelling and simulation of a photovoltaic array to find out its overall operational efficiency under various controlling

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Vol. 7, Issue 5, May 2018

algorithms, there by comparing and studying the effectiveness of these algorithms in tracking and obtaining the maximum power point [3]. The comparative simulation study of two important MPPT algorithms specifically perturb and observe and incremental conductance is performed as these are used widely because of its low-cost and ease of realization. Some important parameters such as voltage, current and power output for each different combination have been traced for both algorithms. Sepic have a pulsating output current and it requires current handling capability, in order to overcome these drawbacks the Luo converter is used, as it has the ability to reduce ripple voltage and current levels without inverting the polarities. The converters with incremental conductance can track the maximum power with reduced oscillations [4]. Maximum Power Point Tracking (MPPT) for photovoltaic using incremental conductance method is studied and is applied with various converters and the efficiency of operation of these converters are compared [5]. The incremental conductance MPPT algorithm based on solar photovoltaic system using a CUK converter is designed and simulated and is studied in comparison with other converter topologies and the effectiveness of these converters is determined [6]. Performance enhancement of PV system using Luo converter and improved Luo converter modifications with increasing voltage ratio. The positive output super-lift Luo converter that allows significant increase the voltage transfer gain by the modest means. In the simplest case this increase is provided by replacing the inductor by the switched-inductor structure consisting of two inductors and three diodes. This allows getting practically double increase in the line-to-output voltage ratio at the high values of duty cycle. The study indicates possible ways to further increase the output voltage ratio without additional switches - by the use of magnetically coupled inductors and diode-capacitor voltage multipliers [7],[8]. Simulation of fuzzy logic control based MPPT technique for photovoltaic system is studied and the results are compared with results using incremental conductance method and their efficiency is studied [9]. By applying all these techniques a comparative study is conducted and the overall operating efficiency of various technique is obtained.

II.SYSTEM MODEL

The efficiency of a solar cell is very low. In order to increase the efficiency, different methods are to be undertaken to match the source and load properly. One such method is the Maximum Power Point Tracking (MPPT). This is a technique used to obtain the maximum possible power from a varying source. In photovoltaic systems the I-V curve is Non-linear, thereby making it difficult to be used to power a certain load. This is done by utilizing a boost converter whose duty cycle is varied by using a MPPT algorithm.

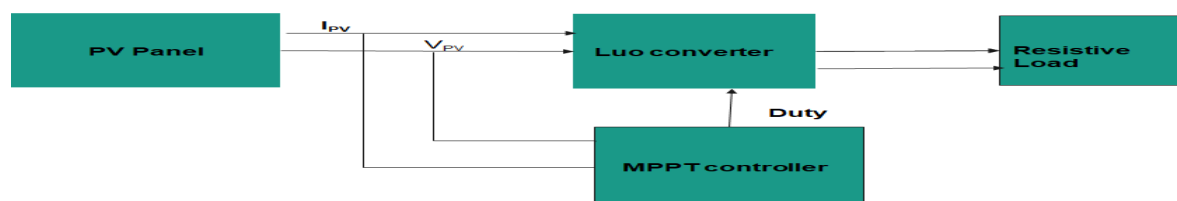


Fig 1: Block diagram of the proposed system.

MPPT CONTROLLER: MPPT algorithms are used by the converters to match the impedance of the load and the out impedance of the solar cell system. Thus the power delivered will be maximum, which defines the peak power point. This can be achieved by placing a boost converter in between the solar and the load. Hence the net impedance viewed by the solar cell is changed by changing the duty cycle of the boost converter. A MPPT algorithm is implemented to change the duty cycle of the boost converter thereby forcing the solar cell to operate in its Maximum Power Point

Incremental conductance method: According to maximum power transfer theorem, the power output of a circuit is maximum when source impedance matches with the load impedance. Hence the problem of tracking the maximum power point reduces to an impedance matching problem. $\Delta P / \Delta V = 0$ and that $P = IV$. The current from the array can be expressed as a function of the voltage $P = I(V) \cdot V$. The PV generator voltage and/or current are then

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Vol. 7, Issue 5, May 2018

incrementing/decrementing until MPP is reached. Therefore, the maximum power point is achieved when the incremental conductance is equal to the negative of the instantaneous conductance.

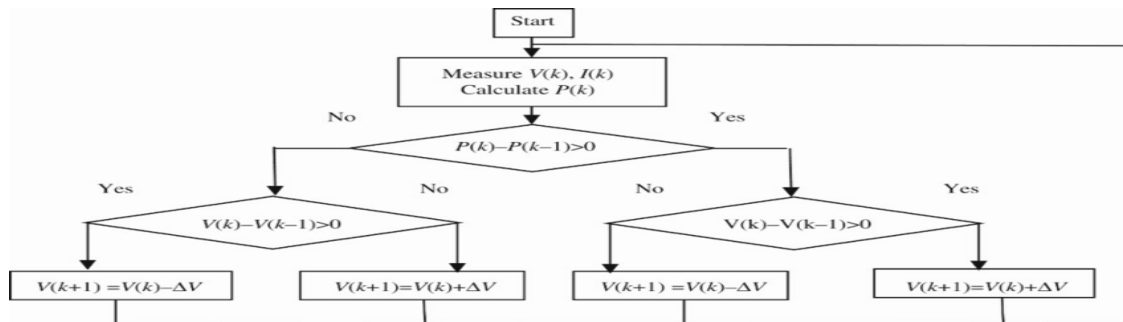


Fig.2: Flow chart of incremental conductance method

Fuzzy logic control:The basic concept understanding fuzzy logic is that of a linguistic variable, that is a variable whose values are words rather than number. Fuzzy logic uses fuzzy sets to related classes of objects with unclearly defined boundaries in which membership is a matter of degree. The fuzzy logic system is more flexible than classical and conventional method. Fuzzy logic controller works with imprecise inputs, it does not need an accurate mathematical model

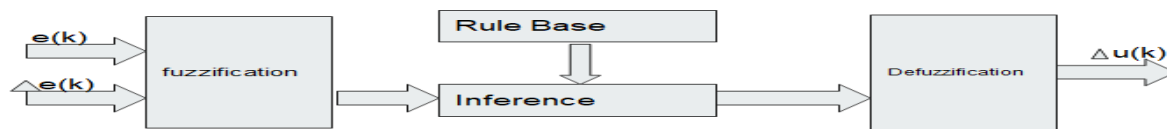


Fig.3: Components of fuzzy logic based MPPT

The fuzzy controller consists of four functional blocks, fuzzification, fuzzy rule, an inference Engine and the defuzzification. The fuzzy controller design contains the three following steps:

Fuzzification:In this process of fuzzification, converting the systems actual input value E and CE into linguistic fuzzy labels using fuzzy membership function. In fuzzification fuzzy logic collects the raw data from system and it converts crisp inputs into fuzzy inputs. Here fuzzy inputs are error (E) and change in error (CE), which are based on the laws of MPPT.

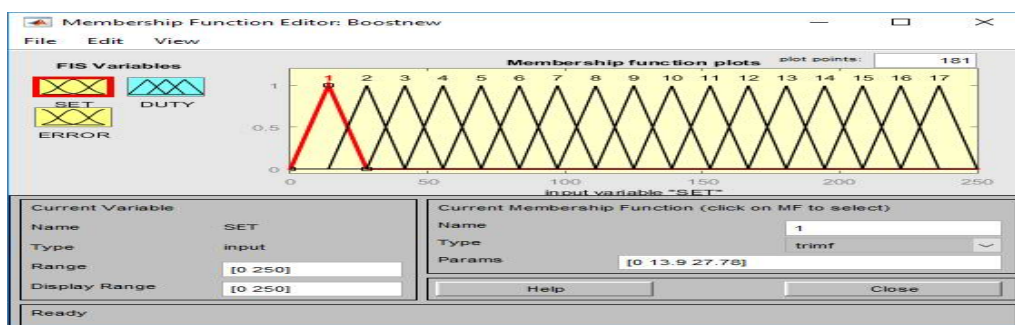


Fig.4: Membership function for input E

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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Website: www.ijareeie.com

Vol. 7, Issue 5, May 2018

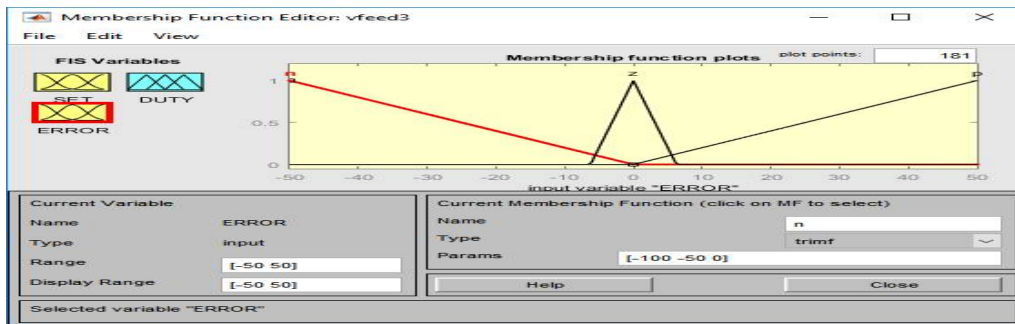


Fig 5: Membership function for input CE

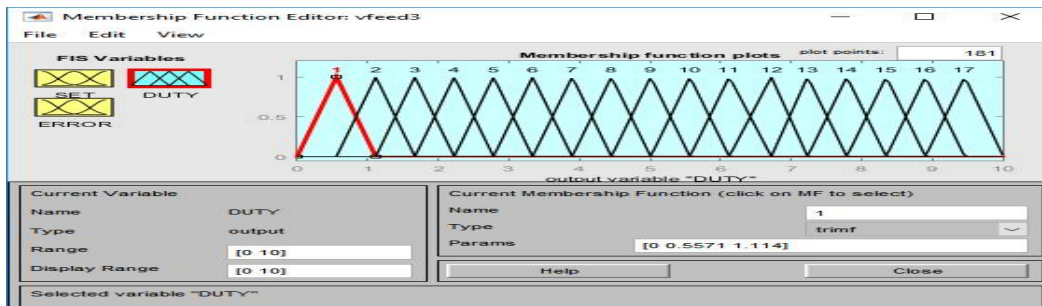


Fig 6: Membership function for output duty cycle (D)

Table.1: Fuzzy logic rule table

1	if (set is 1)	And (Error is z)	then (Duty is 1)
2	if (set is 1)	And (Error is p)	then (Duty is 2)
3	if (set is 1)	And (Error is n)	then (Duty is 2)
4	if (set is 2)	And (Error is p)	then (Duty is 3)
5	if (set is 2)	And (Error is n)	then (Duty is 1)
6	if (set is 2)	And (Error is z)	then (Duty is 3)
7	if (set is 3)	And (Error is p)	then (Duty is 4)
8	if (set is 3)	And (Error is n)	then (Duty is 2)
9	if (set is 3)	And (Error is z)	then (Duty is 4)
10	if (set is 4)	And (Error is p)	then (Duty is 5)
11	if (set is 4)	And (Error is n)	then (Duty is 3)
12	if (set is 4)	And (Error is z)	then (Duty is 5)
13	if (set is 5)	And (Error is p)	then (Duty is 6)
14	if (set is 5)	And (Error is n)	then (Duty is 4)
15	if (set is 5)	And (Error is z)	then (Duty is 6)
16	if (set is 6)	And (Error is p)	then (Duty is 7)
17	if (set is 6)	And (Error is n)	then (Duty is 5)
18	if (set is 6)	And (Error is z)	then (Duty is 7)
19	if (set is 7)	And (Error is p)	then (Duty is 8)
20	if (set is 7)	And (Error is n)	then (Duty is 6)
21	if (set is 7)	And (Error is z)	then (Duty is 7)
22	if (set is 8)	And (Error is p)	then (Duty is 9)
23	if (set is 8)	And (Error is n)	then (Duty is 7)
24	if (set is 8)	And (Error is z)	then (Duty is 9)

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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Vol. 7, Issue 5, May 2018

25	if (set is 9)	And (Error is p)	then (Duty is 10)
26	if (set is 9)	And (Error is n)	then (Duty is 8)
27	if (set is 9)	And (Error is z)	then (Duty is 10)
28	if (set is 10)	And (Error is p)	then (Duty is 11)
29	if (set is 10)	And (Error is n)	then (Duty is 9)
30	if (set is 10)	And (Error is z)	then (Duty is 11)
31	if (set is 11)	And (Error is p)	then (Duty is 10)
32	if (set is 11)	And (Error is n)	then (Duty is 12)
33	if (set is 11)	And (Error is z)	then (Duty is 12)
34	if (set is 12)	And (Error is p)	then (Duty is 13)
35	if (set is 12)	And (Error is n)	then (Duty is 11)
36	if (set is 12)	And (Error is z)	then (Duty is 13)
37	if (set is 13)	And (Error is p)	then (Duty is 14)
38	if (set is 13)	And (Error is n)	then (Duty is 12)
39	if (set is 13)	And (Error is z)	then (Duty is 14)
40	if (set is 14)	And (Error is p)	then (Duty is 15)
41	if (set is 14)	And (Error is n)	then (Duty is 13)
42	if (set is 14)	And (Error is z)	then (Duty is 15)
43	if (set is 15)	And (Error is p)	then (Duty is 16)
44	if (set is 15)	And (Error is n)	then (Duty is 14)
45	if (set is 15)	And (Error is z)	then (Duty is 16)
46	if (set is 16)	And (Error is p)	then (Duty is 17)
47	if (set is 16)	And (Error is n)	then (Duty is 15)
48	if (set is 16)	And (Error is z)	then (Duty is 17)
49	if (set is 17)	And (Error is p)	then (Duty is 17)
50	if (set is 17)	And (Error is n)	then (Duty is 15)
51	if (set is 17)	And (Error is z)	then (Duty is 17)

Defuzzification: Fuzzy rule based systems evaluate linguistic if-then rules using fuzzification, inference and transform the fuzzy results in to crisp, defuzzification is performed. Defuzzification is the process of converting a fuzzified output into a single crisp value with respect to a fuzzy set. The defuzzified value in FLC (Fuzzy Logic Controller) represents the action to be taken in controlling the process.

LUO CONVERTERS: Luo converters are the simplest form of DC-DC converter which operates on voltage lift technique. This Luo converter operates on PUSH-PULL state. The switched type Luo converter is developed. Switched capacitor DC-DC converters are made only of switched capacitors. Because switched capacitors can be integrated into power semiconductor integrated circuit (IC) chips, they have limited size and work at high switching frequency. The elementary LUO converter performs buck or boost operation in DC to DC conversion.

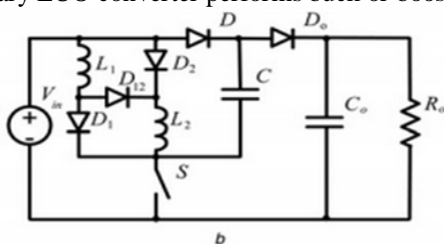


Fig.7:Equivalent circuit of luo converter

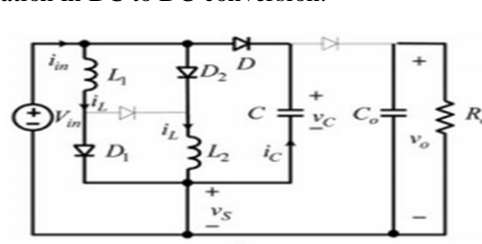


Fig.8:Luo converter when the switch is in ON condition

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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Website: www.ijareeie.com

Vol. 7, Issue 5, May 2018

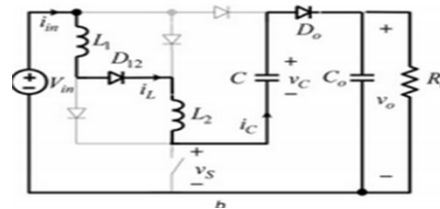


Fig.9: Luo converter when the switch is in OFF condition

III.SIMULATION OF LUO CONVERTER WITH INC AND FUZZY LOGIC CONTROLLER

The simulation is done using MATLAB version R2015a. The model is built using a solar panel with the Luo converter and the maximum power point tracking device mainly. The figures below are the devices used to build the model in the MATLAB.

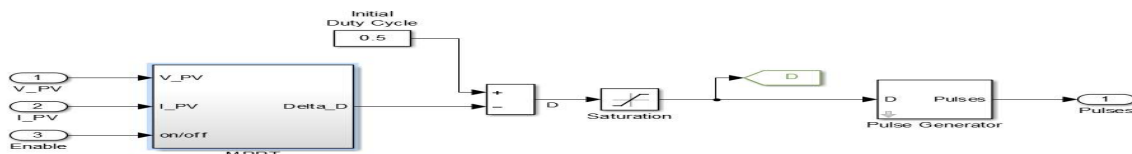


Fig.10: MPPT controller

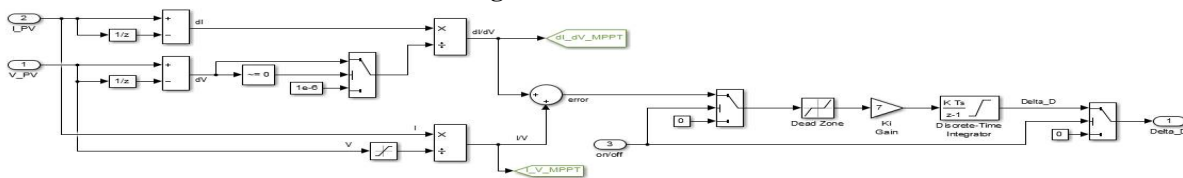


Fig.11: Detailed structure of MPPT controller

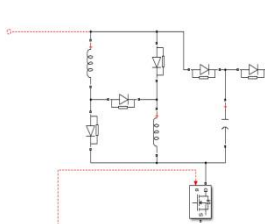


Fig.12: Diagram of the Luo converter

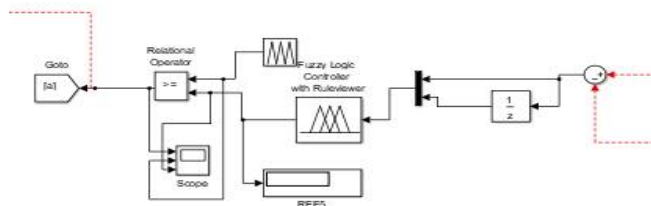


Fig.13: Diagram of fuzzy logic controller

SIMULINK DIAGRAM: The Simulink block diagram gives us the software model of INC and fuzzy logic controller. Using this Simulink block diagram we are able to set up the whole model and get equivalent results as the prototype model.

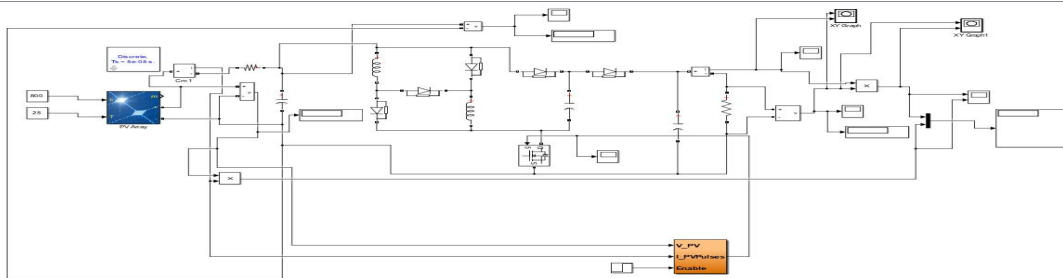


Fig 14: Simulink diagram for Incremental conductance method

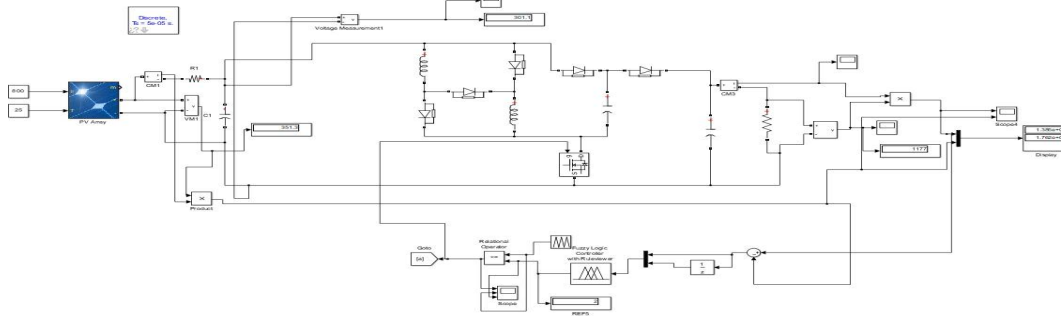


Fig 15: Simulink diagram for Fuzzy logic method

IV. (a) SIMULATION RESULTS OF INC METHOD

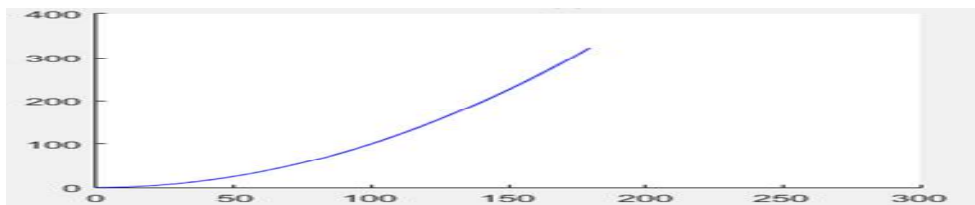


Fig. 16: Output curve between the Power (y-axis) and voltage (x-axis) of INC method.

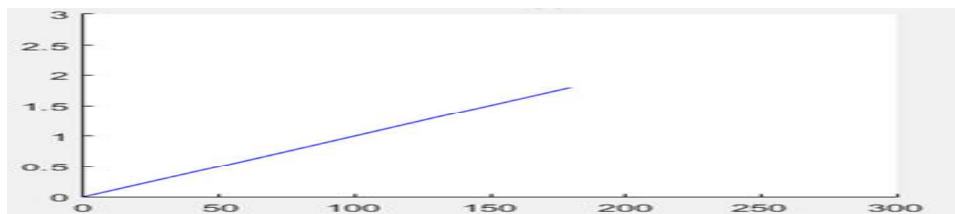


Fig.17:Output curve between the current (y-axis) and voltage (x-axis) of INC method.



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Vol. 7, Issue 5, May 2018

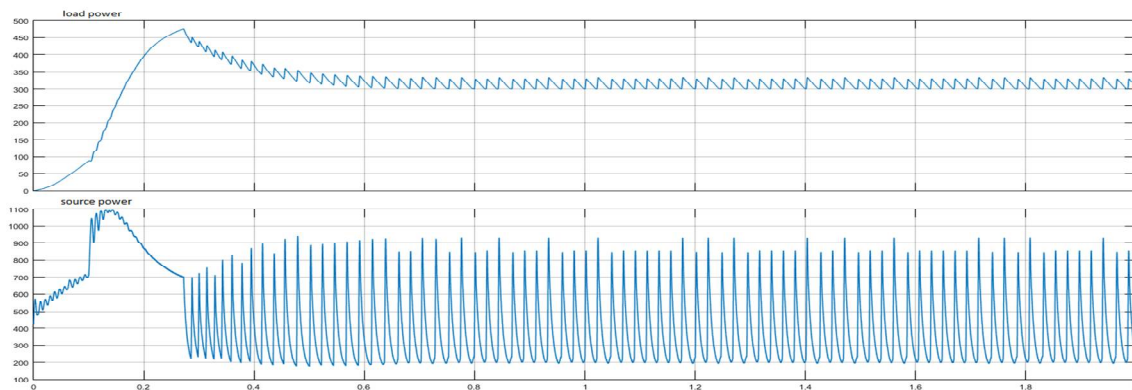


Fig.18: Simulation Output- Power waveform of INC method

(b) SIMULATION RESULTS OF FUZZY LOGIC METHOD

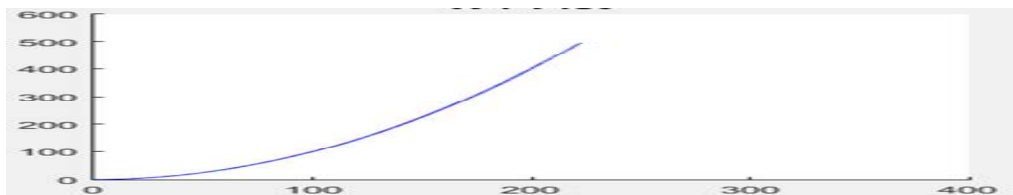


Fig.19: Output curve between Power (y-axis) and voltage (x-axis) of fuzzy logic control method

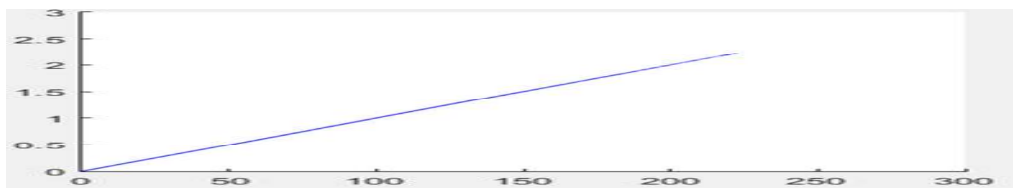


Fig.20: Output curve between current (y-axis) and voltage (x-axis) of Fuzzy logic control method

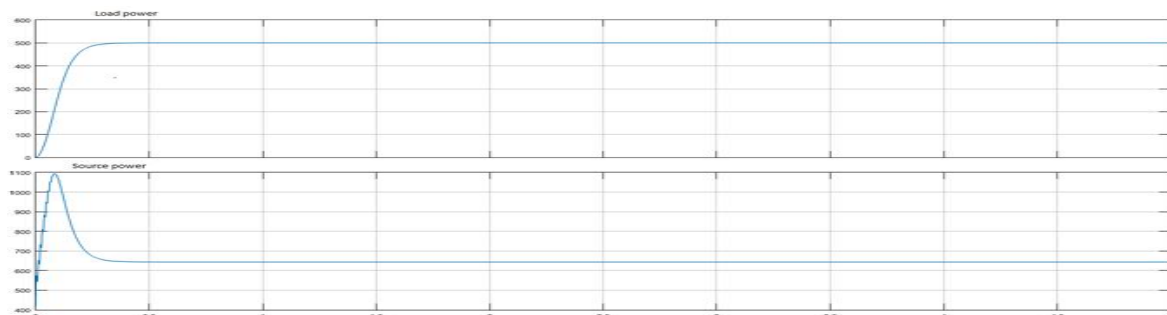


Fig.21: Simulation Output –Power waveform of Fuzzy logic method



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 7, Issue 5, May 2018

Table.3: Comparison based on simulation output

INC Method	Fuzzy Logic
Input voltage: 66.43 V	Input voltage : 67.54 V
Output voltage: 178.3 V	Output voltage: 223.6 V
Output current:2.1A	Output current: 2.3 A
Source power : 781.7 W	Source power:643.9 W
Load end power: 318 W	Load end power:500.1

V.CONCLUSION AND FUTURE SCOPE

Photovoltaic model using MATLAB/SIMULINK and design of appropriate Luo converter with a maximum power point tracking facility are presented here. A new method for MPPT based fuzzy logic controller is presented and compared with the conventional INC MPPT method. The model is tested under disturbance in both solar radiation and photovoltaic temperature. Simulation results shows that the proposed method effectively tracks the maximum power point. The oscillation around MPP is decreased and the response is faster in compared with the conventional methods. Comparing the tracking efficiency of both methods, it indicates that the proposed method has a higher efficiency than the conventional INC MPPT method. In future, Fuzzy logic method, different defuzzification methods can be implemented and further improvements could be implemented.

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