Design of Fuzzy Logic Controller for Speed Control of DC Motor Fed from Solar PV System

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Abstract

The main objective of this paper is to do a comparative analysis between Fuzzy Logic Controller (FLC) and Proportional Integral (PI) Controller in a solar PV system which is to extract maximum power from the solar panel to supply a dc motor. The maximum power point tracking (MPPT) algorithm is necessary for all photovoltaic (PV) system. The Perturb and Observe (P&O) algorithm is used to track maximum power from the solar panel. To step up the voltage obtainable from the solar panel, the SEPIC dc – dc converter is used. The main benefit of the converter is having non-inverted output. The converter act as the interface between PV module and dc motor. The entire system is modelled and simulated using MATLAB/Simulink 2015a software.

Keywords — *MPPT, PV, SEPIC Converter, P&O Algorithm, Fuzzy Logic and PI Controller, DC Motor.*

I. INTRODUCTION

In recent days, energy generated from efficient, fresh and environmentally friendly sources have become one of the major challenges for engineers & scientists. PV energy is getting growing important as a renewable source due to the benefit such as the absence of small maintenance, no carbon emission, the absence of fuel cost and no sound due to the absence of moving parts. Among all renewable energy sources, solar power system attracts extra attention because they provide outstanding opportunity to generate electricity. The efficiency of solar cells depends on various factors such as insulation, spectral characteristics of sunlight, temperature, darkness, dirt, etc [1, 2]. Changes in insulation on panels due to quick climate changes such as the raise in ambient temperature and cloudy weather can decrease the photovoltaic (PV) array output power.

The maximum power point tracking (MPPT) controller is used to get better the efficiency of the PV system. In which P&O and incremental conductance are frequently used [3, 4]. Both algorithms tune the DC–DC converter duty cycle in the PV system. For P&O, steady-state oscillation occurs after the MPP is reached, the perturbation continuously Changes in both directions to maintain the MPP. DC- DC converter can be used as switch mode regulated to convert an unregulated dc voltage to a regulated output voltage [5, 6]. The set frequency PWM is used to attain the regulated voltage and BJT, MOSFET or IGBT are the switching devices. There are various types of dc-dc converters, buck, boost, buck-boost, Cuk and SEPIC [7]. A low input- current ripple is the mainly important requirement of any DC-DC converter used in the MPPT. SEPIC consists of boost converter follow by the buck-boost converter [8, 9]. The main benefit of this converter is capable of providing a non-inverted output (the output and input have the same polarity). Its output voltage must be equal or less than or larger than to the input voltage.

In this paper, SEPIC converter regulates the dc voltage obtain from the solar panel and feeds the dc motor [10, 11]. The output voltage of the SEPIC converter is used as a feedback signal from which voltage is derived and error and change in error are obtained and given to Fuzzy Logic / PI controller [12]. The generated pulses from the controller are combined with the pulses obtained from the Incremental Conductance Algorithm of a Solar panel and given to SEPIC converter and desired output is produced.

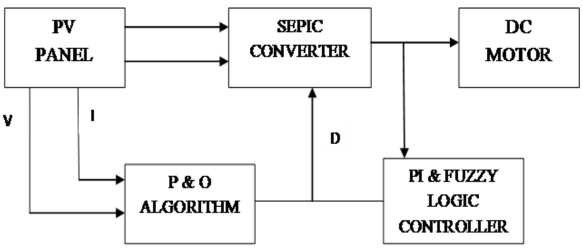


Fig. 1 Block diagram

II. MAXIMUM POWER POINT TRACKING

In wind turbines and PV solar systems, to maximum power extraction is feasible below all conditions, if MPPT technique is used. PV solar system has lots of different configurations. A typical solar panel converts only 30-40 (%) of the incident solar irradiation into electrical power. MPPT increases the efficiency of the solar panel rapidly. If they operate at their MPP even with the inevitable changes in the environment maximum power from the solar panel can be harvested. Over the past decades, many methods to find the MPP have been published and developed. In that most suitable techniques for medium and, large-size photovoltaic applications are P&O and INC. These techniques have the merits of an easy implementation.

A. Perturb and Observe (P&O)

The P&O method offers the merits of simplicity and no difficulty to implementation. It can also be easily applied to any PV panel as it has the advantage of not relying on the PV module characteristics in the MPPT process. After one perturb operation the power is calculated and compared with earlier value to decide the change in power dP. The P&O perturbation step size plays a very important role in finding the accuracy and speed at which the operating point converge on the MPP. The time period for this algorithm is very less but on reaching a point which is very close to the MPP it doesn't stop there, perturbing on both the directions. We can set an appropriate error limit or can use a wait function which ends up raising the time complexity of the algorithm. However, it does not account the rapid change of irradiation level (due to which MPPT changes).

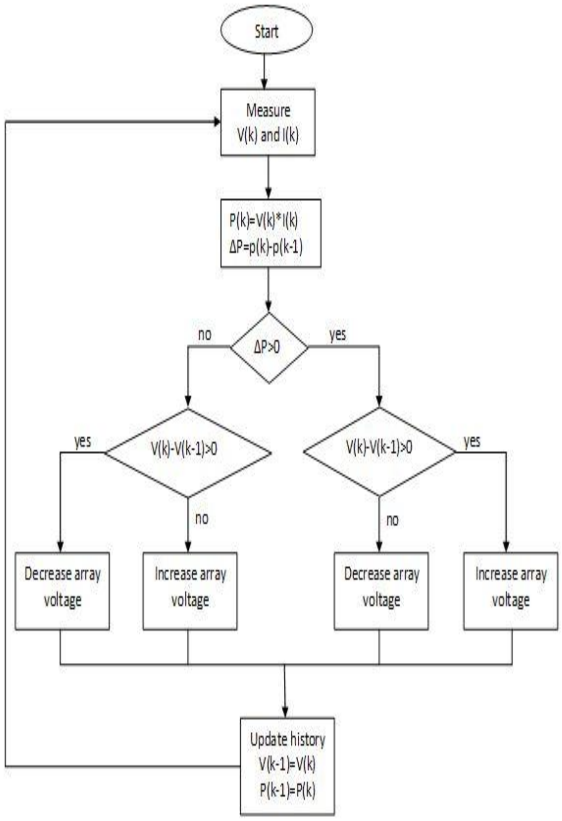


Fig.2. Flow chart for P&O algorithm

III. SEPIC CONVERTER

A SEPIC (single-ended primary inductor converter) is one kind of DC-DC converter. It consists of boost converter follow by a buck-boost converter. The main benefit of this converter is capable of providing a non-inverted output (i.e. the output has the alike polarity as the input). Its output voltage must be larger than or less than or equal to the input voltage and it commonly used in battery operated applications.

The output voltage is controlled by adjusting the duty cycle of the control switch. The control switch is typically a MOSFET, which offers much higher input impedance, low voltage drop and lesser switching losses. A SEPIC converter is a fourth order converter, it means these converters have four energy storage elements they are two inductors & two capacitors, and it is used to transmit the energy from input side to output side. The input inductor L_1 is collective with the MOSFET control switch to be like a boost topology. Where the inductor L_2 location is similar to a buck-boost topology.

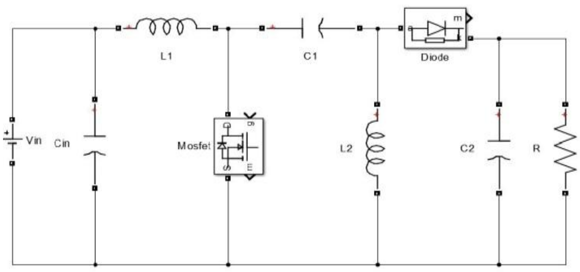


Fig.3. SEPIC operational diagram

IV. PI CONTROLLER

PI controller is formed from the combination of proportional and integral mode. While changing the proportional gain, integral gain also changes but the integral gain can be changed independently. The integral function provides a new controller output and so the error value is zero when the load changes. When load changes it produces an error and so a new controller output is required this is provided through a sum of integral and proportional action. Mostly open loop operation is insensitive to load and disturbances and so closed loop operation is preferred which uses the error value as feedback signal which is processed so as to reach the desired output. In this system, input is voltage error and the output is incremental duty ratio. Its transfer function is given by,

$$G(s) = Kp+(Ki/s)$$

Where,
Kp is the proportional gain and
K_i is the integral gain.

V. FUZZY LOGIC CONTROLLER (FLC)

Fuzzy logic depends on the model of the fuzzy set. A fuzzy set is a set with blurred boundary. In fuzzy logic, a curve is defined in which the input space is mapped to a membership value range from 0 to 1 is called as a membership function. The input space is also referred as a universe of communication

[13]. To maintain the fuzzy values at the extremer, a standard logical operation is used. The logical operations used are AND, OR and NOT. If then statement rules are used to make the conditional statements [14]. The process involved in the fuzzy logic controller is

- Fuzzification: During fuzzification, all fuzzy statements are resolved into a degree of membership between 0 to 1.
- Rule base: To form the fuzzy output, the degree of support is used. Mainly, one rue alone will not be so effective. Each and every rule deliver fuzzy set as output [15]. In this manuscript, Mamdani base fuzzy inference system is used.
- Defuzzification: After defuzzification, crisp numerical output values are obtained. For this centre of gravity, a method is used.

Table i- Fuzzy Logic Rule Table

e \ ce	NB	NM	NS	ZE	PS	PM	PB
NS	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NB	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Fig.4. Fuzzy Logic Input 1

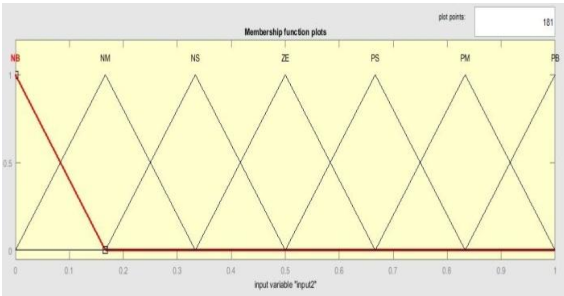
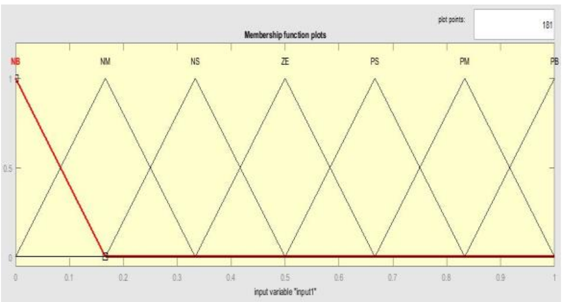


Fig.5 Fuzzy Logic Input 2



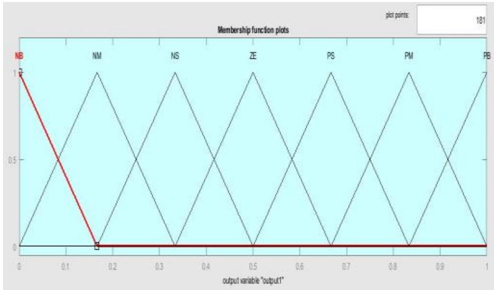
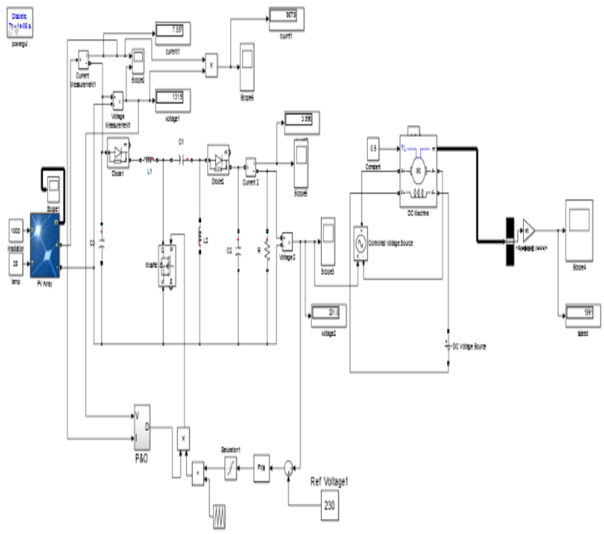
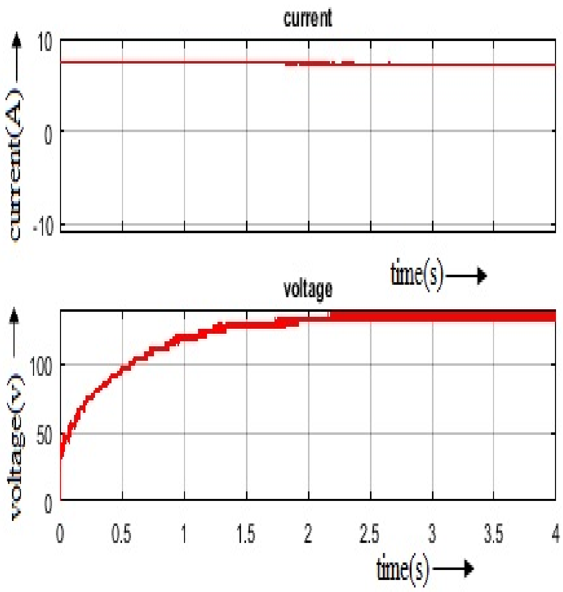


Fig.6. Fuzzy Logic Output

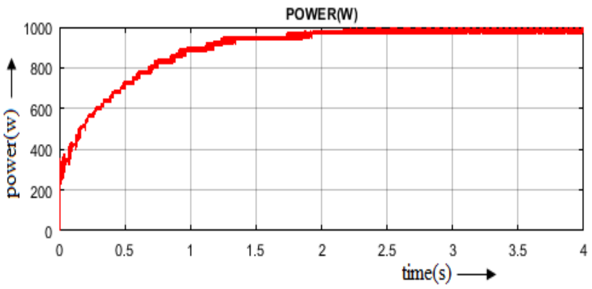
VI. SIMULATION RESULT



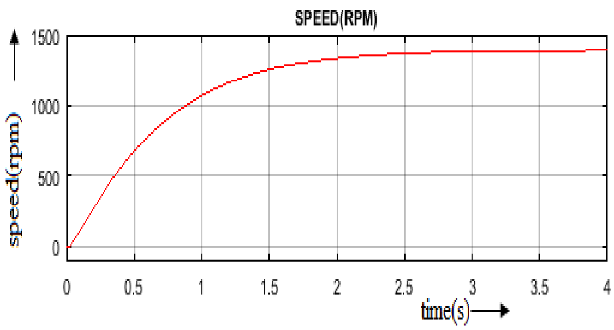
(a)



(b)

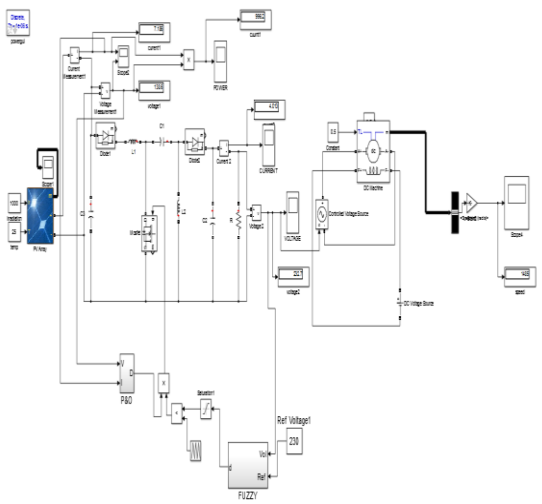


(c)

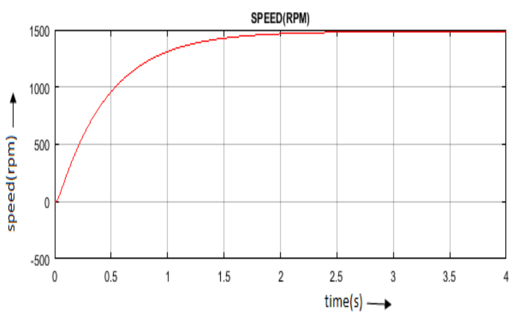


(d)

Fig.7. (a) Simulation circuit of P&O (b) output current and output voltage (c) output power (d) speed of the motor



(a)



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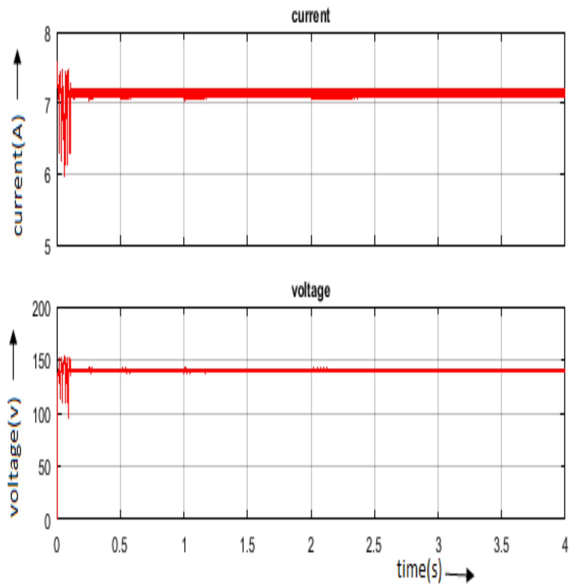
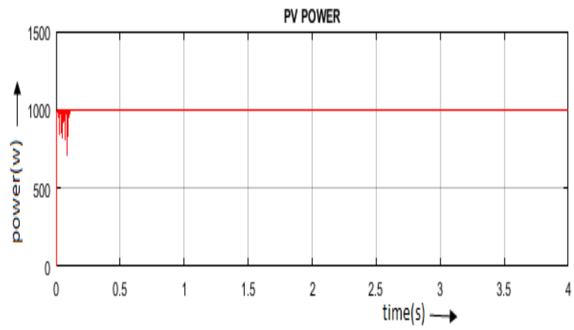


(c)



(d)

Fig.8. (a) Simulation circuit of FLC (b) speed of the motor (c) output current and output voltage (d) output power

Table II-Comparison between pi and fLC controller

Controller	PV voltage	PV Current	Output Power (W)	Motor Speed (rpm)
PI	132	7.33	968	1391
Fuzzy	138.6	7.2	996.2	1486

VII. CONCLUSION

The P&O algorithm along with SEPIC converter is designed for a typical 1kW solar system. The SEPIC converter is most appropriate converter topology which serves the capability for tracking the maximum power point irrespective of irradiation, temperature and load condition. The simulation for the Fuzzy Logic Controller (FLC) and Proportional Integral (PI) controller separately has been carried out and the comparison between FLC and PI controller (output voltage, current, power and motor speed) are done. From simulation results obtained, it is observed that Fuzzy Logic controller performs better than the Proportional Integral controller for the speed control of dc motor.

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REFERENCE

[1] Gwo-Bin Wu and Chin-Sien Moo, "Maximum Power Point Tracking with Ripple Current Orientation for Photovoltaic Applications", IEEE Journal of Emerging and Selected Topics in Power Electronics, December 2014, Vol. 2, No. 4.

[2] T. Shanthi, N. Ammasai Gounden, "Power electronic interface for grid-connected PV array using boost converter and line-commutated inverter with MPPT", International Conference on Intelligent and Advance systems, pages: 882-886, DOI: 10.1109/ICIAS.2007.4658513.

[3] Mahesh Kumar Mishra and Sathish Kumar Kollimalla, "Variable Perturbation Size Adaptive P&O MPPT Algorithm for Sudden Changes in Irradiance" IEEE Transactions on Sustainable Energy, July 2014, Vol. 5, No. 3.

[4] William Christopher and Dr.R.Ramesh, "Comparative Study of P&O and INC MPPT Algorithms" American Journal of Engineering Research (AJER), Volume-02, Issue-12, pp-402-408, 2013.

[5] Dezso Sera, Laszlo Mathe, TamasKerekes, SergiuViorelSpataru "On the Perturb-and-Observe and Incremental Conductance MPPT Methods for PV Systems", IEEE Journal of Photovoltaic, July 2013, Vol. 3, No. 3.

[6] Tey Kok Soon and Saad Mekhilef, "A Fast-Converging MPPT Technique for Photovoltaic System under Fast-Varying Solar Irradiation and Load Resistance" IEEE Transactions on Industrial Informatics, Vol. 11, No. 1, February 2015.

[7] Jehanzaib Ali, Usama Ijaz, M. Hasan Khan Niazi, M. Shahroze Amer, M. Mobeen Younis and Waqas Hassan, "Simulation and Implementation of Solar Power Battery Charger using Perturb & Observe Algorithm" 978-1-4673-6813-1/15/$31.00 ©2015 IEEE.

[8] Chetan P. Ugale, R. B. Dhumale, V. V. Dixit3, "DC-DC Converter Using Fuzzy Logic Controller", International Research Journal of Engineering and Technology (IRJET), Volume: 02 Issue: 04 | July-2015.

[9] Nur Mohammad, Muhammad Quamruzzaman, Mohammad RubaiyatTanvir Hossain, Mohamad RafiqulAlam, "Parasitic Effects on the Performance of DC-DC SEPIC in Photovoltaic Maximum Power Point Tracking Applications", Copyright © 2013 SciRes, Published Online February 2013.

[10] Sangeetha S, Jitha joseph "Design and Implementation of Sepic Converter Based PV System Using Modified Incremental Conductance Algorithm", International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) - 978-1-4673-9939-5/16/$31.00 ©2016 IEEE.

[11] James Dunia, Bakari M. M. Mwinyiwiwa, "Performance Comparison between ĆUK and SEPIC Converters for Maximum Power Point Tracking Using Incremental Conductance Technique in Solar Power Applications", International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:7, No:12, 2013.

[12] Astitva Kumar, Priyanka Chaudhary and M. Rizwan, "Development of Fuzzy Logic based MPPT Controller for PV System at varying Meteorological parameters" 978-1-4673-6540-6/15/$31.00 ©20 15 IEEE.

[13] Anusuya.V and Vishnupraba.G, "MPPT Using Fuzzy Logic Controller for SEPIC Converter And Three Phase Inverter", International Journal of Advanced Research in Computer and Communication Engineering Vol. 4, Issue 4, April 2015.

[14] S. Karthika, K. Velayutham, P. Rathika, D. Devaraj, "Fuzzy Logic Based Maximum Power Point Tracking Designed for 10kW Solar Photovoltaic System with Different Membership Functions", International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:8, No:6, 2014.

[15] Ahmad El Khateb, NasrudinAbd Rahim, JeyrajSelvaraj, and Mohammad Nasir Uddin, "Fuzzy-Logic-Controller-Based SEPIC Converter for Maximum Power Point Tracking", IEEE Transactions on Industry Applications, VOL. 50, NO. 4, JULY/AUGUST 2014.

[16] Abdulbari Ali Mohamed Frei, Huseyin Demirel, and Bilgehan Erkal, "Design Implementation and Evaluation of Fuzzy Logic and PID Controller for Fuel Cell System", International Journal of Electronics and Electrical Engineering, Vol.5, No.1,pp.84-89, February 2017.doi: 10.18178/ijeee.5.1.84-89

[17] Sivasankari Sundaram, K.N. Sheeba and Jakka Sarat Chandra Babu, "Grid Connected Photovoltaic System: Challenges and Control Solutions – A Potential Review", International Journal of Electronics and Electrical Engineering, Vol.4, No.6, pp. 463-473, December 2016.doi: 10.18178/ijeee.4.6.463-473.

[18] Khadim m. Siddiqui, kuldeep sahay, and v.k. giri, "modelling and analysis of open and closed loop induction motor fed pwm inverter", International Journal of Electronics and Electrical Engineering, Vol.4, No.6, pp.474-481, December 2016. doi: 10.18178/ijeee.4.6.474-481.

[19] Cite: K.Kouzi, T.Seghier and A.Natouri, "Fuzzy Speed Sensorless Vector Control of Dual Star Induction Motor Drive Using MRAS Approach", International Journal of Electronics and Electrical Engineering, Vol.3, No.6, pp.445-450, December 2015.doi: 10.12720/ijeee.3.6.445-450.

[20] Maheshkumar.k and s. Ravivarman, "high step up swithed capacitor inductor DC-DC converter for UPS system with renewable energy source", International Journal of Electronics and Electrical Engineering, Vol.3, No.2, pp.89-94, april 2015.doi: 10.12720/ijeee.3.2.89-94.

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