Available online at: http://www.ijmtst.com/vol4issue12.html
International Journal for Modern Trends in Science and Technology
ISSN: 2455-3778 :: Volume: 04, Issue No: 12, December 2018

Transformer less Inverter for Reactive Power Compensation in Grid Tied PVG System with Fuzzy Logic

Neyyala Raju [1] | A Apparao [2]

[1]PG Scholar, Department of EEE, Sri Venkateswara College of Engineering and Technology, Srikakulam, India.
[2]HOD & Associate Professor, Department of EEE, Sri Venkateswara College of Engineering and Technology, Srikakulam, India.

To Cite this Article
Neyyala Raju and A Apparao, "Transformer less Inverter for Reactive Power Compensation in Grid Tied PVG System with Fuzzy Logic", *International Journal for Modern Trends in Science and Technology*, Vol. 04, Issue 12, December 2018, pp.-24-30.

Article Info
Received on 02-Oct-2018, Revised on 22-Nov-2018, Accepted on 03-Dec-2018.

ABSTRACT

The Rise in power demand with growing population across the world has led to the development of renewable energy sources. Among all the renewable energy sources PV power generation system proves to be more superior and efficient than other renewable sources. Recent innovations in transformer less inverters have proven to be efficient and reliable than conventional ones. Here the proposed transformer less inverter for grid connected PV system has the capability of reducing the leakage currents. It also provides the required reactive power to the system to maintain constant CM voltage. To provide high quality current injection in to the grid, PR controller and fuzzy controller are used. In this study the detailed analysis of the operating modes of the proposed PV transformer less inverter system, analysis of the leakage currents and results in MATLAB simulation are presented.

Keywords: *Common mode (CM), parasitic capacitance, reactive power, Fuzzy logic controller, Transformer less inverter.*

I. INTRODUCTION

With the rapid growth in population the demand for electrical power has been increasing and there has been a limitation on usage of natural resources. In order to meet the electrical power demand there has been great interest towards renewable energy sources. Among all the renewable sources solar power is considered to be the better in order to meet the demand since it is pollution free and inexhaustible. With the rapid increase in power electronic devices and incentive beneficiary from the government, PV module price decreases, and so grid-connected PV systems plays an important role in distributed power generation. Mostly galvanic isolatedtransformers are used in grid connected PV system for safety purpose. Galvanic isolationprevents DC current injection into the grid and the leakage currents between grid and PV module are reduced. By using high frequency transformers on the DC side and low frequency on inverter side the overall efficiency of the system is reduced. In order to overcome this problemtransformer less grid tied PV system is employed.

By removal of galvanic isolated transformer, the leakage currents between grid and PV module are increases, the parasitic capacitance effect occurs and it leads to common mode voltage fluctuation at grid side. This common mode voltage fluctuation depends on the switching scheme and topology structure hence which leads to capacitive leakage currents. These leakage currents increases the grid harmonic currents and system losses. Grid-tied transformer less PV inverter has the ability to inject reactive power into the utility grid. In recent international regulations certain rules have been imposed regarding minimum reactive power handling by grid-tied PV inverter system.

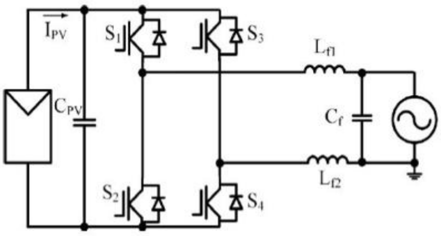

Fig.1: The single phase H-bridge inverter

Previously transformer less H-Bridge inverter is utilized for PV System. The basic simple H-Bridge PV transformer less inverter is shown in figure1.The main advantage of this topology is ability to generate reactive to the grid. The main disadvantage of this system is the bipolar pulse width modulation to avoid common mode voltage and high switching losses in IGBTs.

High Efficient Reliable Inverter Circuit (HERIC) topology has been utilized to overcome these problems. High Efficient Reliable Inverter Circuit (HERIC) topology is shown in figure 2. For better reduction of core and switching losses, the proposed topology is implemented with unipolar. When HERIC topology operated under Reactive Power Generation, the MOSFET switches causes the reverse recovery voltage issues.

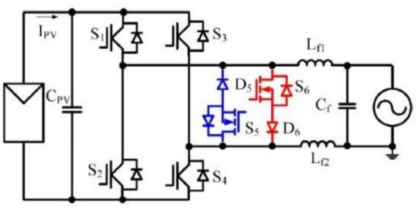

Fig. 2: The HERIC inverter with paralleled auxiliary freewheeling switches

Another H5 transformerless topology show in figure 3 which is make from fig1 by adding an extra switch at the at DC side of the full bridge inverter. For example when this system preform with input voltage 345V dc and switching frequency 16-kHz then system efficiency has 98%. However, this topology has high conduction losses due to the fact that the current must conduct through three switches in series during the active phase. Another disadvantage of the H5 is that the line frequency switches S1 and S2 cannot utilize MOSFET devices because of the MOSFET body diode's slow reverse recovery.

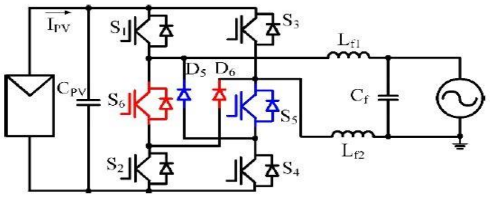

Fig .3: The H6 inverter topology

Another transformerless topology implemented with MOSFET switches as shown in figure 4 is the dual The dual- paralleled buck inverter eliminates the problem of high conduction losses in the H4 and H5inverter topologies because there are only two active switches in series with the current path during positive cycle. This adjustment to improve the system reliability comes at the cost of highzero-crossing distortion for the output grid current. the main disadvantage of this system are all the mosfet diodes bodies are operated when the phase difference occurred between grid voltage and grid current .therefor the reliability of the system will be decreased.

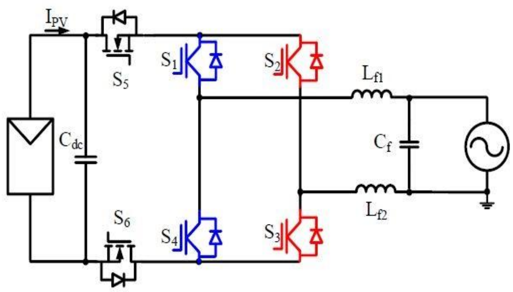

Fig .4: The symmetrical H6 inverter topology

When we are able to developed a transformerless inverter two major issues are considered.one of the issue for a high efficiency and reliability transformerless PV inverter is that in order to achieve high efficiency over a wide load range it is necessary to utilize MOSFETs for all switching devices. Another issue is that the inverter should not have any shoot-through issues for higher reliability. In order to address these two key issues, a new inverter topology is proposed for single-phase transformerless PV grid- connected systems.

The another important function for grid connected photovoltaic systems are generation real power and compensation of reactive power.in this paper implemented with two current controllers are Fuzzy controller and PR controller. These current controllers are effectively generate grid current and also maintain power flows between the grid and system. The PR controller can maintain the grid current in phase with the grid voltage by the inverter, so unity power factor can achieved. The PR+HC controller are minimize lower order odd harmonics components present in inverter output current, and also these are gives high gain at resonant frequency. Therefore the system study state error reduce to zero. Due this THD value of the system has been decreased. Therefore these controllers can reducing harmonic currents rejection and steady state errors as compared to the PI controllers.

This paper presents a new future topology in transformerless inverter for grid connected PV system is developed.in section II, structure of the circuit and operating principle of proposed topology is presented. Next in section III, common mode characteristics of the system presented. Later in section IV, control methods of the system are presented. In section V, presents the simulation results of the proposed topology with real and reactive power using fuzzy controller and PR controller. after that theoretical analysis is initially verified in MATLAB Simulink software environment and results are presented in section V

II. PROPOSED TOPOLOGY ANDOPERATING PRINCIPLE

A.Circuit configurations

The proposed transformerless inverter topology shows in Figure 5 and its consists of 6 MOSFET switches(S1-S6) along with 6 Diodes(D1-D6). The coupled inductors L_{1A}, L_{2A}, L_{1B}, L_{2B}, L_{1g},L_{2g}form the LCL type filter adopted to the grid. V_{PV} and C_{dc} signifies the input dc voltage and dc link capacitor. In proposed topology the MOSFETs body-diodes contains of low reverse- recovery problems when injecting the reactive power into the grid.in order to reduce issues present topology developed with high reliability and efficiency. The proposed topology can also consists of unipolar-SPWM with three level outputvoltage.

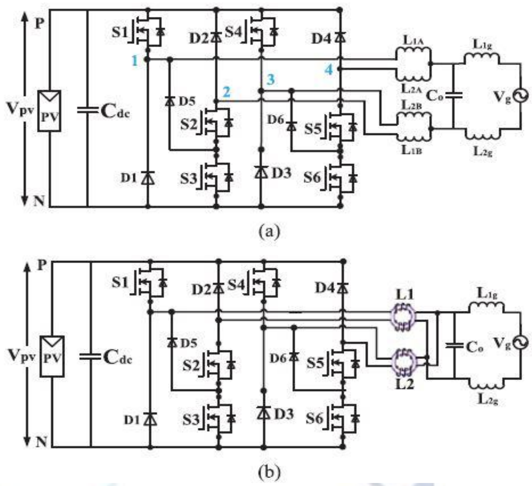

Fig.5: (a) Proposed topology
(b) Circuit with coupled inductor.

B. Operating principle of proposed topology.

The switching pattern of the proposed topology as shown in fig.6 where the switches S1,S2,S3,S4,S5,S6 signifies main switches and their operating Gate signals are G1,G2,G3,G4,G5,G6 respectively. The principle of operationof the proposed topology is classified in to four regions as shown in Fig5. The proportional operation of the positive and negative half cycle of the grid current are same, therefore here positive half cycle has discussed .however the negative half cycle operation is shown in Fig.7.

Region I: In this region, both the grid voltage and grid current are positive. During the period within this region S2 is always on, while S1 & S3 synchronously and S5 complementary commutate with switching frequency. There are always two states that generate the output voltage of + V_{PV} and 0.

State 1(t_0:t_1): At t = t_0, the switches S_3& S_1 are switched on and the current through inductor rises through grid as shown in Fig.7 (a). In this state, the voltages V_{1N} and V_{2N} can be defined as: V_{1N} = + V_{PN} and V_{2N} = 0, thus the output voltage of inverter V_{12} = (V_{1N} -V_{2N}) = + V_{PV}.

State 2(t_1:t_2): When the switches S1 and S3 are turned-off, the current through inductor freewheels through D5 and S2 .In this state,V_{1N} falls and V_{2N} rises until their values are equal. Therefore, the voltages V_{1N} and V_{2N} becomes: V_{1N} = V_{PV} /2 and V_{2N} = V_{PV} /2 and the inverter output voltage V_{12} = 0

Region II: In this region, the inverter output voltage is negative, but the current remains positive. During the period of this region, S_5 is always on, while S_6 & S_4 synchronously and S_2 complementary commutate with switching frequency. There are also two states that give the output voltage of $-V_{PV}$ and 0.The negative half cycle operated in two states that produce the output voltage of $-V_{PV}$ and 0.

State 3(t_3:t_4): In this state, the switches S_6 and S_4 are turned-on and the filter inductors are demagnetized. Since the inverter output voltage is negative and the current remains positive; therefore, the inductor current is forced to freewheel through the D_1 and D_2 diodes and decreases rapidly for enduring the reverse voltage as shown in Fig. 7(c). The voltages V_{1N} and V_{2N}can be defined as: V_{1N}= 0 and V_{2N} = + V_{PV}, thus the inverter output voltage $V_{12} = (V_{1N} - V_{2N}) = -V_{PV}$

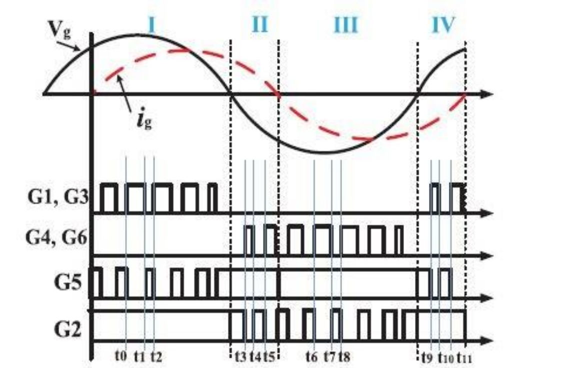

Fig.6: Switching pattern of this proposed topology

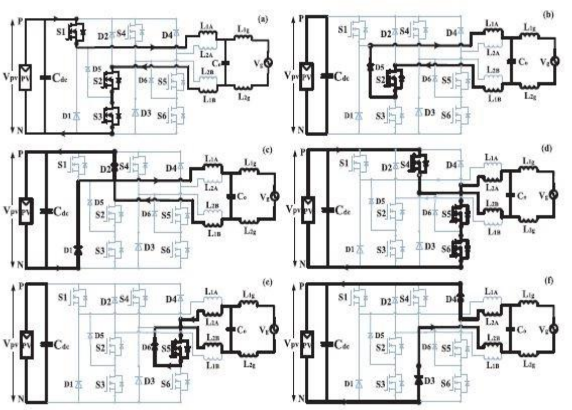

Fig.7: The operating principle of the proposed topology: (a) state 1 (b) state 2 (c) state 3 (d) state 4

State 4(t_4:t_5): At t = t_4, the switches S_6 and S_4 are switched off and S_2 is turned-on. Therefore, the current allows through D_5 and S_2 like as state 2 (Fig. 7(b) can be referred as equivalent circuit) in inductor. This state is called as energy storage mode.

The voltages $V_{1N}$and V_{2N}could be: $V_{1N}= V_{PV}/2$ and $V_{2N}= V_{PV}/2$, and thus the inverter output voltage, $V_{12} = 0$.

According to the principle of operation of this topology presented, the total CM voltages can be calculated for each state of positive half cycle operation as follows:

State 1:$V_{tCM} = \frac{1}{2}(V_{1n} + V_{2n}) = \frac{1}{2}(V_{pv} + 0)$

$$=\frac{1}{2}V_{pv} \quad (7)$$

State 2 :$V_{tCM} = \frac{1}{2}(V_{1n} + V_{2n}) = \frac{1}{2}(\frac{1}{2}V_{pv} + \frac{1}{2}V_{pv})$

$$=\frac{1}{2}V_{pv} (8)$$

State 3:$V_{tCM} = \frac{1}{2}(V_{1n} + V_{2n}) = \frac{1}{2}(0 + V_{pv})$

$$=\frac{1}{2}V_{pv} \quad (9)$$

State 4:$V_{tCM} = \frac{1}{2}(V_{1n} + V_{2n}) = \frac{1}{2}(\frac{1}{2}V_{pv} + \frac{1}{2}V_{pv})$

$$=\frac{1}{2}V_{pv} (10)$$

It is clear from equations (7)-(10) that the total CM voltage for this topology is kept same at $V_{pv}/2$ during positive half cycle operation. Likewise, the total CM voltage for the negative half cycle operation can be calculated and found to be constant at $V_{pv}/2$ due to the symmetry of operation for the negative and positive half cycle of grid current. The only variation is the activation of different power devices. Hence, it can be summarized that the total CM voltage during the entire grid cycle is kept same, decreasing ground leakage current.

III.CONTROLLER DESIGN FOR SINGLE PHASE GRID TIED TRANSFORMERLESS INVERTER

The controlling structure of the proposed topology has shown in figure 8, this contains orthogonal signal generator (OSG) system for calculations of active and reactive power of the system, Two fuzzy logic controller for grid current controlling, and SPWM generation block

In single phase grid connected transformerless inverter, two controllers are developed. One is the Fuzzy Logic controller (FLC) and PR Current controller. The current controller takes care of the quality of current injected into the grid and the power interchange between the system and grid.$I_g\alpha$reference which is in phase with the grid voltage controls the real power of the system and the orthogonal component $Ig\beta$ reference controls the reactive power exchange of the system with the grid. Hence a decoupled control of reactive and real power can be achieved.

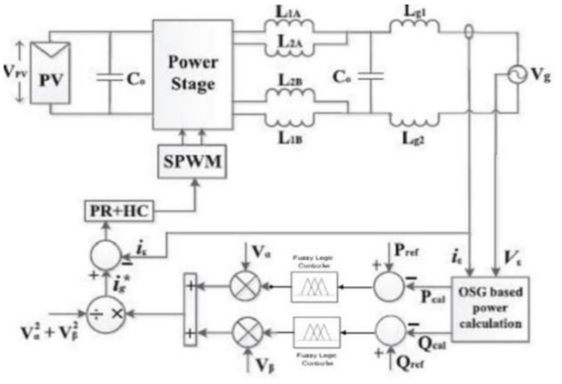

Fig.8: Block diagram of control of proposed system with Fuzzy Logic controller

A. Fuzzy Logic controller

The traditional PI controller requires rigorous linear mathematical models, which are not easy to acquire and cannot give satisfactory results under parameter variations, load disturbances, etc. In these latest years, the number and variety of uses of fuzzy logic have increased significantly. Fuzzy logic is a superset of Boolean logic which has been prolonged to manage the idea of partial truth- truth values between "totally false" and "totally true". These control strategies come from trails and practices rather than form mathematical models and linguistic implementations are much faster accomplished. These control schemes entail more number of inputs, most of which are common only for some special conditions.

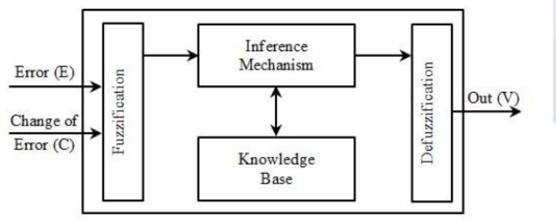

Fig .9: Structure of the Fuzzy Logic Controller

These systems generally consist of four components: Fuzzification, Rule base, Inference engine and Defuzzification interface as shown in figure 9.The first process is altering the crisp values of input variables into membership values according to proper fuzzy sets and there are three methods which are utilized in inference process. When the changes occur in the second process, then the results of all rules are integrated into a single precise value for output.

In this paper we considered the membership function as a type in triangular membership function and method for Defuzzification here we considered as centroid. The error which is obtained from the comparison of reference and actual values is given to fuzzy inference engine. In this paper we consider as a single input and single output fuzzy inference system. The number of membership variables for input and output is assumed as 5. The number of rules we formed as 25.

B. Proportional Resonant Current Controller

The block diagram of the PR controller with harmonic current compensator is shown in Fig.13 the transfer function of fundamental current controller are $G_c(s)$, $G_h(s)$, and $G_d(s)$, harmonic compensator, and inverter respectively

The PR current controller is utilized in the stationary frame which is different from the traditional PI controller. Due to no transformation from stationary frame to synchronous frame, the computation pattern of this controller is simple. For these cases, processor which is less in cost can be used. Besides, when grid imbalances or a sensing error occurs, this controller is more robust than the PI controller. Especially, the PR controller is suitable for constant frequency operation in the grid-connected system. Generally, the PI controller has disadvantages such as issue in eliminating the steady-state error in a stationary reference frame. This controller structure has obtained familiarity due to its ability of removing steady-state error when regulating sinusoidal signals. Moreover, the simple execution of a harmonic compensator without any counter cause on the controller results prepares this controller well befit for grid-linked systems.The transfer function of the PR controller is defined below:

$$G_c(s) = K_{pi} + K_{ii} * \frac{n}{s^2 + w^2}$$

$$G_h(s) = \sum_{h=3,5......} \frac{K_{ih}s}{s^2 + (hw_f)^2}$$

$$G_d(s) = \frac{1}{1 + 1.5T_s s}$$

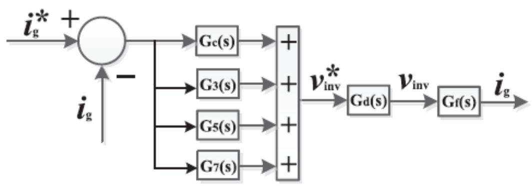

Fig.10: PR controller with harmonic compensator

Where K_{pi} and K_{ii} are the proportional and resonant gain, w_f is the fundamental frequency, K_{ih} is the resonant gain at the nth order harmonic, h is the harmonic order, and T_s is the sampling period.

IV. SIMULATION RESULTS

The Analysis of this transformer less inverter topology was performed using the MATLAB/SIMULATION SOFTWARE. The parameters are considered in simulation are given in Table I. in this simulation PV module are replaced with 400V DC Voltage source. C_{PV1}, C_{PV2} are parasitic capacitance between the PV module and ground, which is emulated using thin film capacitor of 75nf. In this section, comparison of different parameters such as inverter voltage, common mode voltage (CMV), leakage current and the performance of proposed topology under changes of reactive and real power are discussed.

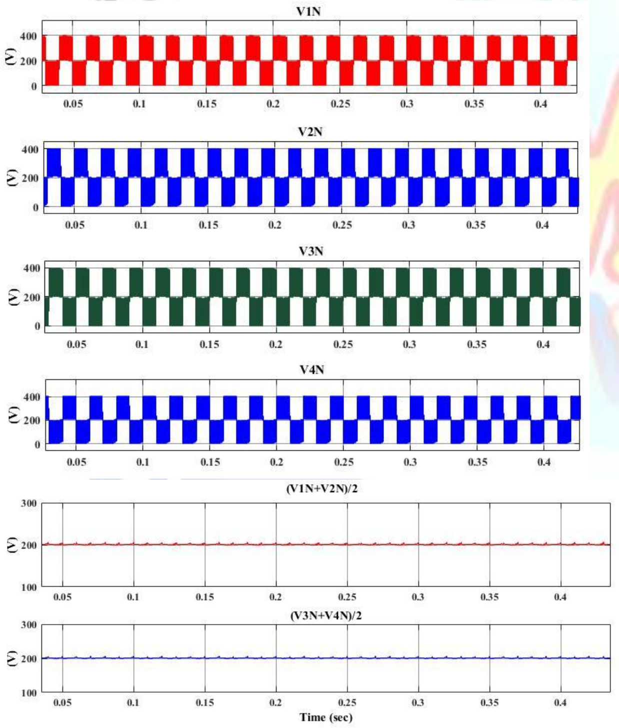

Fig.11.CMcharacteristicsoftheproposed topology

The Characterestics of CM voltages for proposed converter topology with pure real and reactive powers are expressed as; for positive half cycle of CM voltage $(V_{1N}+V_{2N})/2$ and fornegativehalf cycle of CM voltage $(V_{3N}+V_{4N})/2$. The characterestics of CM Voltages (V_{1N}, V_{2N}, V_{3N}, and V_{4N}) are shown in figure 11.Due to the fluctuation of CM voltage. However, the peak and RMS value of leakage current flows through this topology shown in figure 12.

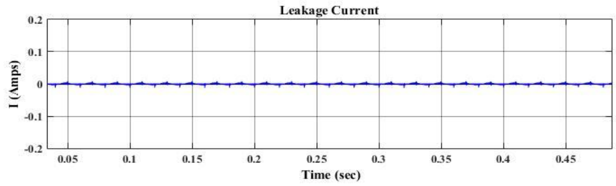

Figure 12: Simulation Result for Leakage Current

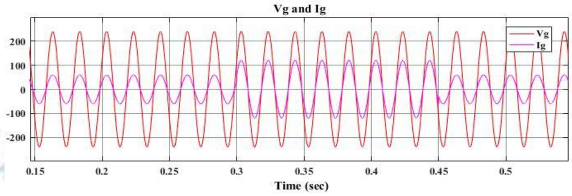

Figure 13: Performance of Grid Voltage and Current

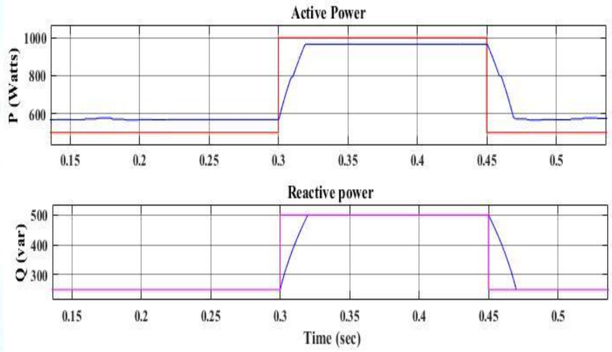

Figure 14: Performance of Grid active and Reactive Powers

The dynamic performance of the proposed system is simulated under changes in both P_{ref} and Q_{ref}. The simulation results of Grid Voltage and Current and its measured active and reactive powers are shown in figure 13 and 14 respectively.

From the results, it shows that there is a change in grid current with respect to step change in load and the active and reactive powers tracks the reference powers. From the results, there is very low distortion in grid voltage and current, hence the leakage current flows through the system is also very low.

VI. CONCLUSIONS

This paper Proposes a system for governing the flow of current from PV system when with the grid depended on FLC (fuzzy logic controller). PV system with inverter topology and its regulation action was developed using MATLAB / Simulink environment. With the Proper design of FLC and PR controller, the proposed PV inverter had succeeded in producing an excellent response, where the output current of inverter was sinusoidal and the harmonic values met with international standards. The Simulated Results have been analyzed.

References

[1] Monirul Islam, Nadia Afrin, and SaadMekhilef, Senior Member, IEEE "Efficient Single Phase Transformerless Inverter for Grid-Tied PVG System with Reactive Power Control," IEEE Transactions On Sustainable Energy, 2016.

[2] X. Huafeng and X. Shaojun, "Leakage current analytical model and application in single-phase transformerless photovoltaic Grid connected inverter" IEEE Trans. Electro-magn. Compat., vol. 52, no. 4, pp. 902–913, Nov. 2010

[3] T. Kerekes, R. Teodorescu, P. Rodriguez, G. Vazquez, and E. Aldabas, "A new high-efficiency single-phase transformerless PV inverter topology," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 184–191, Jan. 2011.

[4] Y. Bo, L. Wuhua, G. Yunjie, C. Wenfeng, and H. Xiangning, "Improved transformerless inverter with common-mode leakage current elimination for a photovoltaic grid-connected power system," IEEE Trans. Power Electron., vol. 27, no. 2, pp. 752–762, Feb. 2012.

[5] O. Lopez et al., "Eliminating ground current in a transformerless photovoltaic application," IEEE Trans. Energy Convers., vol. 25, no. 1, pp. 140–147, Mar. 2010.

[6] T. F. Wu, C. L. Kuo, K. H. Sun, and H. C. Hsieh, "Combined unipolar and bipolar PWM for current distortion improvement during power compensation, " IEEE Trans. Power Electron., vol. 29, no. 4, pp. 1702–1709, Apr. 2014.

[7] D. Schmidt, D. Siedle, and J. Ketterer, "Inverter for transforming a DC voltage into an AC current or an AC voltage," EP Patent 1, 369, 985, 2009

[8] M. Victor, F. Greizer, S. Bremicker, and U. Hübler, "Method of converting a direct current voltage from a source of direct current voltage, more specifically from a photovoltaic source of direct current voltage, into a alternating current voltage," U.S. Patents 7 411 802 B2, 2008

[9] M. Islam and S. Mekhilef, "An improved transformerless grid connected photovoltaic inverter with reduced leakage current," Energy convers. Manage, vol. 88, pp. 854–862, 2014

[10] E. Gubía, P. Sanchis, A. Ursúa, J. López, and L. Marroyo, "Ground currents in single-phase transformerless photovoltaic systems," Progr. Photovoltaics Res. Appl., vol. 15, pp. 629–650, 2007.