Modeling and Analysis of Maximum Power Point Tracking for Photovoltaic System using Fuzzy Logic Controller

P.Pushparani[1], M.Valan Rajkumar[2], R.Suganya[3]
Department of Electrical and Electronics Engineering
[1, 2, 3]Gnanamani College of Technology, Namakkal-637018, India

Abstract*-This paper presents the simulation and analysis of maximum power point tracking (MPPT) for photovoltaic (PV) system using Fuzzy Logic Controller (FLC) algorithm. The ultimate aim of the paper is, a new one input FLC to improve the maximum power point tracking capability for PV system under partial shading condition. The fuzzy control method is used for haul out the highest power source from the PV scheme with change in value of temperature and under variable value of solar irradiations. The scheme rigging the FLC as a MPPT controller is to take out the highest voltage and power source profile from PV scheme under variable temperature and solar irradiations. The dc-dc converter is used to boost the tracked voltage from the PV system. The membership function of FLC for PV voltage and current sampled with variations of solar irradiations and temperature change. Fuzzy logic controller stand MPPT can pull out the highest power from PV system compare to other conventional MPPT algorithms. Therefore overall proposed system output voltage can be enhanced. The effectiveness of the proposed system is proved with the help of simulation. The simulation is performed in MATLAB/Simulink.*

Keywords: Photovoltaic (PV) Systems, DC-DC Converters, Maximum Power Point Tracking (MPPT), Fuzzy Logic Controller (FLC)

I. INTRODUCTION

In recent years, the growths of energy demand and of the pollution from use of fossil fuels are pushing the public to use renewable energies. In this context, solar energy is one of the major renewable energy sources that appears as a solution to our problems of energy production. Moreover, this energy resource seems to be the most promising, and inexhaustible. However, the generation of this kind of energy is non-linear. It varies and depends on insolation and ambient temperature. Therefore, the operating point of photovoltaic doesn't always coincide with the point of maximum power. For this, we used a mechanism research called maximum power point tracker (MPPT) to extract the maximum power [1-5].

Due to power require and ecological accountability, growing energy values, global warming and air pollution, the photovoltaic (PV) systems are becoming more effective and alternative sources of energy. Currently the solar scheme has turn into one of the majority gifted renewable source due to its infinite with other environmental rewards. In daily activities the energy plays a significant function, as there is much increase in population and industrial applications. It is one of renewable energy source, which has more potential of counteracting a significant amount of the world's energy requirement [6-14]. The main fuels like coal, diesel, and petrol, nuclear and other natural gases are depleting day by day. PV array has concerned additional concentration in the very last few years as it meets the requirements of creature environmentally well-suited with reserve preserving. The occurrence of increasing the rate of energy expenditure and supply is decreasing that the result into energy deficiency [15-25].

The PV system is set to play a continually increasing part in generating the form, the affecting the exterior and creation of construction. When linking the PV array to the load, the photovoltaic voltage and current value PV a cell varies according to the solar irradiations. The source produced from the PV scheme is not sufficient to run the motor load system, for that the DC-DC boost up converter employed to get superior the engendered PV power [26-36]. Generally used MPPT algorithms like perturb and observe (P&O), incremental conductance method, neural network technique, short circuit process and fuzzy logic control to get better output from the PV cells. In this proposed system, the simulation of highest power point path with fuzzy logic controller technique fed voltage source inverter was realized. The PV system investigated with change in temperature and solar radiations and for extracting the maximum power fuzzy logic control MPPT prepared [37-48].

In the literature, the fuzzy logic control method has shown its advantage in terms of performance, robustness and flexibility. This method could quickly respond to the variation of environmental conditions, by keeping PV system working at maximum power point at all times, and eliminate the oscillation power around point of maximum power [49-60]. There are always two inputs in a MPPT fuzzy logic controller. This causes complexity in fuzzification, fuzzy rules and defuzzification. In this paper, a new one input MPPT fuzzy logic controller, by using only one input dP/dV, the structure of the proposed MPPT controller is simple. To show the control performance, numerical simulations were performed under the variation of environmental condition and load [61-68].

II.PV ARRAY MODELLING

The power circuit of PV array consists of current source, 2 diodes and resistors and load, which is shown in Fig 1.

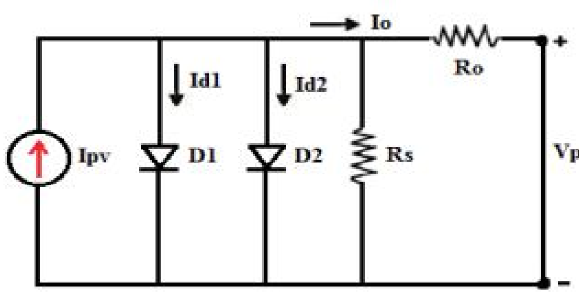

Fig. 1 Power circuit for PV array modelling

The photovoltaic or photo-electric unit is a power semiconductor apparatus to exchanges light to electrical source with PV consequence. When power of photon of radiance is more than the band gap of electron is released with surge of electron which generates the current flow in the circuit. Regularly, the solar cell model can be sculpted by a current source with an inverter system diode associated in equivalent to it. And it has both parallel and series type of resistance and where Iq – reverse use saturation current value of the device, p- electron charge in the device, Vn – the voltage across the device, r - Boltz fixed value and T is the branch temperature for the PV model. PV system assembled to generate the DC voltage from the light energy and a PV panel is one or more PV cell assembled, designed to provide a field connected unit, while a PV array is the smallest installed assembly of PV panels or modules, carry structures, practicalities and other components used for installation.

III. MPPT METHOD

A typical solar radiation converted into electrical energy by 35 to 45 percent from the solar panel. To progress effectiveness of the solar scheme highest power source point tracking is prepared. The extracting of maximum power decided when the solar irradiations and temperature will be constant. When the variations occur in solar irradiation and temperature, the improved MPPT method has to implement. The dc-dc boost up converter supplementary in the PV array side in direct to augment the tracked source as of the PV scheme. Moreover with altering duty value of dc boost converter the requisite demand voltage could achieve, to facilitate gives the source voltage matched with the load voltage. Based on this situation PV voltage source with current value deliberated and The PV array scheme, a P-V characteristic of is exposed with Fig 2.

The P&O technique chooses the maximum extracts of power based on the position movement. When the percentage of alteration in voltage source to modify in current is positive, then there is a small increment.

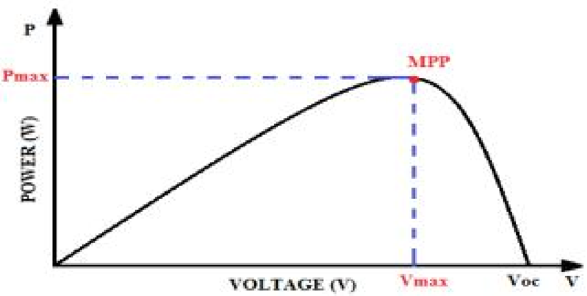

Fig.2 P-V characteristics of PV array system

If the proportion of modify in voltage to adjust in current is less than zero, then the large increment will occur at the same position of tracking also change. By observance the solar irradiation and temperature as constant to take out the maximum power from the projected system and the value of PV voltage, current & power can be determined. The PV array systems I-V characteristics of are shown in Fig 3.

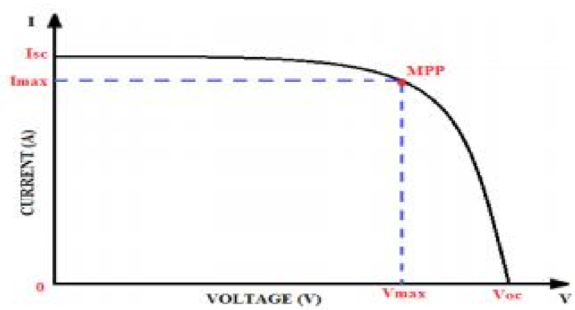

Fig.3 I-V characteristics of PV array system

3.1 Variation in Temperature and solar radiation

The conventional MPPT process can track in incorrect direction due to the changes occur in temperature and solar irradiations. And solar irradiations can change moderately faster corresponding to a variation of the rated power from 0% to 100% ranges within very small period of time in very small PV systems. But the chance of such fast solar radiation changes is tremendously very low. The PV system with variation of solar radiation of I-V characteristics are shown in Fig 4.

If the changes in the temperature and solar radiations cause a greater revolutionize in power source than the one reason by the growth in the voltage value, the MPPT could acquire perplexed, as it will understand the revolutionize in the power source as an outcome of its own exploit. The conventional MPPT algorithm cannot read the direction of tracking the maximum power and voltage at the time variation occur in the temperature and solar radiations.

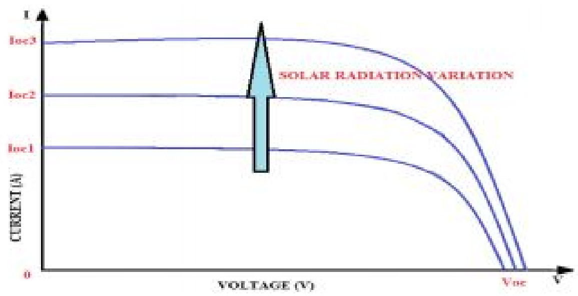

Fig. 4 I-V characteristics of PV system with variation of solar radiation

The PV system with variation of temperature of I-V characteristics are shown in Fig 5.

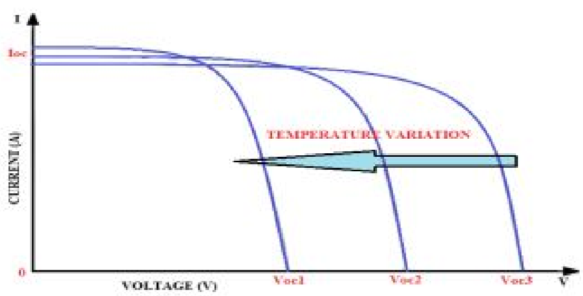

Fig. 5 I-V characteristics of PV system with variation of Temperature

IV.FUZZY LOGIC CONTROLLER

Our main idea is to combine Perturb and Observe (P&O) method in a one input fuzzy logic controller, in order to take into account the direction of variation of perturbation is shown in Fig 6. The input of fuzzy logic controller is a derivative of dP/dV and the output is different between the current duty cycle and the previous duty cycle ΔD of boost converter DC/DC.

The rules table easily enables action on the control surface. If we choose a high value of output ΔD, we can quickly achieve the PPM. But it leads us above the point of maximum power (PPM). This also causes oscillations around the PPM. On the contrary, if we choose a small value of output ΔD, the response time of our fuzzy logic controller is slow. But, we can easily reach the PPM. To solve this problem, we used thirteen membership functions of input dP/dV, and thirteen constant values of output ΔD. The PPM was quickly reached, but was not exceeded. There were no oscillations anymore.

When the operating point was far to the left hand side of the PPM, the value of dP/dV was very positive; the duty cycle was shortened rapidly to increase the voltage toward the PPM.

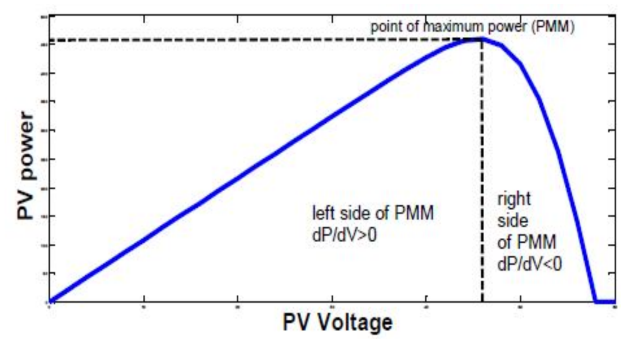

Fig.6 Description of the P&O method

When the operating point was close to the left hand side of the PPM, the value of dP/dV was positive but small, the duty cycle slowly decreased. When the operating point was the PPM, the value of dP/dV was zero, the duty cycle was kept constant, and there are no longer an oscillation anymore around the PPM is shown in Fig 7. There are three mains advantages to this method. By using only one input dP/dV, the structure of the proposed MPPT controller is simple.

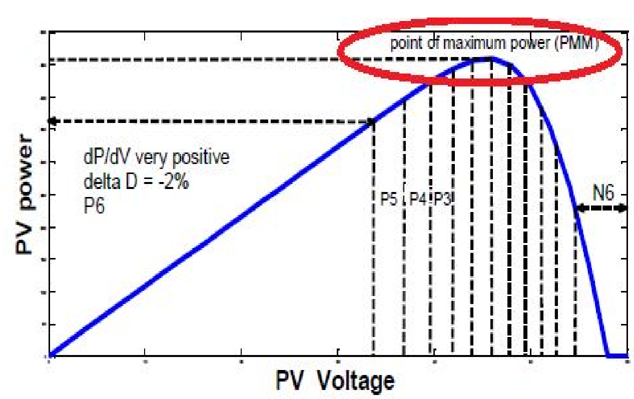

Fig.7 Description of the proposed method

The value of input dP/dV converges exactly to zero. And, it depends on the position of the operating point (near or far from the PPM): if it is near the value of output ΔD is small, if it is far the value of output ΔD is big. This improves the response time compared to using the traditional method P&O.

After the derivative dP/dV is calculated, it is converted into thirteen linguistic variables dP/dV = {N6, N5, N4, N3, N2, N1, Z, P1, P2, P3, P4, P5, P6}. The domain of the input dP/dV is set to be [-1; 1]. A coefficient k will be used to adapt to each level power of panel PV. The output ΔD was generated by thirteen value constants ΔD = {+2%, +0.2%, +0.1%, +0.01%, +0.006%, +0.005%, 0%, -0.005%, -0.006%, -0.01%, - 0.1%, -0.2%, -2%}.

V. RESULT AND DISSCUSSION

In order to verify the feasibility of our controller, insolation was modified, a resistive load 100 Ω was fixed, and another resistive load 100 Ω was switched. We tested our one input fuzzy logic controller in a number of cases during a long period of 25 seconds, and during a short period. In this case, we chosen Ns=3, Np=12. The coefficient k of MPPT controller was 1/9. The maximum power of PV panel at 900 W/m2 was 459.5 W. During a long period of 25 seconds, the insolation variation and load variation are varied and to verify the response of the proposed MPPT fuzzy logic controller.

During the first five seconds, the insolation was 800 W/m2 (the optimal voltage of PV panel was Vopt = 46.1 V, the maximum power of PV panel was Pmax = 410.1 W). Our MPPT controller increased voltage of PV panel (Vpv) from zero to Vopt that enabled maximum power extraction. It needed 0.2 seconds for our system to reach permanent regime. When the insolation was changed, there were small oscillations of dP/dV value from -0.3 to 0.3 during 0.5 seconds. This leads a small oscillation of PV panel power. After 0.5 seconds, the dP/dV value was controlled to zero. The operating point was reached exactly to the PPM. It proved the accuracy of our controller.

When the isolation was changed from 800 W/m2 to 300 W/m2 (from 5th second to 10th second), our MPPT controller decrease Vpv to 45.5 V to extract the maximum power. We found the same phenomenon under different insolation variation (increased de 300 W/m2 to 900 W/m2, then down to 400 W/m2, then increased to 700 W/m2). We noted that Vpv always followed the Vopt for each level of the insolation. Under a load variation at 3rd second, a load variation and an insolation variation at the same time 5th second, we noted that our controller always managed to keep Vpv around its optimal value. The duty cycle D of boost converter was changed to extract the maximum power. After reaching the PPM, the duty cycle was kept constant. So, there was not power oscillation around PPM. It proved the proper operating of our MPPT controller under the load variation and the insolation variation is shown in Fig 8.

At 5th, 10th, 15th, 20th, 25th second, when the insolation was changed, there were significant oscillations of the duty cycle D and of the input dP/dV. But, there were only small oscillations of PV panel power and PV panel voltage. It proved the stability of our controllers.

The simulations showed good results in terms of performance, robustness and flexibility of our MPPT controller. It always followed the PPM under variation of atmospheric condition and of the load. Under the rapid insolation variation, the simulations results show the power curve of PV panel, from 0.3s to 5s and from 0.2s to 5s, the power extracted is 99.9% of the maximal power. In this case, we chosen Ns=20, Np=30. The coefficient k of MPPT controller was 1/20.

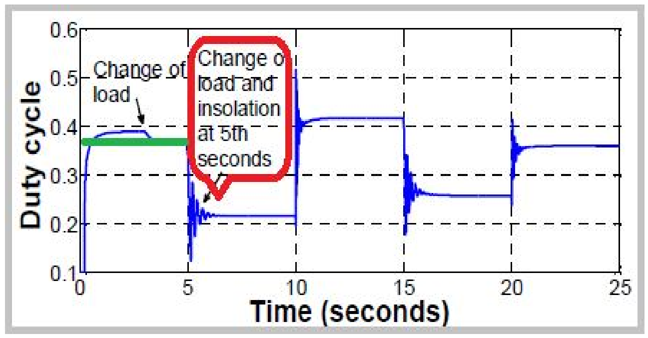

Fig.8 Duty cycle of boost converter

The same way in the PV system of small power, the simulation results in Fig. 9 show our MPPT controller operates very well under the variation of atmospheric condition and load in the PV system of high power.

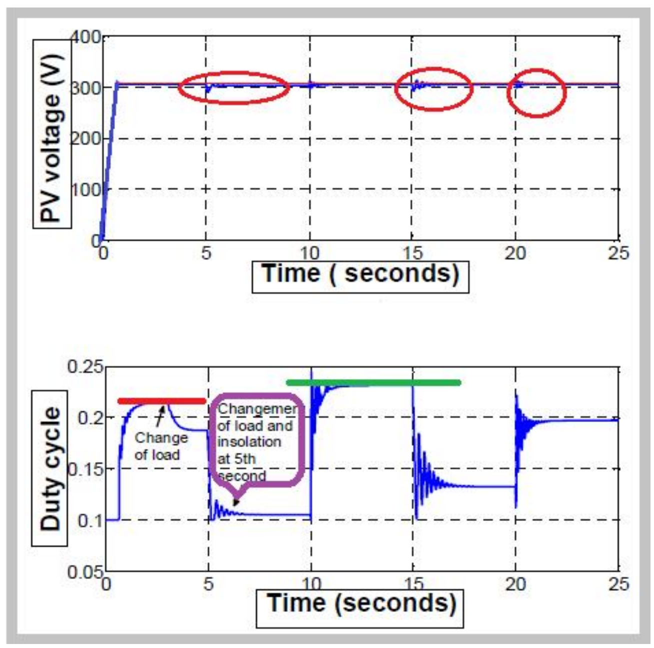

Fig.9 Voltage of PV panel and duty cycle of boost converter

To compare between on input MPPT fuzzy logic controller and two input ones. A simulation was performed with the same PV panel and the same resistive load during 50 seconds. The parameters of the proposed MPPT fuzzy logic controller were used in this paper. The simulations type is continuous. The two inputs ones were used. The simulation type was discrete, while there is a variation insolation and load, one input MPPT fuzzy logic controller work with a faster response time, more accurate, and more stable than two inputs one.

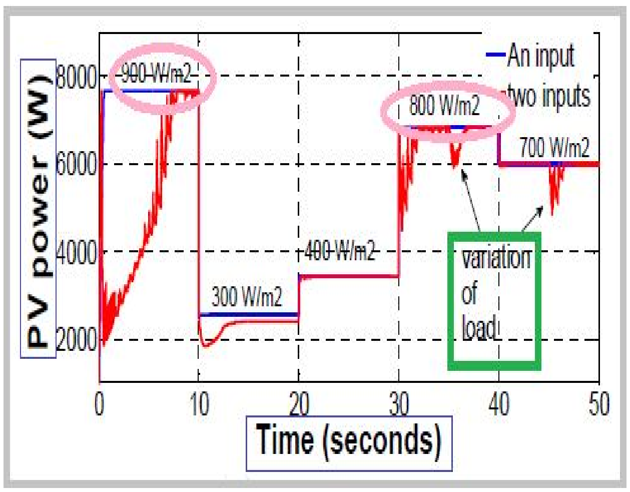

Fig.10 Power of PV panel

When the operating point reaches the PPM, there is any more oscillation in case of the one input MPPT. But, there is still a small oscillation in case of the two inputs MPPT is shown in Fig 10. In this simulation, we can conclude that one input MPPT fuzzy logic controller is better than two inputs one in terms of in terms of performance, robustness and flexibility.

VI.CONCLUSION

In this paper, a new simple one input MPPT fuzzy logic controller is presented. By using only one input dP/dV, the structure of the proposed MPPT controller is simple. The value of input dP/dV converges exactly to zero. And, it depends on the position of the operating point and if it is near the value of output ΔD is small, if it is far the value of output ΔD is big. Simulation results clearly showed that the one input MPPT fuzzy logic controller operated with fast time response, no overshoot, low oscillation, and was more stable with noise in the PV system as compared with two inputs MPPT fuzzy controller in. The proposed MPPT fuzzy logic controller also worked well at rapid insolation variations. Simulation results have shown that the proposed method outperforms the conventional method in terms of tracking performance under several different irradiance conditions, including various patterns for fuzzy logic.

REFERENCES

[1] A. Chel, G.N. Tiwari, A. Chandra, Simplified method of sizing and life cycle cost assessment of buildings integrated photovoltaic system, Energy and Buildings 41 (2009) 1172-1180.

[2] F. Blaabjerg, Z. Chen, S. Kjaer, Power electronics as efficient interface in dispersed power generation systems, IEEE Transactions on Power Electronics 19 (2004) 1184-1194.

[3] G. M. Master, Renewable and efficient electric power systems, A John Wiley & Sons, Inc., Publication, pp. 385-604, 2004.

[4] R. Faranda and S. Leva, "Energy comparison of MPPT techniques for PV systems", WSEAS Trans. Power Syst., vol. 3, iss. 6, pp. 446-455, 2008.

[5] Jose Rodriguez, Jih-Sheng Lai and Fang Zheng Peng "Multilevel Inverters: A Survey of Topologies, Controls, and Applications", IEEE transactions on industrial electronics, vol. 49, no. 4, pp. 724–738, august 2002

[6] M. Schneider, L. Moran and J. Dixon, "An active power filter implemented with a three-level NPC voltage-source inverter", 28th Annual IEEE Power Electronics Specialists Conference (PESC'97), Volume 2, 22-27 Oct. 1997, Page(s):1121 - 1126.

[7] Sun Hui, Zou Ji-yan and Li Wei-dong, "A novel active power filter using multilevel converter with self voltage balancing", IEEE Proceedings of International Conference on Power System Technology (PowerCon 2002),Volume 4, 13-17 Oct. 2002 Page(s):2275 - 2279.

[8] Bin Wu, High-Power Converters and AC Drives, IEEE Press and Wiley, 2006, pp 143-176.

[9] M.ValanRajkumar, P.S.Manoharan, Modeling and Simulation of Three-phase DCMLI using SVPWM for Photovoltaic System, Springer Lecture Notes in Electrical Engineering, under the volume titled "Power Electronics & Renewable Energy Systems", Volume 326, Chapter No 5, January 2015, Pages 39-45.

[10] M.ValanRajkumar, P.S.Manoharan, Harmonic Reduction of Fuzzy PI Controller based Three-Phase Seven-level DCMLI with SVPWM for Grid Connected Photovoltaic System, Journal International Review on Modeling and Simulations, Volume 6, No 3, June 2013, Pages 684-692.

[11] O. Vodyakho, T. Kim, S. Kwak, C.S. Edrington, "Comparison of the space vector current controls for shunt active power Filters" IET Power Electron., 2009, Vol. 2, Iss. 6, pp. 653–664

[12] A.Ravi, P.S.Manoharan, M.ValanRajkumar, "Harmonic Reduction of Three-Phase Multilevel Inverter for Grid

connected Photovoltaic System using Closed Loop Switching Control", Journal-IREMOS, Volume 5, No 5, October 2012, Pages 1934-1942. ISSN: 1974-9821 (Print), 1974-982X (Online)

[13] P.Thirumurugan, P.S.Manoharan, M.ValanRajkumar, "VLSI Based Inverter Switching Control" in the proceedings of International Conference on Mathematical Modeling and Applied Soft Computing MMASC'12 – Coimbatore Institute of Technology on July 2012, Vol-2 (Page):965-973.

[14] C.Hemalatha, M.Valan Rajkumar, G.Vidhya Krishnan, "Simulation and Analysis for MPPT Control with Modified firefly algorithm for photovoltaic system", International Journal of Innovative Studies in Sciences and Engineering Technology, Volume 2, No 11, Nov.2016, Pages 48-52.

[15] G.Vidhya Krishnan, M.Valan Rajkumar, C.Hemalatha, "Modeling and Simulation of 13-level Cascaded Hybrid Multilevel Inverter with less number of Switches", International Journal of Innovative Studies in Sciences and Engineering Technology, Volume 2, No 11, Nov.2016, Pages 43-47.

[16] M.ValanRajkumar, P.S.Manoharan, FPGA Based Multilevel Cascaded Inverters with SVPWM Algorithm for Photovoltaic system, Elsevier Journal Solar Energy, Volume 87, Issue 1, January 2013, Pages 229-245.

[17] M.ValanRajkumar, P.S.Manoharan, Space Vector Pulse Width Modulation of Three-Phase DCMLI with Neuro-Fuzzy MPPT for Photovoltaic System, World Journal of Modelling and Simulation, Volume 10, No 3, August 2014, Pages 193-205.

[18] Mansour Mohseni, and Syed M. Islam, "A New Vector-Based Hysteresis Current Control Scheme for Three-Phase PWM Voltage-Source Inverters", IEEE Transactions on Power Systems, vol.25,No.9,September-2010.

[19] M.Valan Rajkumar, Prakasam, P. and Manoharan, P.S. (2016) Investigational Validation of PV Based DCDMLI Using Simplified SVM Algorithm Utilizing FPGA Tied with Independent Sources. Circuits and Systems, Volume 7, No 11, 3831-3848. http://dx.doi.org/10.4236/cs.2016.711320

[20] P.Thirumurugan, P.S.Manoharan, M.ValanRajkumar, VLSI Based Space Vector Pulse Width Modulation Switching Control in the proceedings of IEEE International Conference on Advanced Communication Control and Computing Technologies ICACCCT 2012 on August 2012, ISBN No. 978-1-4673-2045-0 (Print) (Page):366-370.

[21] M.ValanRajkumar, P.S.Manoharan, "Modeling, Simulation and Harmonic Reduction of Three-Phase Multilevel Cascaded Inverters with SVPWM for Photovoltaic System", Journal International Review on Modeling and Simulations, Volume 6, No. 2, April 2013, Pages 342-350. ISSN: 1974-9821 (Print), 1974-982X (Online)

[22] Carlos Henrique da Silva, Rondineli R. Pereira, Luiz Eduardo Borges da Silva, Germano Lambert-Torres, João Onofre Pereira Pinto, and Se Un Ahn, "Dead-Time Compensation in Shunt Active Power Filters Using Fast Feedback Loop" IEEE conference, 2008.

[23] M.Valan Rajkumar, G.Ranjhitha, M.Pradeep, Mohammad Fasil PK, R.Sathishkumar, "Fuzzy based Speed Control of Brushless DC Motor fed Electric Vehicle", International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET), Volume: 3, Issue: 3, March 2017, Pages 12-17. ISSN: 2455-4863 (Online).

[24] M.Valan Rajkumar, J.Chandramohan, D.Aravind, M.Basker, "Performances Analysis of Power Factor Correction for PWM Control based Bridgeless Cuk Rectifier with Positive Output Voltage", International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 4, April 2017, Pages 116-121. ISSN: 2454-6410 (Online).

[25] K.Aswini, K.Nandhini, SR.Nandhini, G.Akalya, B.Rajeshkumar, M.Valan Rajkumar, "Simulation and Analysis of ASCAD Multilevel Inverter with SPWM for Photovoltaic System", International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET), Volume: 3, Issue: 4, April 2017, Pages 1-9. ISSN: 2455-4863 (Online).

[26] M.Valan Rajkumar, M.Mahakumar, M.Manojkumar, M.Hemaraj, E.Kumaravel, "Modelling and Analysis of DC-DC Converter with Various MPPT Algorithms for PV System", International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET), Volume: 3, Issue: 4, April 2017, Pages 17-22. ISSN: 2455-4863 (Online).

[27] M.Valan Rajkumar, T.Indumathi, "Analysis of Low Power Multi-core Embedded Management for Energy Harvesting", IOSR-Journal of Electrical and Electronics Engineering, Volume 12, Issue 2, Ver. II, March-April 2017, Pages 25-33. ISSN: 2320-3331 (Print) 2278-1676 (Online).

[28] A.Ravi, M.Valan Rajkumar, P.S.Manoharan, "Harmonic Reduction of Three-Phase Eleven-level DCMLI with Fuzzy MPPT for Grid Connected Photovoltaic System", International Journal of Applied Engineering Research (IJAER), Volume 10, No 2, 2015, Pages 3251-3268. ISSN: 0973-4562 (Print).

[29] A. Masaoud, P. Hew Wooi, S. Mekhilef, and A. S. Taallah, "New Three- Phase Multilevel Inverter With Reduced Number of Power Electronic Components,"

Power Electronics, IEEE Transactions on, vol. 29, no. 11, pp. 6018-6029, 2014.

[30] M.Valan Rajkumar, J.Karthikeyan, P.S.Manoharan, “Modeling and Simulation of Multiphase DCMLI with SVPWM for Photovoltaic System”, International Journal of Applied Engineering Research (IJAER), Special Issue: Volume 9, No 24, 2014, Pages 8477-8483. ISSN: 0973-4562 (Print).

[31] S. Yeongrack, and H. Jung-Ik, “Direct Power Control of a Three-Phase Inverter for Grid Input Current Shaping of a Single-Phase Diode Rectifier With a Small DC-Link Capacitor,” Power Electronics, IEEE Transactions on, vol. 30, no. 7, pp. 3794-3803, 2015.

[32] M.ValanRajkumar, P.S.Manoharan, “Modeling and Simulation of Five-level Five-phase Voltage Source Inverter for Photovoltaic Systems”, Journal PrzegladElektrotechniczny, Volume 10, No. 10, October 2013, Pages 237-241. ISSN: 0033-2097 (Print)

[33] T. Ghennam, E. M. Berkouk, and B. Francois, “A Novel Space-Vector Current Control Based on Circular Hysteresis Areas of a Three-Phase Neutral-Point-Clamped Inverter,” Industrial Electronics, IEEE Transactions on, vol. 57, no. 8, pp. 2669-2678, 2010.

[34] M.Valan Rajkumar, P.S.Manoharan, A.Ravi, “Simulation and an Experimental Investigation of SVPWM Technique on a Multilevel Voltage Source Inverter for Photovoltaic Systems”, Elsevier International Journal of Electrical Power and Energy Systems, Volume 52, Issue 9, November 2013, Pages 116-131. ISSN: 0142-0615 (Print), 1879-3517 (Online)

[35] SR.Nandhini, G.Akalya, K.Aswini, K.Nandhini, M.Valan Rajkumar, B.Rajeshkumar, “A New Topology of H-bridge based Multilevel Inverter for PV System with Reduced Switches”, International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 4, April 2017, Pages 60-68. ISSN: 2454-6410 (Online).

[36] M.Valan Rajkumar, M.Mahakumar, M.Manojkumar, M.Hemaraj, E.Kumaravel, “A New DC-DC Converter Topology with Grey Wolf MPPT Algorithm for Photovoltaic System”, International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 4, April 2017, Pages 54-59. ISSN: 2454-6410 (Online).

[37] L.Malliga, K.Bommannaraja, M.Valan Rajkumar, “Investigation of FCM based Image Retrievel-Segmentation on Human Computational Intelligent Systems”, International Journal of Applied Engineering Research (IJAER), Special Issue: Volume 10, No 12, 2015, Pages 10769-10774. ISSN: 0973-4562 (Print).

[38] U.Suresh Kumar, P.S.Manoharan, M.Valan Rajkumar, “Feasibility Sensitivity Analysis in Potential Area for Standalone Hybrid Renewable Energy in Tamil Nadu, India”, Applied Mechanics and Materials Journal, under the volume titled “Advancements in Automation and Control Technologies", Volume 573, June 2014, Pages 757-766. ISSN: 1660-9336 (Print), ISBN-13: 978-3-03835-124-5 (Online).

[39] C.Hemalatha, M.Valan Rajkumar, M.Gayathri, “IOT Based Building Monitoring System Using GSM Technique”, IOSR-Journal of Electronics and Communication Engineering (IOSR-JECE), Volume 12, Issue 2, Ver. III, March-April 2017, Pages 68-75. ISSN: 2278-8735 (Print) 2278-2834 (Online).

[40] S.Rashini, P.S.Manoharan, M.Valan Rajkumar, “Interfacing PV system to the Utility Grid using a Voltage Source Inverter”, Journal of Emerging Technologies Electrical Engineering, Special Issue- ICBDM 2013, Volume 1, No 1, March 2013, Pages 124-129. ISSN: 0973-2993 (Print)

[41] S.Sathyaraj, M.Valan Rajkumar, J.Chandramohan, “Modeling and Simulation of Asymmetric Cascaded Multilevel Inverter with Reduced Switches using Multicarrier PWM Control”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE), Volume 5, Issue 10, October 2016, Pages 8064-8071. ISSN: 2320-3765 (Print), 2278-8875 (Online)

[42] G.Ranjhitha, M.Valan Rajkumar, “Implementation of Genetic Algorithm based Maximum Power Point Tracking for Photovoltaic System”, International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), Volume 5, Issue 11, November 2016, Pages 18860-18868. ISSN: 2347-6710 (Print), 2319-8753 (Online)

[43] S.Sathishkumar, M.Valan Rajkumar, R.Yuvaraj, “Modeling and Analysis of Soft-Switched Interleaved Boost Converter for Photovoltaic System”, International Journal for Science and Advance Research in Technology (IJSART), Volume 2, Issue 11, November 2016, Pages 43-48. ISSN: 2395-1052 (Online)

[44] M.Sundaraperumal, M.Valan Rajkumar, A.Venkatesh, “Modeling and Analysis of Current Source Multilevel Inverter using PI Controllers with Multicarrier PWM Technique”, International Journal for Science and Advance Research in Technology (IJSART), Volume 2, Issue 11, November 2016, Pages 275-280. ISSN: 2395-1052 (Online)

[45] R.Yuvaraj, S.Sathishkumar, M.Valan Rajkumar, “Analysis of PV based Soft Switching Boost DC-DC Converter with Zero Current Switching Technique”, International Journal of Advanced Research in Management, Architecture, Technology and Engineering

(IJARMATE), Volume 2, Issue 12, December 2016 Pages 1-5. ISSN: 2454-9762 (Print) 2454-9762 (Online)

[46] M.Valan Rajkumar, M.Mahakumar, M.Manojkumar, M.Hemaraj, E.Kumaravel, “A New MPPT design using Grey Wolf Optimization Techniques with DC-DC Converter for PV System”, International Journal for Science and Advance Research in Technology (IJSART), Volume 3, Issue 3, March 2017, Pages 829-835. ISSN: 2395-1052 (Online)

[47] K.Nandhini, SR.Nandhini, G.Akalya, K.Aswini, M.Valan Rajkumar, B.Rajeshkumar, “Implementation of 21-level Asymmetrical Cascaded Multilevel Inverter with Reducing Number of Switches”, International Journal for Science and Advance Research in Technology (IJSART), Volume 3, Issue 3, March 2017, Pages 809-818. ISSN: 2395-1052 (Online)

[48] S.Sathishkumar, M.Valan Rajkumar, S.Vinothkumar, M.Maruthamuthu, A.Sounder, A.Kumaresan, “A New Design for DC-DC Converter Topology with MISO for Renewable Energy Resources”, International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 4, April 2017, Pages 143-149. ISSN: 2454-6410 (Online)

[49] M.Valan Rajkumar, M.Mahakumar, M.Manojkumar, M.Hemaraj, E.Kumaravel, “Implementation of Various MPPT Algorithms with SEPIC Converter for PV System”, International Journal of Engineering Research & Technology-Special Issue 2017, Volume 5, Issue 13, 2017, Pages 589-593. ISSN: 2278-0181 (Print)

[50] G.Akalya, K.Aswini, K.Nandhini, SR.Nandhini, M.Valan Rajkumar, B.Rajeshkumar, “Modelling and Analysis of Multilevel Inverter for Photovoltaic System”, International Journal of Advanced Research Methodology in Engineering & Technology (IJARMET), Volume 1, Issue 3, May 2017, Pages 36-43. ISSN: 2456-6446 (Online)

[51] Mohammad Fasail PK, M.Pradeep, R.Sathishkumar, G.Ranjhitha, M.Valan Rajkumar, “Speed Control BLDC Motor using Fuzzy Logic and PID Controller fed Electric Vehicle”, South Asian Journal of Engineering and Technology, Volume 3, Issue 3, March 2017, Pages 118-131. ISSN: 2454-9614 (Print)

[52] Y. Hao, Z. Fang, Z. Yanjun, L. Yu, Z. Wenda, C. Wenjie, and L. Jinjun, “A Source-Current-Detected Shunt Active Power Filter Control Scheme Based on Vector Resonant Controller,” Industry Applications, IEEE Transactions on, vol. 50, no. 3, pp. 1953-1965, 2014.

[53] A. Nabae, I. Takahashi, and H. Akagi, “A New Neutral-Point-Clamped PWM Inverter,” Industry Applications, IEEE Transactions on, vol. IA- 17, no. 5, pp. 518-523, 1981.

[54] G.Vidhya Krishnan, M.Valan Rajkumar, D.Umakirthika, “Role of Internet of Things in Smart Passenger Cars”, International Journal of Engineering And Computer Science (IJECS), Volume: 6, Issue: 5, May 2017, Pages 21410-21417. ISSN: 2319-7242 (Online).

[55] M.Valan Rajkumar, T.Indumathi, “Performance Analysis of PV based Low Power Multi-Core Embedded Management using Wireless Communication System”, International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 5, May 2017, Pages 129-136. ISSN: 2454-6410 (Online).

[56] C.Hemalatha, M.Valan Rajkumar, M.Gayathri, “Performance Analysis of IoT based Secured Smart Building Monitoring System Interface using GSM Technique”, International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 5, May 2017, Pages 141-147. ISSN: 2454-6410 (Online).

[57] [24] K. Ishaque, Z. Salam, H. Taheri, A. Shamsudin, “A critical evaluation of EA computational methods for Photovoltaic cell parameter extraction based on two diode model”, Solar Energy, vol 85 ,pp.1768-1779,2011.

[58] E. Ott, C. Grebogi, and J. A. Yorke, “Controlling chaos,” Physical Review Letters, vol. 64, no. 11, pp. 1196–1199, 1990.

[59] L. Liu, Z. Han, and Z. Fu, “Non-fragile sliding mode control of uncertain chaotic systems,” Journal of Control Science and Engineering, vol. 2011, Article ID 859159, 6 pages, 2011.

[60] E. N. Lorenz, “Deterministic non periodic flow,” Journal of the Atmospheric Sciences, vol. 20, no. 11, pp. 131–141, 1963.

[61] V. Pediroda, L. Parussini, C. Poloni, S. Parashar, N. Fateh, and M. Poian, “Efficient stochastic optimization using chaos collocation method with mode frontier,” SAE International Journal of Materials and Manufacturing, vol. 1, no. 1, pp. 747–753, 2009.

[62] Y.Huang, P. Zhang, andW. Zhao, “Novel grid multiwing butterfly chaotic attractors and their circuit design,” IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 62, no. 5, pp. 496–500, 2015.

[63] X. H. Mai, D. Q. Wei, B. Zhang, and X. S. Luo, “Controlling chaos in complex motor networks by environment,” IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 62, no. 6, pp. 603–607, 2015.

[64] Z.Wang, J. Chen, M. Cheng, and K. T. Chau, “Field-oriented control and direct torque control for paralleled VSIs Fed PMSM drives with variable switching frequencies,” IEEE Transactions on Power Electronics, vol. 31, no. 3, pp. 2417–2428, 2016.

[65] J. D. Morcillo, D. Burbano, and F. Angulo, “Adaptive ramp technique for controlling chaos and sub harmonic oscillations in DC-DC power converters,” IEEE Transactions on Power Electronics, vol. 31, no. 7, pp. 5330–5343, 2016.
[66] G. Kaddoum and F. Shokraneh, “Analog network coding for multi-user multi-carrier differential chaos shift keying communication system,” IEEE Transactions on Wireless Communications, vol. 14, no. 3, pp. 1492–1505, 2015.
[67] J. M. Valenzuela, “Adaptive anti control of chaos for robot manipulators with experimental evaluations,” Communications in Nonlinear Science and Numerical Simulation, vol. 18,no. 1, pp. 1–11, 2013.
[68] Y. Feng,G.-F. Teng,A.-X.Wang, and Y.-M. Yao, “Chaotic inertia weight in particle swarm optimization,” in Proceedings of the 2nd International Conference on Innovative Computing, Information and Control (ICICIC ’07), p. 475, Kumamoto, Japan, September 2007.