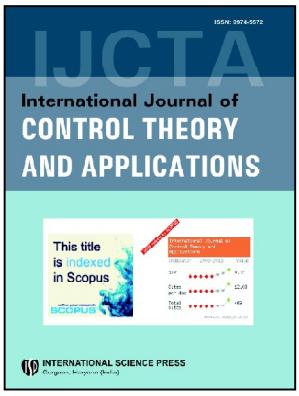


International Journal of Control Theory and Applications

ISSN : 0974-5572



Volume 10 • Number 6 • 2017

# Multi-Level inverter (13) for Grid Connected PV system with PID Controller

**A. Ambikapathy[1] and Gajendra Singh[2]**

[1] *Department of Electrical and Electronics Engineering, Galgotia College of Engineering and Technology, Gr. Noida, UP, India*
*E-mail: ami_ty21@yahoo.com*
[2] *Department of Electrical and Electronics Engineering, Sharda University, Gr.Noida, UP, India*
*E-mail: gajendra.singh3@sharda.ac.in*

***Abstract:*** in this paper thirteen level multi - level inverter topology being used in the ON grid connected solar PV system is realized with PID controller by adopting PWM technique. The algorithm realization, simulation execution and its results are displayed with details of harmonic distortion level. It has already been established that the multi-level inverter reduces the harmonics and improves the quality of the signal. In this work, an effort has been made to get more refined output the PID controller with PWM control technique which gives the best and less rippled inverter output. It also helps in improving the synchronization between output power of solar plant and the ON grid system. As we know that supplying or connecting the output power of solar PV to the ON or commercial grid is the best solution in terms of utilization of energy in the efficient manner, the present researchers are working on designing inverter smarter with improved efficiency, reduced harmonics, soft switching etc. This paper presents the comparison of various types of inverters with their technical advantages, difficulties in handling the issues, capability to work in buck and boost mode with interfacing compatibility also discussed in detail.

***Keywords:*** Solar PV, PID controller, PWM technique, MAATLAB, Harmonics, commercial Grid, Efficiency.

## I. INTRODUCTION

The significance of saving one unit of electricity in terms of cost, degradation of resources, environmental issues we can easily understand the value of turning towards the renewable energy sources and it also encourage us to think how important it is to increase the efficiency of any of the plant in various stages[1]. In this paper the major part of the grid connected PV systems is being discussed to improve the efficiency so as to justify the saving of electricity. The one of the major property of the inverter is considered to be that the inverter should be capable of maintaining the output voltage to the desired level even fault in one of the PV string or corresponding inverter. This kind of property can be obtained by decoupled space vector PWM method [2]. Capability of High step up and step down, high shoot through immunity are required behavior from inverter and qualities can be obtained from impedance source inverter (ZSI). Switched boost inverters (SBI) also has the same advantages as ZSI and it also has less L-C component pair which can reduces the losses but it has less gain as compared to ZSI. Current

fed switched inverter (CFSI) has high gain as well as less L-C component pair. [3] Operating the ZSI in different modes can again improve the operating capability efficiently. In order to get the high boost factor, less voltage stress at switches and to reduce the number of passive components the ZSI can be operated in ripple input current mode and continuous input current mode [4]. Apart from controlling the inverter within the operating mode one can improve the shape of the waveform of the output by using another type of technology for this we may use delta inverter compensation method, in this method the medium frequency inverter output waveform is being improved by delta inverter compensation technology by reducing the distortion caused by dead time of the voltage source inverters [5]. The transformer less inverters are now a days more common due to its tremendous advantages over ordinary inverter such as lowering size, cost, weight, complexity and increasing the efficiency of the inverter [6]. A novel single stage with active hybrid filter can reduce the complexity of the circuit and reduce the bulky inductance in dc side which is responsible for losses as compared to current source two stage inverters. And single stage inverter problem such as requirement of input dc voltage higher than the peak off line – line voltage also can resolved by novel single stage with active shunt hybrid filter with transformer[7]. In recent days the fuzzy logic controlled dc-dc converters and inverters are used to improve the reliability, reduce the harmonics, improve the efficiency, improve the connectivity of service by improving the synchronization capability.[8] in case of multi-level inverters though the level of inverter is increased but the number of switches needed are reduced so as to reduce the switching losses [9]. The reliability of the power transfer is the most important criteria for ensuring the efficiency and avoids the wastage of power generated. The reliability can be increased by improving the performance of different parts of the plant by increasing the ability of the particular circuit or algorithm or technique [10]. The reliability revolution also includes the invention of DC-DC converters not only with too many topologies but also with multiple input and one constant output which solves the problem of maintaining the constant frequency generation after converting DC into AC]11]. In addition to all those there is 'n' umber of technologies which are included in the recent days to improve the reliability and efficiency of the grid connected PV system. The new concept of AC link, Differential power processing to increase the level of production of electrical energy, different protections to monitor the crucial data's, input voltage control with monitoring so as to ensure the stability of the input as well, and also proper selection of source in order to keep the maximum output possibility[12-16] The different authors have analyzed and tried to implement the different types of inverters in different modes of operations in order to achieve less switching loss, size of the inverter, complexity etc. and also to improve the efficiency, ripples etc. hence to find the best solution, beside of all of these types of inverters the multi-level inverters are now more in common and it gives the better output as compared with the other inverters. In this paper the fast switching type multi-level inverter has been proposed with shunt active filter at the end of grid and their simulation results are displayed.

## II. MULTI LEVEL INVERTER WITH PWM TECHNIQUE

Improving the reliability, efficiency, loss reduction of inverters and converters are the major research area of the renewable field and there are so many approaches are being carried out by several authors such as soft switching technique [17], predictive control technique [18], converters and inverters with controllers [19], different smart algorithm based converter and inverter circuits for renewable energy usages[20] are The general reason for use of multi-level inverter in grid connected PV system is to get the fast switching response, unwanted signals reduction, especially this technique is being more adopted in voltage source type of inverters rather than the other type of topologies. This special kind of combination of topology improves the harmonics level and it is being used without transformer hence the losses are reduced to great extent of level. [21-22] the more the level of the inverter the less the harmonic distortion hence the multi-level inverters are more dominantly preferred by the researchers in this field. The PWM technique is used so as to get the smooth and also less harmonized output. The size of the pulse can be controlled by varying the modulation index. [23] In pulse width modulation if the width of the pulse is $\alpha$ then the value of $\alpha$ becomes,

$$\alpha = 2\pi/np \quad (1)$$

$$np = fs/ff \quad (2)$$

$$\theta_{0} = \alpha/4 = 2+\pi/np/4 \quad (3)$$

$$\mu = Vm/Vs \quad (4)$$

Where,

np - Number of pulses; fs- Switching frequency; ff - Fundamental frequency

Vm - Maximum applied voltage; Vs - Switching frequency; μ- the angle in which the modulation is carried out.

The fig (1) shows the description of pulse which can help us to find easily how the PWM technique is being adopted, in which $\delta_1$ and $\delta_2$ are called angle of modulation which keeps varying along with the pulses. The PWM can be carried out by varying the various descriptions of pulses which is mentioned in the Fig (1).

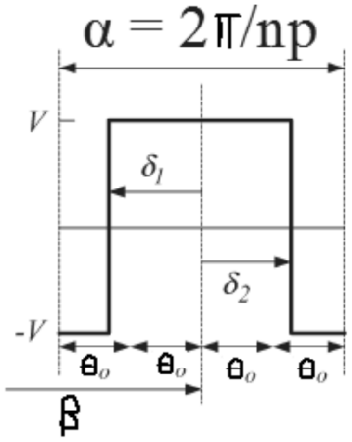


**Figure 1: Description of Pulse to apply PWM technique**

with this PWM technique the PID controller is established to control the operation of multi level inverter. Here we use thirteen level inverter as we know that the more the multi level inverter is used the more hormonics less output is obtained. The Fig (2) shows the basic diagram in which thirteen level inverter with PWM technique in grid connected PV system. The output parameter from the PV pannel is measured and multiplied using multiplier

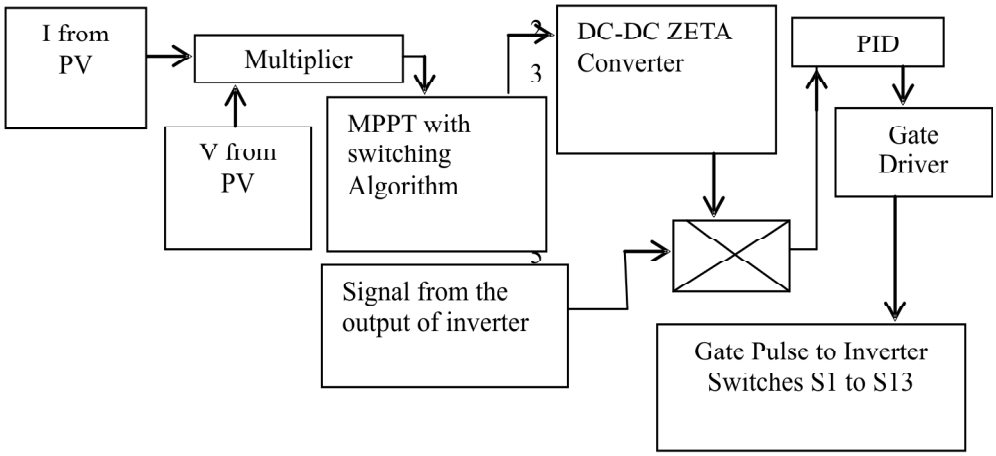


**Figure 2: PID controlled thirteen level inverter for Grid connected PV system**

and then the new advanced smart switching MPPt algorithm used to get the best output out of PV system and then it is again further regulated using the ZETA dc-dc converter.

the signals from dc- dc converter is being compared from the inverter output before the connected to the grid and its compared signal is processed by the PID controller to get the triggering pulse for the inverter to get the desired output from the inverter so that it can be more compatible for connecting to the giid.

## III. PID CONTROLLER REALIZATION

The realization of PID controller has been adopted so as to control the gate triggering of the thirteen level inverter circuit. This PID controller controls the pulse of the gate triggering signal where the PWM technique is used. In fig (3) the realization of PID controller in order to get the signal which can control the width of the pulse by changing the modulation index is shown. The terms which are used are PID controller constants (Kp, Kd, and Ki), error signal e (t), grid current (Iog), controlled output (Con (t)) [24]

The output from PID controller is Con (t) the equation of Con (t) is given by,

$$\text{Con}(t) = \text{Kpe}(t) + \text{Kde}(t) + \text{Kie}(t) \tag{5}$$

The output of PID controlled multi-level inverter is directly connected to the grid. In the figure (3) the factor K is the factor which is being produced by PID controller which triggers the gate triggering circuit which gives the gate pulse to the switches of multi-level inverter. The whole process is being executed in MATLAB simulation and its results are displayed.

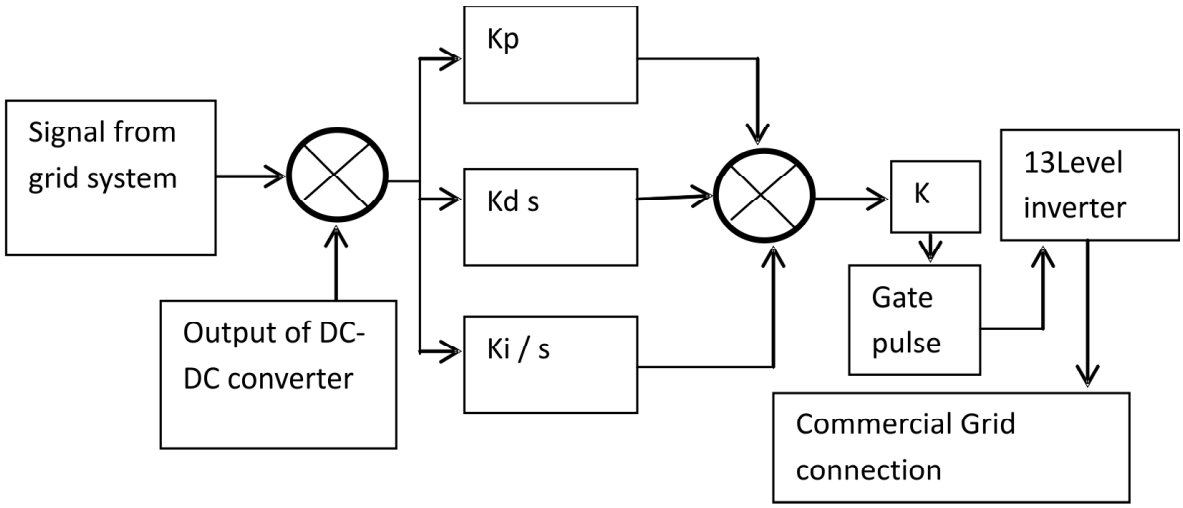


**Figure 3: PID controller algorithm realization**

## IV. SIMULATION RESULTS REALIZATION

The PID controller which is realized in figure (3) helps to improve the performance of the output of the inverter to give the regulated output which can easily and reliable match with the grid system. This PID controlled inverter has the advantages of PD and PI controllers combination, it has very smaller maximum peak overshoot as compared to the other controllers which helps in reducing the settling time of the response, and the main advantages of PID controller is that it does not have the steady state error which makes the system to in the line of more stability. The fig (4 & 5) shows the sub Simulation model and simulation model of PID controlled multi-level inverter for Grid connected PV system.

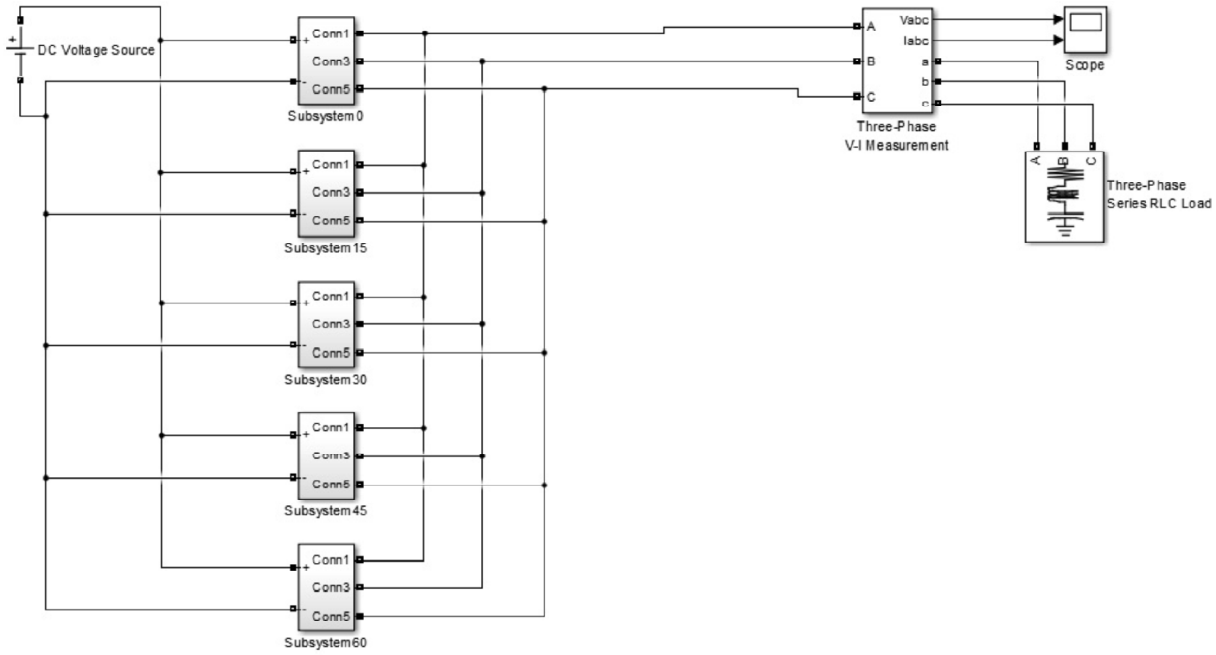


**Figure 4: Simulation model of multi-level controlled inverter (Sub system)**

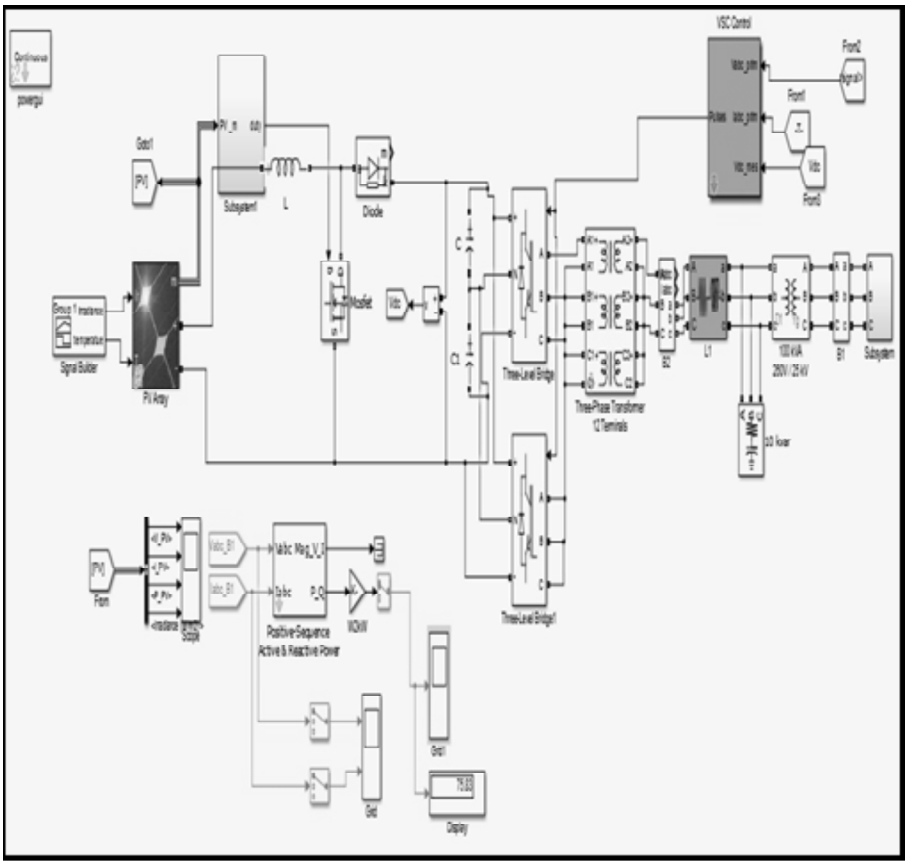

**Figure 5: Simulation model of multi-level controlled inverter for Grid connected PV system**

The simulation results are shown in figure (6, 7 & 8) which shows the voltage, current and THD level.

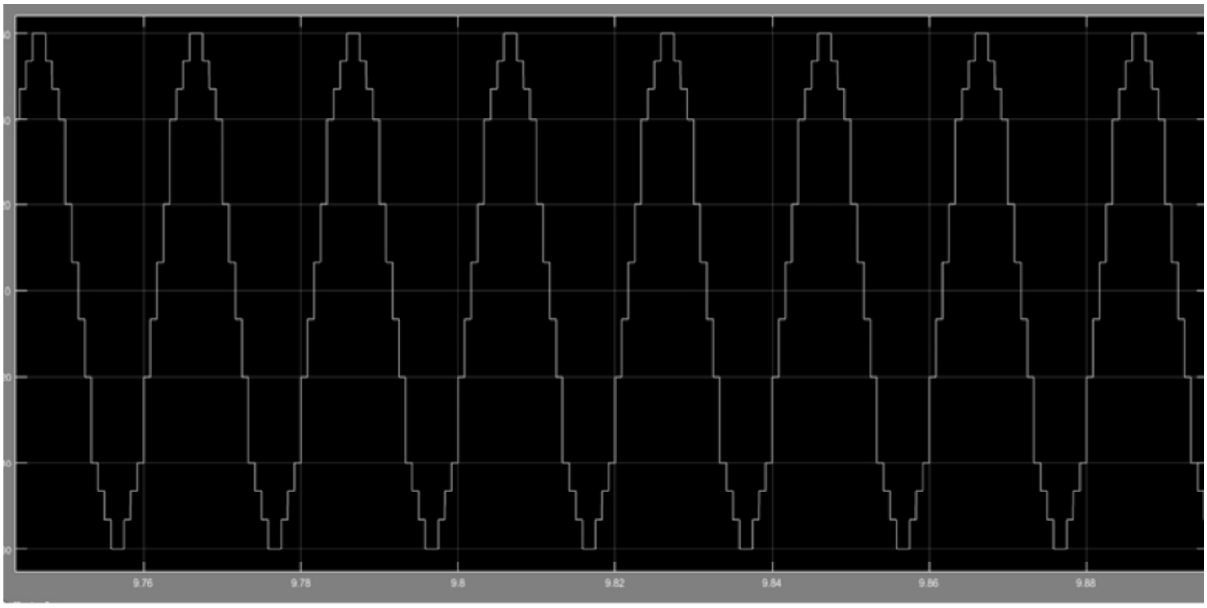

**Figure 6: Simulation result of PID controlled multi-level (13) inverter (Voltage)**

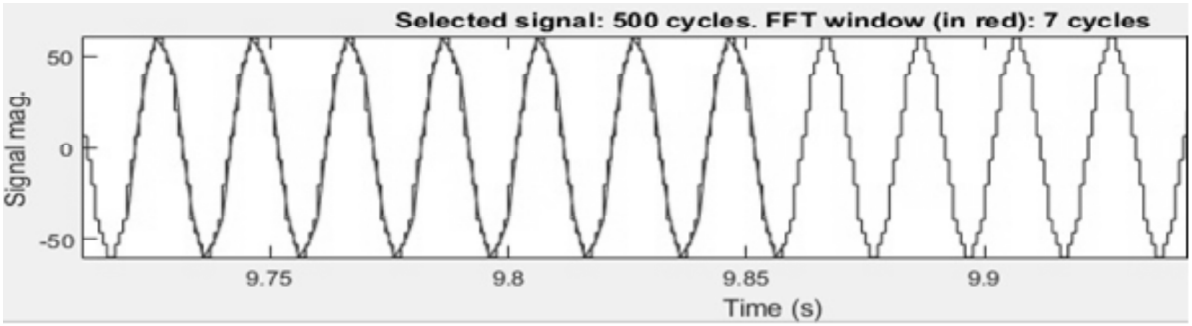


**Figure 7: Simulation result of PID controlled multi-level (13) inverter (Current)**

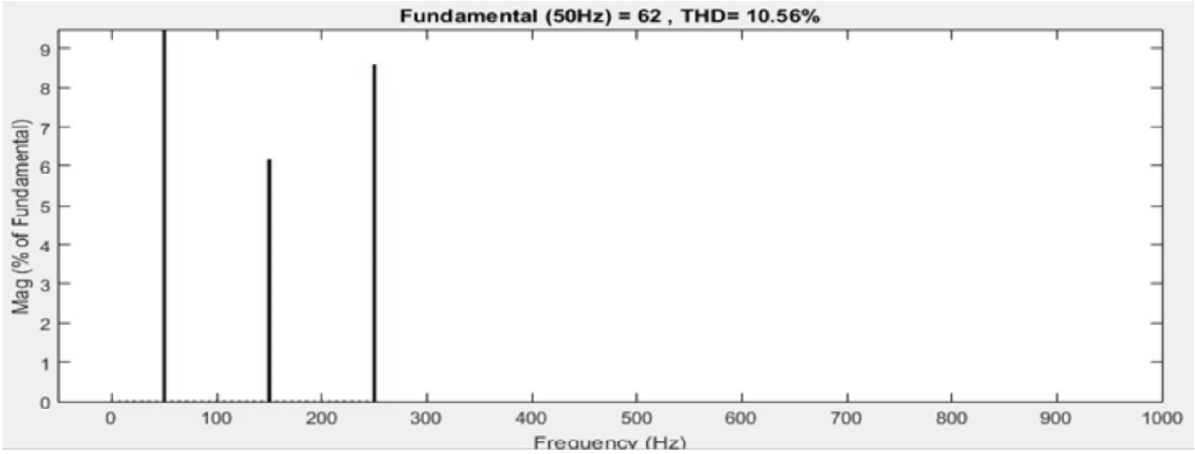


**Figure 8: Simulation result of PID controlled multi-level (13) inverter (THD Level)**

The proposed PID controlled Thirteen Level inverter with symmetrical and dynamic approach results are shown. This thirteen level inverter requires 24 switches and it has different switching combinations which in turns generate the required thirteen level output signals.

## V. CONCLUSION

This paper presented the most demanded technique by the Photovoltaic system which needs to be connected to the commercial grid, as the basic requirement of commercial grid is that the standard voltage and frequency in this paper the PID controller with PWM technique has been discussed. As the result shows that this technique improves and gives the better efficiency in terms of reliability, ripples, impedance matching, fast response etc., and it also reduces the switching losses.

## REFERENCES

[1] A. Ambikapathy., Gajendra Singh, Prabhakar Tiwari : Significance of Saving one unit of electricty.,1st UPCON- ICEEE2015, 26-28MARCH 2015, IEEE XPLORE, pp1-6.

[2] Madhukar Rao A, umesh B S, Sivakumar K "A fault tolerent dual inverter configuration for islanded mode photovoltaic generation sytstem" 1stInternational conference on Future energy electronic conference , Tainan. 3-6 Nov 2013, pp 816-821. IEEE Xplore.

[3] Soumya Shubhra Nag, Santanu mishra "Current fed switched inverter"IEEE Transaction, Industrial Electronics. Vol 61,No.9, sep 2014. Pp 4680-4690.

[4] Shilpa A S, H Vasanth Kumar shetty" operating states and improved characteristics of new Z soursce inverter topology" International conference on advances in electronics, computer and communications ICAECC 2014, IEEE Xplore. Pp 978-984.

[5] Jingang Li, Jia Li, Shaocheng Ding "Research on Novel methodfor improving inverter output waveform" 5th IEEE International conference on Industrial electronics and applications 2010 pp 1194-1197.IEEE Xplore.

[6] M.Bouzguenada , A.Gastli, A.H. Al badi, T.Salmi" Solar photovoltaic inverter requirements for smart grid appllications" 2011 IEEE PES interenatoinal conference on Innovatice smart grid technology middle – east (SGT middle-east)17-20 Dec 2011.IEEE xplore.

[7] B. Mariappan, B.G. Fernandes, M.Ramamoorthy." A novel single stage solar inverter using hybrid active filter with power quality improvement"oct-nov 2014, 40th annual conference on IEEE industrial electronics society,IECON 2014. IEEE xplore

[8] Siva Gana Prasad,Amrutha Veena, Chandrapati, Navyata yesodha rao.K, Lakshmi Prasanth.K: Fuzzy logiccontrolling of a single phase seven level grid connected inverter for photovoltaic system., International journal of Engineering research, may 2014, vol 3, pp 299-304.

[9] Naresh Kumar Varathe., Ketan mishra., Shubham Shivhare: Simulation and analysis of single phase seven level inverter with number of switches are reduce: International journal of Emerging Trends and Technology in Computer Science. Vol 3, May 2014, pp 14-18

[10] Z.peng., W.yang., X.Weidong., and L.Wenyuan. : Reliability evaluation of grid connected photovoltaic power system. IEEE Transaction on sustainable energy.,vol.3, pp 379-389, 2012.

[11] H.Behjati., A Davoudi. :A multiple input multiple output DC – DC converter. IEEE Transaction on Industry Application., vol.49,pp-1464-1479, 2013.

[12] H.Keyhani., H.A. Toliyat. : A New generation of buck-boost resonant AC-Link DC-DC converter. IEEE Applied Power Electronics Conference and Exposition(APEO). 2013, pp 1383-1390.

[13] P.S.Shenoy., K A kim., B.B.Jhonsons., P.T.Krein. : Differential power processing for increased energy production and reliability of photovoltaic systems. IEEE Transaction on power electronics., Vol 28,pp-2968-2979,2013.

[14] M.Hamzeh., S.Farhang.i, B Farhangi. : A new control method in PV grid connected inverters for anti-islanding protection by impedance monitoring.n IEEE workshop on control and modeling for power electronics., 2008, pp 1-5.

[15] A.R.Kashyap., R.Ahmadi., J.W.Kimball. : Input voltage control of SEPIC for maximum power point in IEEE power and energy conference at Illinois (PECI), 2013. pp 30-35.

[16] A.Ahmadi., A.Kashyap., A.Berrueta Irigoyen., A.Rayachot.i, C.Wright., J.Kimnall. : Selective source power converter for improved photovoltaic power utilization. IEEE power and energy conference at Illinois ., 2013, Pp 247-252.

[17] A.Ambikapathy., Gajendra singh., Ashish Srivastava: Efficienct Sift Switching dc-dc converter for MPPT of a Grid connecte System., ICCCA 2016, March 2016, pp 76-73

[18] A.Ambikapathy., Gajendra Singh., Prabhakar Tiwari: Soft Switching Zeta converter with Predictive control technique for grid connected PV. International journal of Applied Engineering research, vol 10, no 92,2015,pp 276-283.

[19] A.Ambikapathy., Gajendra Singh., Prabhakar Tiwari:Performances of different types of dc- dc converter with P & O Algorithm of MPPT., International Journal of Smart Home., vol 10, No6, 2016, pp 277- 286.

[20] S.Busquests-Monge., J.Rocabert., P.Rodriguez., S.Alepuz., J.Bordonau. : Multilevel diode-clamped converter for photovoltaic generators with independent voltage control of each solar array., IEEE Transaction on Industrial Electronics., Vol 55., July2008, pp 2713-2723.

[21] E.Ozdemir., S.Ozdemir., L.M.Tolbert., B.Ozpineci.: fundamental Frequency Modulated multilevel inverter for three phase stand alone photovoltaic applications., IEEE Applied power Electronics Conference and Exposition, Feb 24-28, 2008, pp 148-153.

[22] Jayraj Selvaraj., Nasrudin Abd Rahim, : Multi Level inverter for Grid conneted PV system employing Digital PI controller., IEEE Transaction on Industrial Electronics., Vol 56., No 1., Jan 2009, pp 148-158.

[23] G balaji., I. Gnanambal., C Gowrishankar: Grid connected WECS with A 5 level DCMCI using PID controller., middle – east journal of scientific research july 2014., 1109-1118.

[24] Bailu Xiao, Li jum Hang, Cameron riley, Leon M.tolbert, Burak Ozpinchei.: three phase modular cascaded H- Bridge multi level inverter with individual MPPT for grid connected photovoltaic systems. IEEE transaction, Industrial electronics, july 2014. pp 1105-1109.