ISSN ONLINE: 2395-695X
ISSN PRINT: 2395-695X

International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.3, Special Issue.20, December 2016

SEPIC converter based grid connected Hybrid energy system by using FLC Technique

[1]A.John Britto, [2]R.Pandiyan
Assistant Professor, Department of Electrical and Electronics Engineering, [1, 2]
Annai College of Engineering and Technology, Kumbakonam, Tamilnadu, India [1]
St.Joseph's college of Engineering and Technology, Thanjavur, Tamilnadu, India [2]
Email: {[1]electricalbrito, [2]pandiya27}@gmail.com

***Abstract*— this paper deals with the SEPIC converter based renewable energy systems by using fuzzy logic technique. These renewable energy resources should provide constant power to the load according to the load requirement. This paper proposed the hybrid system of solar and fuel cell energy fed single phase three level inverter. The hybrid energy system is the combination of fuel cells and solar panels. The green energy is generated from the photovoltaic panel and the chemical energy is converted into electrical energy by fuel cells. The generated voltages are filtered and boosted by Single Ended Primary Inductor converter (SEPIC). The SEPIC converter provides constant DC voltage to the single phase three level inverter. The fuzzy logic control (FLC) based maximum power point tracking algorithm is used to extract the maximum power from the hybrid energy system. The PI controller makes the inverter output voltage is equal to the grid voltage. These control techniques reduces the grid connected issues by taking the reference as reactive power in the grid. The results are verified through MATLAB/Simulink.**

***Index terms*- Fuzzy logic control, SEPIC converter, Renewable Energy Source, THD, PWM pulse.**

I. INTRODUCTION

The renewable energy resources are naturally available and environmentally pollution less sources. A hybrid energy system is the combination of two or more very good naturally optional renewable energy sources. These hybrid energy resources are becoming easily available in remote areas [1]. In this paper the photovoltaic system and fuel cells are combined to form the hybrid energy system. The wind energy is capable to give larger power but the initial and maintenance cost is high. The solar energy is present throughout the day but radiation levels are vary due to intensity, clouds and trees. The fuel cells are provide constant power throughout the time from the various chemicals. The combined power sources makes the system efficiency as too high [2].

When the sources are unavailable or very less when meeting the load demands it requires another power source. In this project the SEPIC converter makes the constant power to the inverter [15]. This Single Ended Primary Inductor converter is the DC-DC converter which works as the second order filter that has reduce the ripples from the hybrid energy sources also the boost inductances will store the energy[4]. This second order filter makes the double frequency suppression in the DC source. The boost converter can able to do these function but in this boost converter the boost ratio is less, at the same time the energy stored in the inductance is very less compared to the SEPIC converter.

The load requires AC voltage, so the next step is DC voltage has converted into AC voltage [3]. In these three level inverter, the total harmonics distortion level in the voltage and currents are high. The PI controller and LC filter makes the three level voltage into sinusoidal output voltage, this voltage is connected to the grid [5], [7]. This PI controller compensates the reactive power and provides sufficient active power to the grid. For this SEPIC converter requires MPPT algorithm is very important [6].

As compared to previous MPPT algorithm like perturb & observe algorithm, incremental conductance algorithm, hills clamping the proposed fuzzy logic algorithm extracts maximum power from the hybrid energy system[8], [9].

II. SEPIC CONVERTER

SEPIC converter is the Single-ended primary-inductor converter (SEPIC) is a type of chopper that has two inductors L_1 & L_2. Capacitors C_1&C_2 the diode D will protect the source from back emf. Similar to the buck boost converter it will do both buck and boost operation [10], [11]. The series inductor L_1 will provides continuous input current, when the duty cycle is less than 0.5, it will works in discontinuous mode that means buck mode so that the output voltage is less than input voltage [12]. When the duty cycle is greater than 0.5, it is in continuous mode that means boost mode. So that output voltage is greater than input voltage.

ISSN ONLINE: 2395-695X
ISSN PRINT: 2395-695X

International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.3, Special Issue.20, December 2016

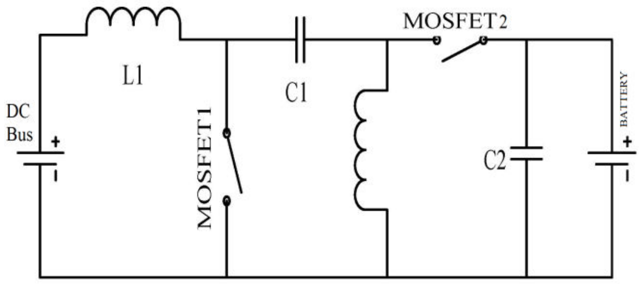

Fig 1. Circuit diagram of SEPIC Converter

The PWM pulse is control the output of the SEPIC converter. In this SEPIC converter the output voltage is none inverted so that it overcomes the drawbacks of buck boost and Cuk converter [12], [14]. Christo Ananth et al. [13] presented a brief outline on Electronic Devices and Circuits which forms the basis of the Clampers and Diodes. The input power factor becomes unity due to this continuous input current. The SEPIC converter have internal protection that has provided by the diode D, so it does not require any snubbed protection [16].

III. PROPOSED SYSTEM OPERATION

The block diagram shows the solar and fuel cell based hybrid energy system with SEPIC converter. The output from the solar panel is directly connected to the SEPIC converter, another fuel cell outputs are connected in parallel with the source from the solar energy. That means hybrid energy sources may be connected in series are parallel. This multi input voltage is connected to the SEPIC converter, it will work as a second order filter and reduce the ripple contents. The main advantage of the SEPIC converter is for double frequency suppression effect in the DC voltage.

Here the energy sources may provide supply to the SEPIC converter individually or combine. The fuel cell energy is connected to the SEPIC converter through diode, this will protect the fuel cell from the return current of the SEPIC converter. The inductor and capacitor that has available in the SEPIC converter will store the energy and this converter provide the continuous input current to the grid, so that reactive power has reduced. This variable boosted DC output voltage is given to the three level inverter. The reference voltage and currents are generated from the fuzzy logic algorithm and the mppt pwm pulses has produced. This pulses width has been automatically adjusted by fuzzy logic control technique.

Fuzzy logic based maximum power point tracking method extracts the maximum power from the hybrid energy sources, it will provide constant voltage to the inverter. The switching frequency of the carrier signal that has used in the PWM technique is 10 KHz.

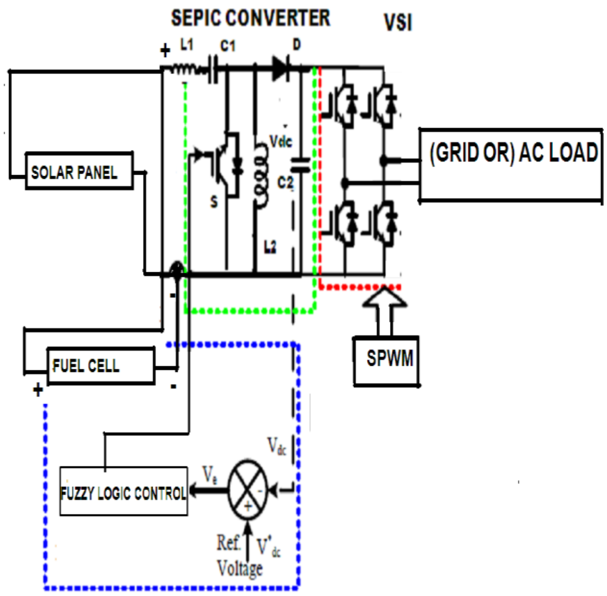

Fig 2. Proposed system

The three level inverter has four devices S1, S2, S3, and S4. The switches S1 & S2 are turned ON for positive cycle, S3 & S4 are turned ON for negative cycle. The mode of operation is 180 degree conduction mode. To avoid the short circuit problems 4micro seconds dead band has provided in the PWM pulses. The grid voltages and currents are

ISSN ONLINE: 2395-695X
ISSN PRINT: 2395-695X

International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.3, Special Issue.20, December 2016

taken to calculate the real and reactive power. From this reactive power the comparator compares the actual and the reference grid voltages and current. This error signal has fed to the PI controller, the controller produce the reference sinusoidal signal that is compared with the carrier signal which has 10KHz switching frequency. These PWM pulses are fed to the three level voltage source inverter. This inverter will give AC output voltage to the grid.

The PI controller makes reactive power compensation, so that the power quality issues like sag, swell and harmonics problem has reduced at point of common connection in the grid.

a. Low output voltage

The output voltage of the SEPIC converter can be lower than the input voltage. In this mode the duty cycle is less than 0.5 sec that means the converter is in discontinuous mode. Slowly the inductor current L_1 comes to zero. The capacitor voltage C1 is lower than input voltage Vg.

In this mode the current through the inductor L_1 is

$$\Delta IL1 = \frac{V0}{L1}(0.5 - D)T \quad \text{--- (1)}$$

$$\frac{dIL1}{dt} = (Vg + kV0)/(1-k^2)L1 \quad \text{--- (2)}$$

$$\frac{dIL2}{dt} = -(V0 + kVg)/(1-k^2)L2 \quad \text{--- (3)}$$

Where K is the winding constant.
D is the PWM duty cycle of the SEPIC converter.
T is the total time of the PWM pulse.

From the above equation the inductor current is decreasing. Therefore the SEPIC converter output voltage will decrease. It is the buck mode.

a. Higher output voltage

In this mode the duty cycle is comes to more than 0.5, it is the boost mode. Here the inductor current IL_1 and IL_2 is keeps on increasing.

$$\frac{dIL1}{dt} = Vg/(1+k)L1 \quad \text{--- (4)}$$

$$\frac{dIL2}{dt} = Vg/(1+k)L2 \quad \text{--- (5)}$$

The capacitor voltage C_1 is equal to the input DC voltage Vg. The change in inductor current can be expressed as,

$$\Delta IL1 = \frac{V0}{L1}(D - D')T \quad \text{--- (6)}$$

Due to this inductor current the output voltage becomes high.

IV. MPPT ALGORITHM

To extract the maximum power from the solar array and wind energy, and to track the changes due to environment, maximum power point tracking should be implemented. The hill climbing mppt method involves moving the operating voltage by one step and then examining the change in generated power. If the power increases, the operating point moves in the same direction; otherwise it moves in the opposite direction. The wind power system design must optimize the annual energy capture at a given site. The only operating mode for extracting the maximum energy is to vary the turbine speed with varying wind speed such that at all times the TSR is continuously equal to that required for the maximum power coefficient. The power generated from a given PV module mainly depends on solar irradiance and temperature for a system without MPPT, the voltage will quickly collapse to zero. A system with MPPT avoids the voltage collapse by keeping the operating point near the Maximum Power Point. The advantages of MPPT algorithm are robustness and the easy to implement.

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The fish system is shown in figure 1. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves membership functions, fuzzy logic operators, and if-then rules. Two types of fuzzy inference systems that can be implemented in the Fuzzy Logic Toolbox are,

- Mamdani type
- Sugeno type

ISSN ONLINE: 2395-695X
ISSN PRINT: 2395-695X

International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.3, Special Issue.20, December 2016

Mamdani type inference expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. It is possible, and in many cases much more efficient, to use a single spike as the output member ship functions rather than a distributed fuzzy set. This type of output is sometimes known as a singleton output membership function, and it can be thought of as a pre-defuzzified fuzzy set. It enhances the efficiency of the defuzzification process because it greatly simplifies the computation required by the more general Mamdani method, which finds the centroid of a two-dimensional function. Rather than integrating across the two-dimensional function to find the centroid, we use the weighted average of a few data points. Sugeno-type systems support this type of model. In general, Sugeno-type systems can be used to model any inference system in which the output membership functions are either linear or constant.

a. Basic Fuzzy Algorithm

In a fuzzy controller as shown in figure 3, the control action is determined from the evaluation of a simple linguist rules. The development of the rules requires a thorough understanding of the process to be controlled but it does not require a mathematical model of the system A fuzzy controller consists of fourth stages: fuzzification, knowledge base, inference mechanisms, and defuzzification.

In order to implement the control algorithm of a SAPF in closed loop, the optimum value of K gain is calculated by a fuzzy inference system, which receives as inputs the slope of D.C. average bus voltage and D.C. voltage error. Both quantities (error and slope of DC voltage) are normalized by suitable values. Thus, each range is between -1 and 1 normalized unity. Taking into account that the value of K is quite near unity, we consider the range of the output weight membership function between 0.6 and 1.4.We have chosen to characterize this fuzzy controller by seven and five sets respectively for the error and slope inputs. The output is defined by seven sets. The D.C. voltage error normalized, the D.C. voltage slope normalized and the output weight membership functions are shown in figure 3. The linguistic rules for the fuzzy logic controller are chosen, in most cases, depending only of the D.C. voltage error.

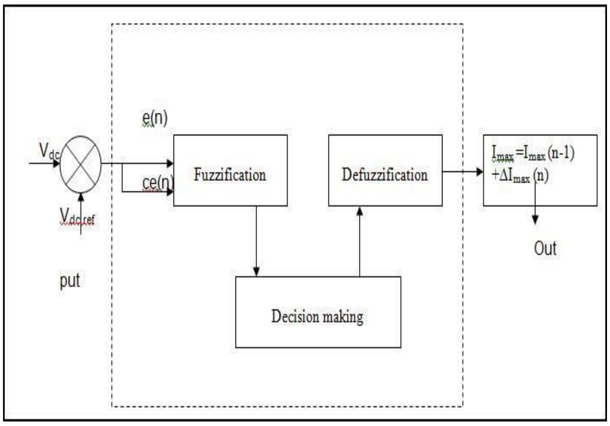

Fig 3. Schematic Diagram of FLC

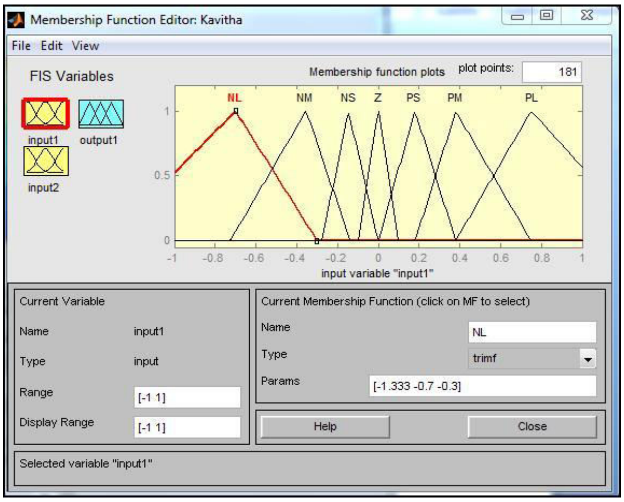

Fig 4. Triangular membership function of FLC

ISSN ONLINE: 2395-695X
ISSN PRINT: 2395-695X

International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.3, Special Issue.20, December 2016

The desired switching signals, according to output inverter currents to follow the reference ones, a current control is made by fuzzy logic controller. The inputs variables for the necessary control action of active filter are the error and the rate change of error between the reference signal and the active filter output current. The membership functions are showed in figure 2. The current control method used in this thesis is related to fuzzy controller based PWM current controller. The switching signals are generated by means of comparing a carrier signal with the output of the fuzzy controller. The error ‘e’ and the change of error ‘cue’ are used as numerical variables from the real system. To convert these numerical variables into linguist variables, the following seven fuzzy sets are used: NL (Negative Large), NM (Negative Medium), NS (Negative Small), Z (zero), PS (Positive Small), PM (positive medium) and PL (Positive Large).

- Seven fuzzy sets for each input and output
- Triangular membership functions for simplicity
- Fuzzification using continuous universe of discourse
- Implication using Mamdani type inference system
- Defuzzification using weighted average method

b. Design of Control Rules

The fuzzy control rule design involves defining rules that relate the input variables to the output model properties as FLC is independent of the system model. The design is mainly based on the intuitive feeling for and experience of the process.

The three level inverter will convert the DC voltage into AC voltage by sinusoidal PWM technique with 4 micro second dead band. The carrier signal frequency is 10 KHz. The PI controller makes the inverter output voltage as same as the grid voltage. Due to this the reactive power has compensated in the grid. The SEPIC converter maximum duty cycle is 80%.

V. SIMULATION RESULTS

The below figure 5 shows the proposed topology of hybrid energy system has been simulated via MATLAB Simulink software rather than conventional method.

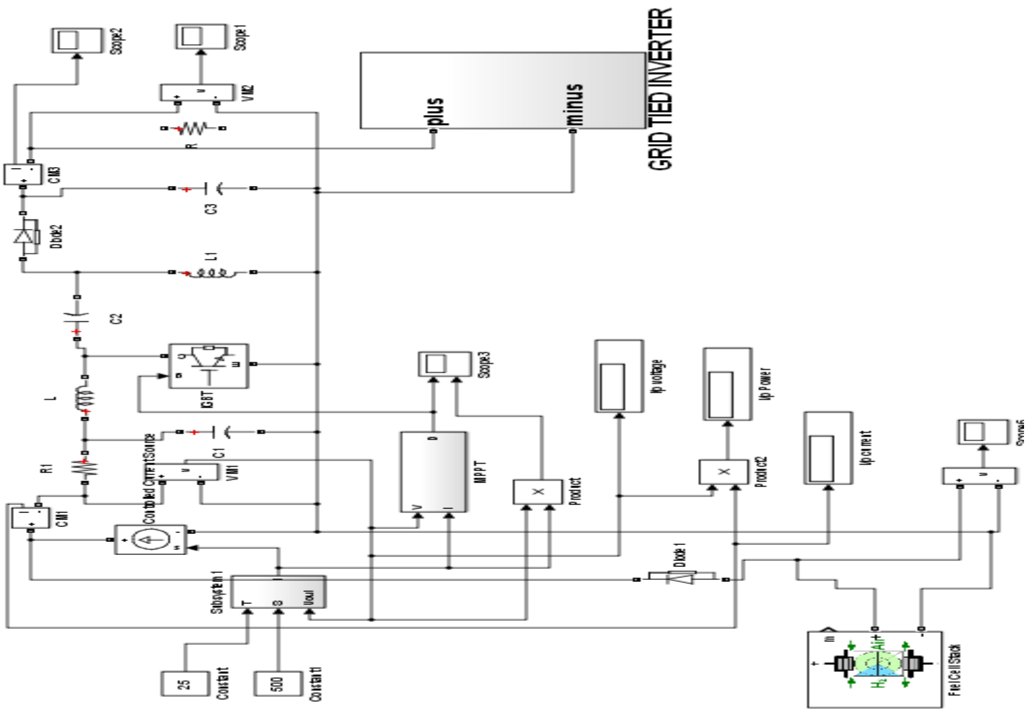

Fig.5. Proposed Simulink model

ISSN ONLINE: 2395-695X
ISSN PRINT: 2395-695X

International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.3, Special Issue.20, December 2016

The fig 6 graph shows the input voltage of SEPIC converter with time plotted in second in x axis and voltage in volt in y axis. Initially the voltage is above the 70 volt in 0 to 0.2sec after that to reach the steady state period to reach 70 volt as an input voltage of SEPIC converter.

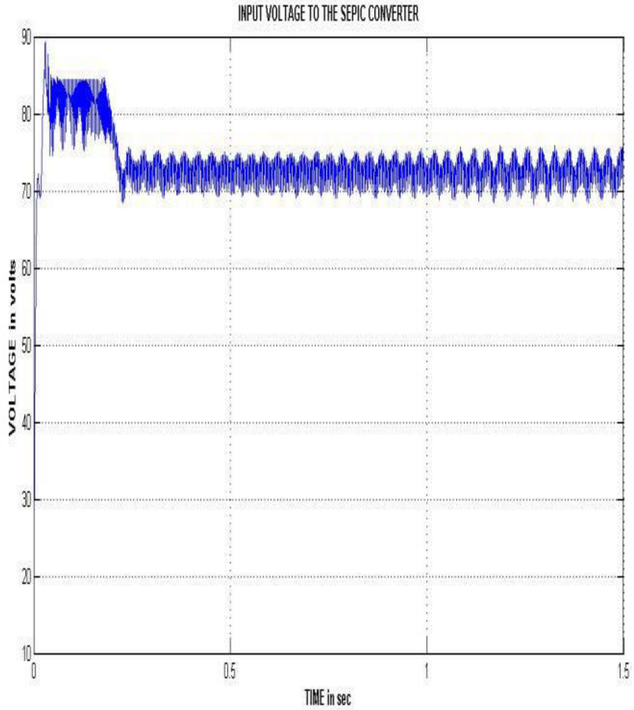

Fig.6 Input voltage of SEPIC converter

The figure 7 graph shows the gate pulse of SEPIC converter with time plotted in second in x axis and gate voltage in volt in y axis. The gate voltage of the SEPIC converter is 1 volt and passing through the IGBT.

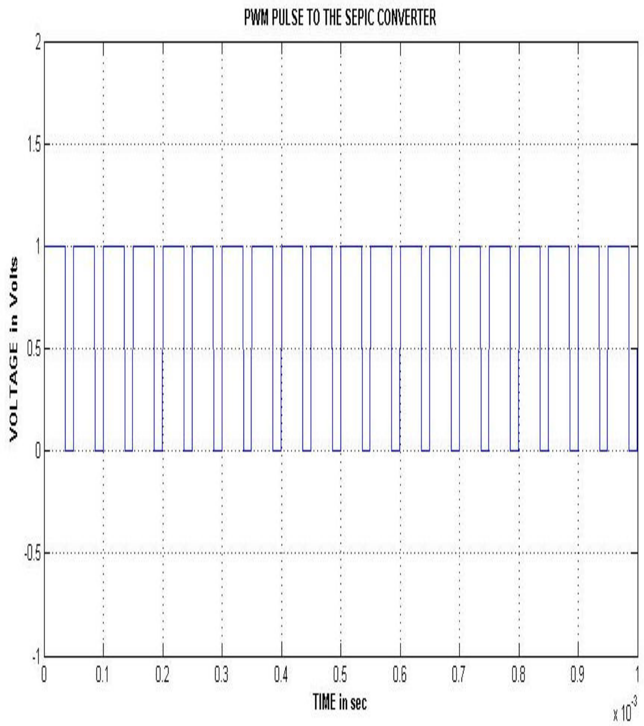

Fig.7. Gate pulse of SEPIC converter

ISSN ONLINE: 2395-695X
ISSN PRINT: 2395-695X

International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.3, Special Issue.20, December 2016

The figure 8 graph shows the output voltage of SEPIC converter with time plotted in second in x axis and output voltage in volt in y axis. The output voltage of the SEPIC converter is 798 V and settling time is 1 second.

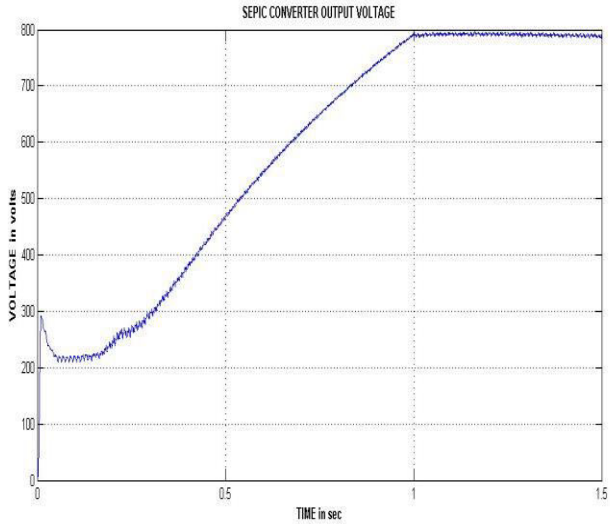

Fig.8. Output voltage of proposed SEPIC converter

The figure 9 graph shows the gate pulse of voltage Source Inverter (VSI) with time plotted in second in x axis and gate voltage in volt in y axis. The gate voltage of the SEPIC converter is 1 volt and passing through the Grid tied inverter.

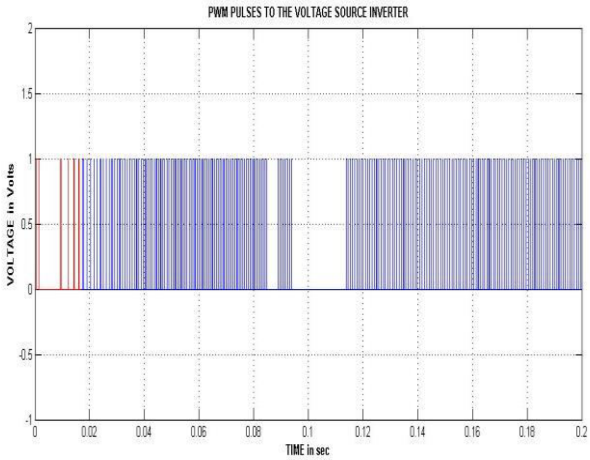

Fig.9. Gate pulse of voltage source inverter

The figure 10 graph shows the output voltage of grid connected inverter with time plotted in second in x axis and output voltage in volt in y axis. The output voltage of the grid tied inverter is 230 volt

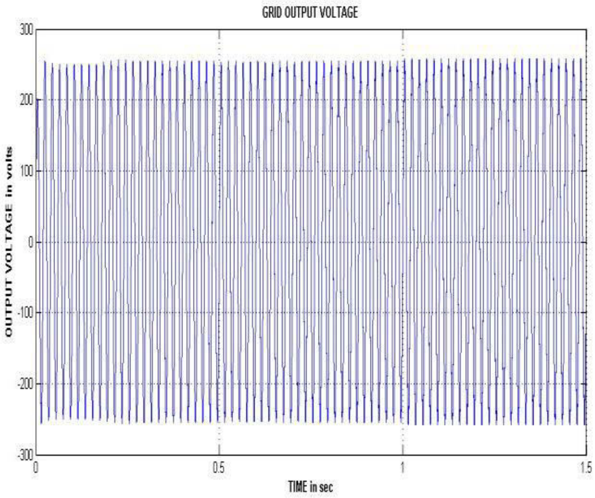

Fig.10. Grid tied iinverter output voltage

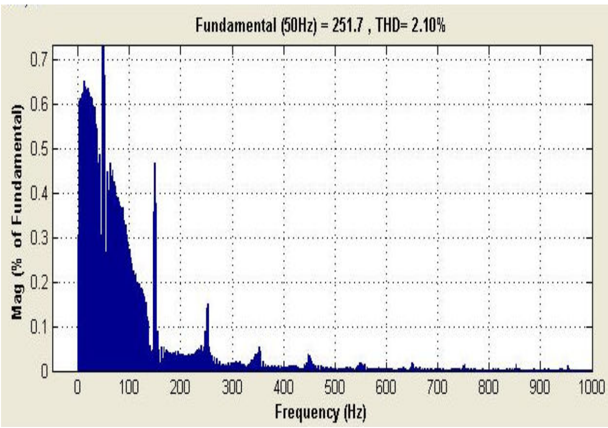

Fig.11. Inverter output voltage THD result

The figure 11 shows the Total harmonics distortion of grid connected inverter, the total harmonics distortion of SEPIC converter is 2.1%. By using SEPIC converter will reduce THD by providing constant voltage to the grid connected system.

VI. CONCLUSIONS

This paper has presented the fuzzy logic based hybrid energy system with SEPIC converter. The proposed SEPIC converter has provides constant DC voltage to the single phase three level inverter. The fuzzy logic control based maximum power point tracking algorithm is used to extract the maximum power from the hybrid energy system. The PI controller makes the inverter output voltage is equal to the grid voltage. The proposed system techniques to reduces the grid connected issues like power disturbance, total harmonics etc. This system has lower operating cost and finds applications in remote area power generation, constant speed and variable speed energy conversion systems and rural electrification. The performance of the line side and grid side output voltage is maintain and the inverter output voltage of total harmonics distortion is 2.1%.

REFERENCES

[1] A. Bakhshai et al., (2010) 'A Hybrid Wind – Solar Energy System: A New Rectifier Stage Topology', IEEE Magazine.
[2] B. Singh, B. N. Singh, A. Chandra, K. Al-Haddad, A. Pandey, and D. P. Kothari, (2003) 'A Review of Single-Phase Improved Power Quality AC-DC Converters', IEEE Transactions on Industrial Electronics, Vol. 50, Nº 5, pp. 962-981.
[3] C. M. C. Duarte and I. Barbi, (1998) 'A New ZVS-PWM Active-Clamping High Power Factor Rectifier: Analysis, Design and Experimentation', Applied Power Electronics Conference and Exposition (APEC), pp. 230-236 v1.
[4] C. Xiao and K. M. Medley, (2001) 'A topology survey of single-stage power factor corrector with a boost type input current-shaper', IEEE Trans. Power Electron., vol. 16, no.3, pp. 360–368.

[5] C. Xiao and K. M. Medley, (2001), 'A Universal Input Single- Phase Single-Stage Power Supply with Power Factor Correction and Automatic Voltage Clamping', Power Electronics Specialist Conference, (PESC), pp. 907-913.

[6] D. D. C. Lu, H. H. C. I, and V. Pjevalica, (2008) 'A Single- Stage AC/DC Converter with High Power Factor, Regulated Bus Voltage, and Output Voltage', IEEE Transactions on Power Electronics, Vol. 23, No.1, pp. 218-228.

[7] D. Xue, L. Kang, L. Chang, B. Cao, (2005) 'Optimal sizing of standalone hybrid wind/PV power systems using genetic algorithms', Proc. Canadian Conference on Electrical and Computer Engineering, pp. 1722- 1725 .

[8] Habib M.A., Said S.A. M., EI-Heidy M.A. and AIZaharna (1999). Optimization of hybrid photovoltaic wind energy system. Vol. 24,929.

[9] Hempen, W. Kleinkauf, U. kernel, (1992) PV –Module with Integrated Power Conditioning Unit, 11^{th} eves, Monteux, Switzerland, 1080-1083

[10] J. Chen, D. Maksimovic and R. W. Erickson 'Analysis and Design of a Low-Stress Buck-Boost Converter in Universal-Input PFC Applications', IEEE Transactions on Power Electronics, Vol. 21, Nº 2, pp. 320- 329.

[11]Jing quant (2006)'A New Low-Stress Buck-Boost Converter for Universal-Input PFC Applications', IEEE Transactions on Power Electronics, Vol. 53, No.10, pp. 2274-2286.

[12] Priscila F.de Melon (1998), 'Modified SEPIC Converter for High Power Factor Rectifier and Universal-Input Voltage Applications', IEEE Transaction on Power Electronics, Vol. 13, No.4, pp. 699-705.

[13] Christo Ananth, W. Stalin Jacob, Jenifer Darling Rosita. "A Brief Outline on ELECTRONIC DEVICES & CIRCUITS.", ACES Publishers, Tirunelveli, India, ISBN: 978-81-910-747-7-2, Volume 3, April 2016, pp: 1-300.

[14] J. Zhang1, M. M. Jovanovich, and F. C. Lee (1999), 'Comparison between CCM Single-Stage and Two-Stage Boost PFC Converters', Applied Power Electronics Conference and Exposition (APEC).

[15] K. M. Smith Jr. and K. Ma Medley, (2001), 'Engineering Design of Lossless Passive Soft Switching Methods for PWM Converters—Part I: With Minimum Voltage Stress Circuit Cells', IEEE Transactions on Power Electronics, Vol. 16, Nº 3, pp. 336-344.

[16] L. Huber and M. M. Jovanovich(1997), "Single stage single switch isolated power supply technique with input current shaping and fast output voltage regulation for universal input voltage range applications," in Proc. IEEE Applied Power Electronics Conference and Exposition (APEC), pp. 272–280.

Biography

PANDIYAN.R working as a Assistant Professor in Department Electrical and Electronics Engineering at St.Joseph's College of Engineering and Technology, Thanjavur. He has completed Bachelor's Degree in Electrical and Electronics Engineering at Dhanalakshmi Srinivasan Engineering College, Perambalur in the year 2008 and Master Degree in Power Electronics and Drives at M.A.M college of Engineering, Trichy in the year 2013.I have published many National and International journals. His Research interests are Power Electronics & Drives, Power System, Control system and Renewable Energy source.

JOHN BRITTO.A Asst.Professor in the Department of Electrical and Electronics Engineering, at Anna College of Engineering, Kumbakonam. He has completed Bachelor's Degree in Electrical and Electronics Engineering at Dr.Navalar Neduncheliyan Engineering College, Tholuthor and Master Degree in Power Electronics and Drives at SRM University, Chennai. His Research interests are Power Electronics & Drives, Power System and Renewable Energy source.