http://www.jctjournals.com ISSN(ONLINE):2278 - 3814

Volume-12, Issue-11, November 2023
JOURNAL OF COMPUTING TECHNOLOGIES (JCT)
International Journal
Page Number: 01-07

A Transformer Less Solar PV Array System With Double Tuned Filter For Minimization Current Losses And THD

[1]Pawan Kumar, [2]Prof. Alka Thakur
[1] M.Tech Scholar, [2]Assistant Professor
[1, 2] School of Engineering (SOE), SSSUTMS, Sehore, India
[1]pawansharma08239@gmail.com,[2] electricalhod06@gmail.com

Abstract*— In the last decade assessment of flicker perturbations in power systems with multiple disturbing consumers is one of the most burning topic between different research groups. There are different research organization focused on power quality as well as flicker perturbations improvement. In the last decade there are different research work presented for the improvement of flicker perturbations between different consumers problem in the field of power. Flicker and voltage level up down is a common in the ruler and suburban area. For the improvement of this problem proposed an improved D-STATCOM, that shows will better power quality of output as compare to other power improvement methods such as STATCOM and others. For the comparison of proposed method calculate the different parameters such as active power, reactive power and the most important parameter that is total harmonic distension. The THD of proposed method will improved.

Keyword:-Day-DSTATCOM, STATCOM, Flicker Perturbations, Power quality improvement, Active power and reactive power.

I. INTRODUCTION

A. Background

In the past century, the burning of fossil fuel has revolutionized the world with rapid industrial development, while there are unavoidable consequences that are seriously affecting public health and the environment. Apart from the obvious issues arising in the fossil fuel supply chain, the most serious risk in terms of universality and irreversibility is global warming associated with the combustion of fossil fuel. It has been reported that over 70% of total greenhouse gas emission is carbon dioxide (CO2), whilst over 60% of the CO2 is emitted from the use of fossil fuels. Although there is a notable slowdown in the growth of global greenhouse gas emission, as long as CO2 is emitted it will continue to build up in the atmosphere . In order to stabilize, or even reduce the effect of global warming, the use of fossil fuel needs to be significantly reduced; and this has led to an increasing demand for clean and sustainable renewable energy resources.

As one of the most effective ways to fight against these environmental concerns, photovoltaic (PV) technology has experienced significant development and huge cost improvements over the past decade. Particularly in recent years, driven by the rising demand for electricity and the increasing competitiveness of solar PV energy, PV capacity has expanded exponentially in some regions. According to data from the Renewables 2017 Global Status Report, additions to the worldwide PV capacity during 2016 reached 75 GW with an increase of 48% compare to 2015, which is greater than the cumulative world capacity five years earlier. Among this amount over 34 GW were contributed from China, representing nearly half of the global additions. Meanwhile the top five markets have been reported to be China, the United States, Japan, India and the United Kingdom, accounting for approximately 85% of additions. By the end of 2016, the total solar PV capacity reached 303 GW. Figure 1 shows the global cumulative solar PV capacity and annual additions between 2006 and 2016. Furthermore, due to the substantial demand from China, IHS Markit predicts another record-breaking year for global photovoltaic's in 2018, forecasting new installations to hit 108 GW by the year's end. Given a continued strong growth of PV deployment through to 2022, the global cumulative PV capacity is forecast to expand by over 920 GW. The International Energy Agency

(IEA) envisions a contribution of 16% of global electricity from PV generation by 2050; this, in turn will lead to an annual reduction in carbon dioxide emission of 4 Gt in the process.

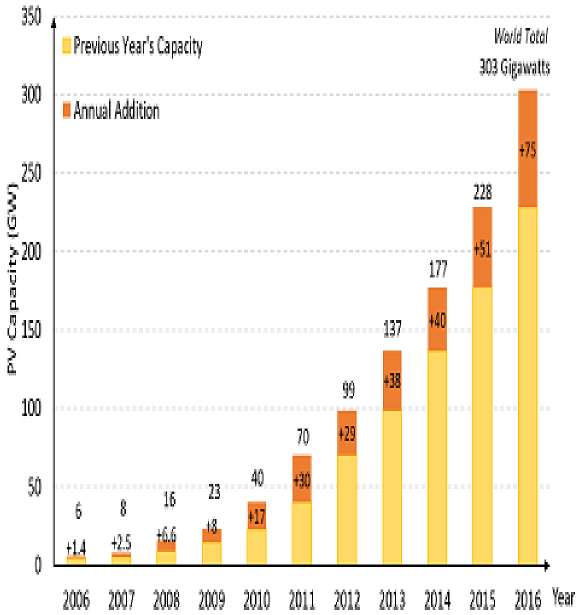

Fig 1 World solar PV capacity and annual additions between 2006 and 2016

While demand for off-grid (stand-alone) PV is growing rapidly, the capacity of grid-connected PV applications is expanding at a faster pace and continues to comprise the vast majority of global solar PV installations. Even though centralized large-scale grid-connected projects have accounted for a rising share of the annual addition compared to other renewable energy sources, one of the advantages of grid-connected PV generation is its wide-ranging power scale. This makes it possible for individuals to implement PV plants, for example, in residential and industrial rooftop systems. Both consumers and power utilities can benefit from the widespread deployment of distributed PV applications which reduce capital expenditure, improve power quality and increase generation and transmission efficiency. In 2016, a capacity of at least 20 GW grid-connected distributed PV systems have been installed worldwide. Supported by new policies established by some countries, there tends to be an increasing demand for small-scale residential PV systems.

B. An Overview Of Grid-Connected Pv Inverter System

As stated earlier, PV systems broadly fall into stand-alone and grid-connected systems. The energy generated in stand-alone systems is consumed by local loads in the same place without the need for interaction with the grid. Therefore, no grid-connected VSI is presented in such systems, and they are outside the scope of this study. Different PV inverter topologies in grid-connected systems are generally categorized based on the number of power processing stages, power scale, and the interconnection of the isolation transformer.

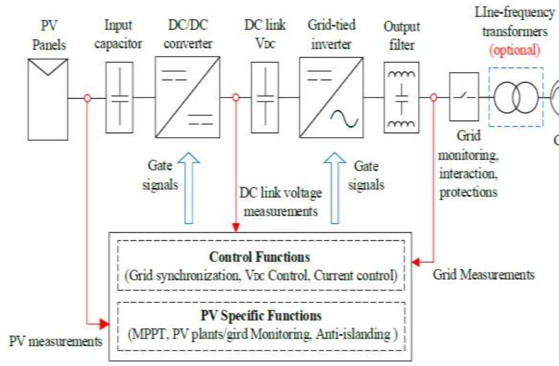

Fig 2 An overview of generic two-stage grid-connected PV inverter system

The control functions are implemented to ensure the grid-connected PV inverter system injects a sinusoidal current to the grid at the highest possible conversion efficiency. More specifically, the outer loop, for DC voltage control, balances the active power between the DC side and the grid side by maintaining the voltage across the DC link capacitor at a specific reference level Meanwhile the current controller and grid synchronization work together as an inner loop to regulate the output sinusoidal current, allowing for the PV inverter and the grid to work in unison. These control functions including output current control and grid synchronization techniques, are discussed in detail in this thesis.

C. Objectives And Scope Of The Research

The utilization of unregulated residential PV systems can have a significant impact on the distribution network. In such systems, power quality aspects have to be addressed so as to ensure reliable grid performance and normal system operation. In recent times, new promising topologies and control methods have been implemented to facilitate less bulky, cost-effective, transformer less solutions. Unfortunately, without galvanic isolation, there are several well-understood technical and safety issues to consider. Among these issues is the risk of DC current flowing into the network which remains a potential concern. Whilst many methods are proposed in the literature there are technical challenges with sensing and controlling DC current injection. Consequently, the present research mainly focuses on the minimization of DC current injection in grid-connected transformer less PV inverter systems.

The specific objectives of the thesis are listed as follows:

- To review the advantages and disadvantages of published DC measurement or suppression techniques along with remaining technical challenges and research barriers.
- To study controller performance against power quality issues including DC and harmonic mitigation in grid-connected PV inverter systems.
- To develop cost-effective solutions to be used to suppress, or compensate for, DC current injection in the grid-connected transformer less inverter.
- To develop simulation models and experimental test rigs in order to validate the proposed DC suppression methods.

D. Contribution

The main original contributions of this research are summarized as follows:

▪ Published DC measurement techniques and suppression methods are categorized based on their desired characteristics. Hardware implementation issues such as the complexity of the design process or cost of components and technical challenges of DC suppression are highlighted.

▪ Mathematical models of the controller, PWM schemes and output filter are developed to determine the system's stability and the power quality of the injected current. The ineffectiveness of current control in terms of DC suppression is confirmed when the measurement devices suffer from offset-drift and non-linearity.

▪ A novel voltage filtering DC extraction approach is developed to detect and suppress the DC voltage component at the inverter output. The approach is low-cost, simple and highly effective and can make a positive contribution in any grid-connected PV inverter system.

• A control-based DC current suppression method using a DC link current sensing technique is developed to minimize DC injection for a grid-connected H-bridge inverter. Full mathematical derivations and detailed analyses are presented to validate the robust performance and cost-effective control offered by the proposed solutions

II. PROPOSED METHODOLOGY

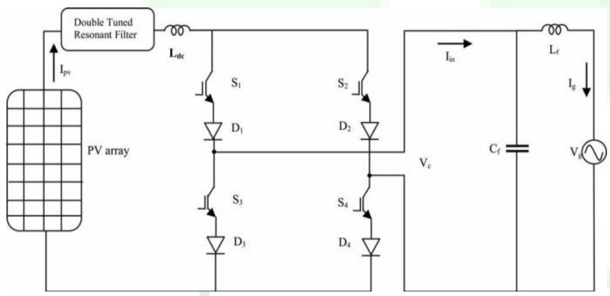

Fig. 3 Main Diagram

A. Double Tuned Resonant Filter

Introduction

In a single-phase Current Source Inverter (CSI), the output is not pure sinusoidal. It is Pulsating. It generates even harmonics in the dc-link current. These even harmonics has two major effects. One is on the ac side as low-order odd harmonics in the current and voltage. Second these even harmonics affect Maximum Power Point Tracker (MPPT) on PV side. This may be reduce Photovoltaic (PV) life. In order to reduce the effect of these dc-side harmonics on the ac side and on the PV. There is a two solution proposed.

One is to use the large value inductance must used. These large value inductance is capable reduce the dc-link current ripple produced by these harmonics. Here we used the inductor of value 300mH.But practically this large value inductance is not possible.

Because it added cost, size, weight & may be losses also. Another major effect is that is slow the MPPT output response. To overcome this, the second solution may be useful. Second To reduce the value of large inductor, a double tuned parallel resonant filter is introduced. This Double Tuned Resonant Filter, generally placed in series with the inductor of low value. This filter is capable of smoothing the dc-link current by using small inductor. Even though the impact of the second-order harmonic is significant in the dc-link current, the fourth-order harmonic can also affect the dc-link current, especially when the Current Source Inverter (CSI) operates at high modulation indices. The basic of Double Tuned Resonant Filter is shown in figure 4.

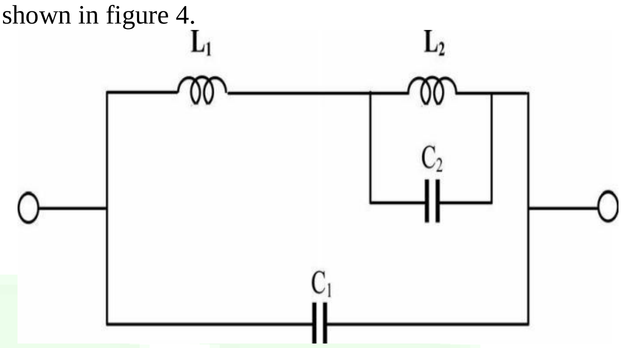

Fig. 4 Double Tuned Resonant Filter

Filter has been widely used in filtering harmonics in power system due to its simple structure, low cost, high reliability, and so on. Usually, there are multiple frequency harmonics in a power system, so a group of parallel single tuned filters are needed to filter harmonics. This filtering method covers a large area and has a high cost. There is a two method for use this filter. One is use two parallel single tuned filters and second is double tuned filters. Double-tuned filter and two parallel single tuned filters have the same function that both of them can filter two different frequency harmonics. However, double-tuned filter has a lower cost than the two parallel single tuned filters.

Design of Double Tuned Resonant Filter

In this section, the design parameters of filter has been discussed. Firstly to eliminate the desired harmonics, the impedance of C1 and the total impedance of L1, L2, and C2 should have equal values of opposite sign. For simplification, assume component resistances are small, and thus negligible for calculation purpose.

Now,

$$\mathbf{Zc1 + Zt = 0} \qquad \mathbf{(1)}$$

Capacitances are given by,

$$C_1 = \frac{L_2C_{2} - 1/\omega^2}{\omega^2 L_1 L_2 C_2 - L_1 - L_2} \qquad (2)$$

$$C_2 = \frac{-L_2}{L_2/C_1 - \omega^2 L_1 L_2} + \frac{1}{\omega^2 L_2} \qquad (3)$$

Here C1 and C2 are the resonant filter capacitances, L1 and L2 are the resonant filter inductances, ZC1 is C1 impedance, Zt is the total impedance of L1, L2 , and C2 respectively. ω is the angular frequency of the second or fourth-orders harmonics.(whatever we consider).By

ISSN(ONLINE):2278 - 3814

solving Equation (2) and (3),we can obtain the value of capacitances. The filter is capable of eliminating both the second and fourth order harmonics.

Now, to obtain the value of inductances L1 and L2,we can get values as

$$L2 \leqslant 1.778L1 \quad (4)$$

To eliminate the no. of harmonics from system, the Capacitances C1,C2.....Cn given as

$$C_1 = L_1\omega_1 + \frac{1}{\omega_1 C_1} + Z_t = 0$$

$$C_2 = L_1\omega_2 + \frac{1}{\omega_2 C_1} + Z_t = 0$$

$$C_n = L_1\omega_n + \frac{1}{\omega_n C_1} + Z_t = 0$$

Hence we can solve it for nth harmonic order.

C. Carrier Based Pulse Width Modulation (CPWM)

Due to some limitation of Sinusoidal Pulse Width Modulation, the Modified Carrier Based Pulse Width Modulation is introduced.

In Sinusoidal Pulse Width Modulation the pulses nearer the peak of sine wave do not change significantly with the variation of modulation index. Second thing that the carrier signal is applied to whole cycle. Its increases no. of switching devices and also increases switching losses.

To overcome above situation Carrier based Pulse Width Modulation is presented. Its provides continuous path for the dc side current. There is one switch either in top or bottom must be ON during every switching period. This can be also achieved in Sinusoidal Pulse Width Modulation (SPWM). In SPWM, due to overlap time. It allows continuous path for dc side current. Overlap time is occur when power devices change it states. This overlap time is not sufficient for energizing dc link inductor. This may be result in increasing Total Harmonic Distortion (THD).

So the Carrier Based sinusoidal Pulse Width Modulation (CBPWM) is presented. Here two carriers and one reference is used. In this carrier wave is applied during the first and last 60º intervals per half cycle. i.e. 0º to 60º and 120º to 180º.This is similarly done for negative half cycle.

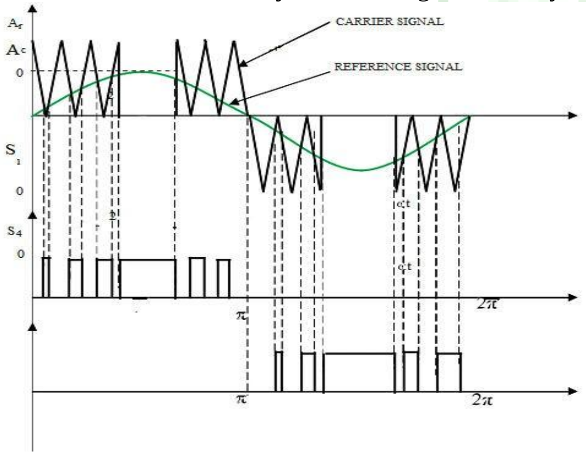

Fig. 5 Carrier Based Pulse Width Modulation

III. SIMULATION AND RESULT

Simulation is done in two modes. One is with use of Double Tuned Resonant Filter and second is without use of Double Tuned Resonant Filter.

A. System Parameters

Table 2.1 System Parameters

PV OpenCircuit Voltage	80 V
PV Short CircuitCurrent	8 A
PV ArrayRated Power	500 W
LDC(With Filter)	5 Mh
LDC(Without Filter)	300 mH
Carrier Frequency	3.5 KHz
L1	5 mH
L2	10 mH
C1	125µF
C2	250µF
AC SideInductorL1	50 mH
AC SideInductorL2	50 mH
AC Side Capacitor	250µF

B. Without use of Double Tuned Resonant Filter

I. Main Diagram

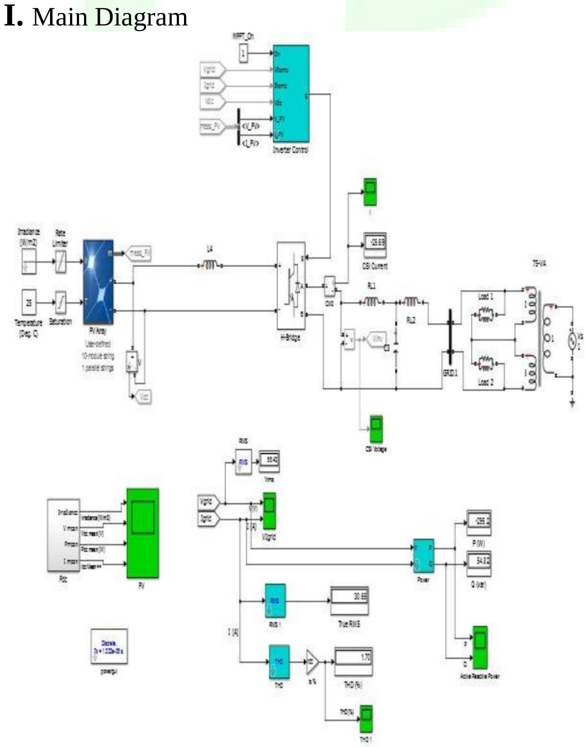

Fig. 6 Main Diagram Without use of Double Tuned Resonant Filter

II. Irradiance

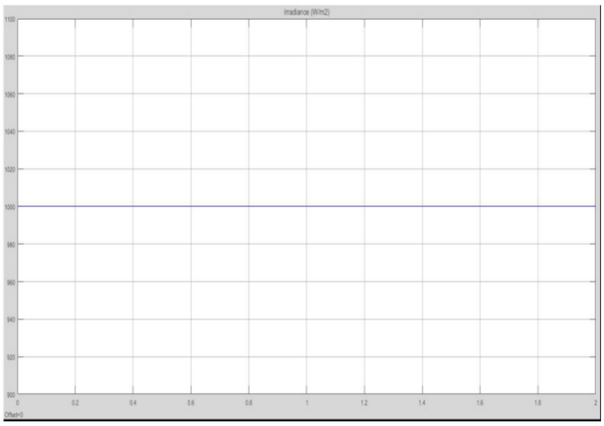

Fig. 7 Irradiance

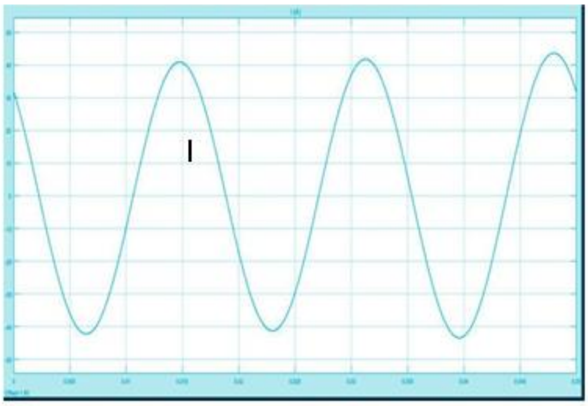

Fig. 8 Grid Current

C. With use of Double Tuned Resonant Filter

I. Main Diagram

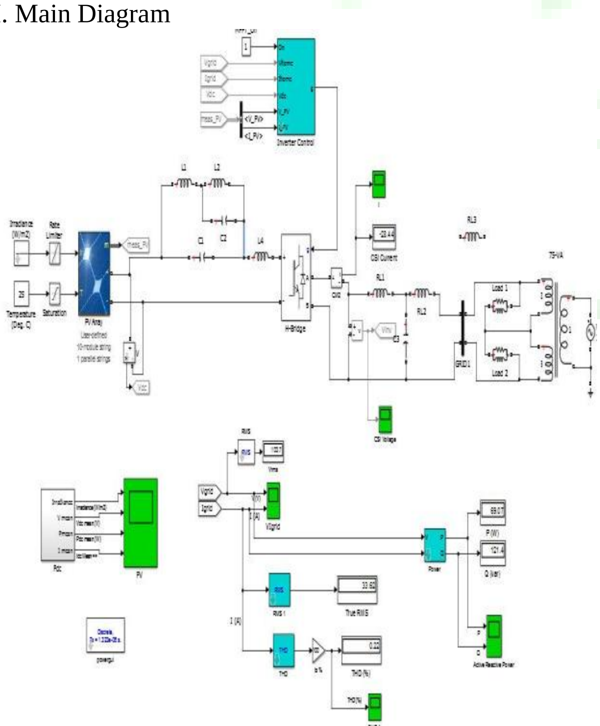

Fig. 9 Main Diagram With use of Double Tuned Resonant Filter

II. Irradiance

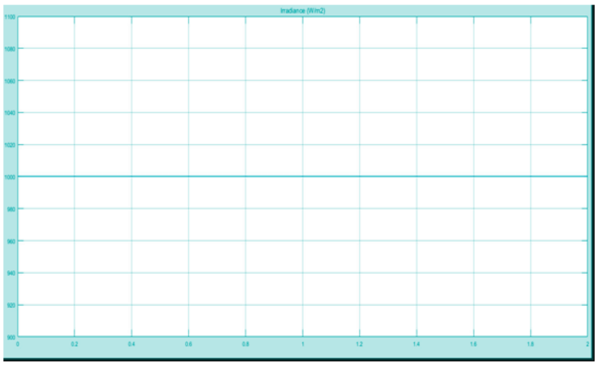

Fig. 10 Irradiance

III. Grid Current

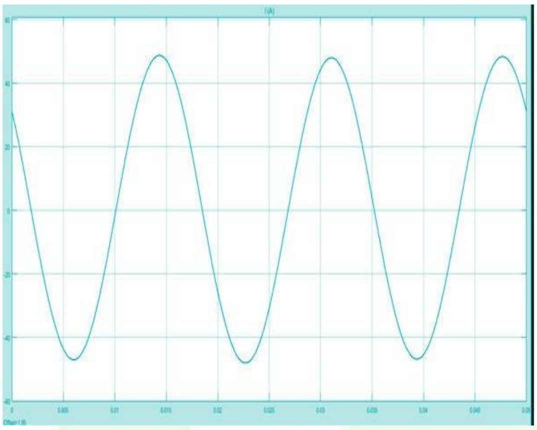

Fig. 11 Grid Current

D. Result Values

I. With Filter

Table 2.2 Result Values 1

Parameter	RMS	Display
Irradiance	1000	1000
InverterCurrent	35.699	28.4344
GridVoltage	101.823	103.721
GridCurrent	33.5222	33.6234
Active Power	676.656	69.0713
Reactive Power	104.793	121.456
THD	1.7323	0.2233
Pdc	488.6	388.44

.

IV. CONCLUSION

This presented work focus on feed forward Cascade-This thesis present a grid connected PV system without use of transformer. The required power for grid is achieved and can be send to grid without use of transformer. The MPPT successfully locks desired voltage at Maximum Power Point. The system uses current source inverter which is further drive by carrier based pulse width modulation. The High value inductor can be reduced by double tuned resonant filter. Resonant filter also eliminated harmonics.

The Total Harmonic Distortion with Inductor is 1.86 and with Double tuned resonant filter 1.73. All results are simulated in MATLAB/SIMULINK.

References

[1] Gallaj, Amir, Mojtaba Beiraghi, Jaber Fallah Ardashir, and Reza Ghanizadeh. "Transformer-less grid-connected 7-level inverter with model predictive control method suitable for PV application." Electrical Engineering (2023): 1-12.

[2] Alam, Md Aftab, S. V. A. V. Prasad, and Mohammed Asim. "Performance analysis of different transformer-less inverter topologies for grid-connected PV systems." Engineering Research Express 5, no. 3 (2023): 035063.

[3] Srivastava, Ankur, and Jeevanand Seshadrinath. "A new nine level highly efficient boost inverter for transformerless grid connected pv application." IEEE Journal of Emerging and Selected Topics in Power Electronics (2022).

[4] Alam, Md Aftab, S. V. A. V. Prasad, and Mohammed Asim. "Comparison and Analysis of Transformer-less Topologies for Grid-Connected PV Systems." In 2022 2nd International Conference on Emerging Frontiers in Electrical and Electronic Technologies (ICEFEET), pp. 1-6. IEEE, 2022.

[5] Chamarthi, Phani Kumar, Ahmed Al-Durra, Tarek HM EL-Fouly, and Khaled Al Jaafari. "A novel three-phase transformerless cascaded multilevel inverter topology for grid-connected solar PV applications." IEEE Transactions on Industry Applications 57, no. 3 (2021): 2285-2297.

[6] Majumdar, Saikat, Kartick Chandra Jana, Pradipta Kumar Pal, Ariya Sangwongwanich, and Frede Blaabjerg. "Design and implementation of a single-source 17-level inverter for a single-phase transformer-less grid-connected photovoltaic systems." IEEE Journal of Emerging and Selected Topics in Power Electronics 10, no. 4 (2021): 4469-4485.

[7] Chandan Kumar, Alka Thakur Wireless Charging Stations for Electric Vehicle IOT Used Solar Power, International Journal of Engineering Applied Science and Management ISSN (Online): 2582 - 6948 Vol. 2 Issue 3 , M arch 2021

[8] Rahimi, Ramin, Masoud Farhadi, Gholam Reza Moradi, Babak Farhangi, and Shahrokh Farhangi. "Filter-clamped two-level three-phase transformerless grid-connected photovoltaic inverter for leakage current reduction." In 2020 IEEE Kansas Power and Energy Conference (KPEC), pp. 1-6. IEEE, 2020.

[9] Guo, Xiaoqiang, et al. "Evaluation of Three-Phase Transformer less DC-Bypass PV Inverters for Leakage Current Reduction." *IEEE Transactions on Power Electronics* 35.6 (2019): 5918-5927.

[10] Sabry, Ahmad H., et al. "Single-phase grid-tied transformer less inverter of zero leakage current for PV system." IEEE Access 8 (2019): 4361-4371.

[11] Li, Xiaoyan, et al. "Simultaneous common-mode resonance circulating current and leakage current suppression for transformer less three-level T-type PV inverter system." IEEE Transactions on Industrial Electronics 66.6 (2018): 4457-4467.

[12] Rajeev, Mini, and Vivek Agarwal. "Analysis and control of a novel transformer-less microinverter for PV-grid interface." IEEE Journal of Photovoltaics 8.4 (2018): 1110-1118.

[13] Valderrama, Gerardo Escobar, et al. "A single-phase asymmetrical T-type five-level transformer less PV inverter." IEEE Journal of Emerging and Selected Topics in Power Electronics 6.1 (2017): 140-150.

[14] Kafle, Yuba Raj, et al. "Performance comparison of single-phase transformer less PV inverter systems." 2017 IEEE Applied Power Electronics Conference and Exposition (APEC). IEEE, 2017.

[15] Sayyed Sadiq Ali; Alka Thakur “Juxtaposition of Different MPPT Algorithms”, International Journal of Research In Science & Engineering, Volume 3 , Issue 3 , May-June,2017. Online ISSN : 2394-8299

[16] Guo, Xiaoqiang, and Xiaoyu Jia. "Hardware-based cascaded topology and modulation strategy with leakage current reduction for transformer less PV systems." IEEE Transactions on Industrial Electronics 63.12 (2016): 7823-7832.

[17] Khan, Shakil Ahamed, Youguang Guo, and Jianguo Zhu. "A high efficiency transformer less PV grid-connected inverter with leakage current suppression." 2016 9th International Conference on Electrical and Computer Engineering (ICECE). IEEE, 2016.

[18] Guo, Xiaoqiang, David Xu, and Bin Wu. "Three-phase DC-bypass topologies with reduced leakage current for transformer less PV systems." 2015 IEEE Energy Conversion Congress and Exposition (ECCE). IEEE, 2015.

[19] Rajeev, Mini, and Vivek Agarwal. "Novel transformer-less inverter topology for single-phase grid connected photovoltaic system." *2015 IEEE 42nd Photovoltaic Specialist Conference (PVSC)*. IEEE, 2015.

[20] Vázquez, Nimrod, et al. "A new common-mode transformer less photovoltaic inverter." *IEEE Transactions on Industrial Electronics* 62.10 (2015): 6381-6391.

[21] Zhao, Tiefu, et al. "Evaluation of commercial scale transformer less solar inverter technology." *2015 IEEE Energy Conversion Congress and Exposition (ECCE)*. IEEE, 2015.

[22] Song, Xiaomei, et al. "Common mode leakage current analysis for transformer less PV system with long DC side cables." *2015 9th International Conference on Power Electronics and ECCE Asia (ICPE-ECCE Asia)*. IEEE, 2015.

[23] Chen, Baifeng, and Jih-Sheng Lai. "A family of single-phase transformer less inverters with asymmetric phase-legs." *2015 IEEE Applied Power Electronics Conference and Exposition (APEC)*. IEEE, 2015.

[24] Islam, Monirul, and Saad Mekhilef. "Analysis and comparison of different grid-tied transformer less inverters for PV system." *2015 Saudi Arabia Smart Grid (SASG)*. IEEE, 2015.

[25] Zhang, Li, et al. "Parallel operation of modular single-phase transformerless grid-tied PV inverters with common DC bus and AC bus." *IEEE Journal of Emerging and Selected Topics in Power Electronics* 3.4 (2015): 858-869.

[26] Wang, Gang, Clifford C. Youn, and Alex M. Stankovic. "DC-side high impedance ground fault detection for transformerless single-phase PV systems." *2015 North American Power Symposium (NAPS)*. IEEE, 2015.

[27] Liu, Chuang, et al. "Transformer less photovoltaic inverter based on interleaving high-frequency legs having bidirectional capability." *IEEE Transactions on Power Electronics* 31.2 (2015): 1131-1142.

[28] Selvamuthukumaran, Rajasekar, Abhishek Garg, and Rajesh Gupta. "Hybrid multicarrier modulation to reduce leakage current in a transformer less cascaded multilevel inverter for photovoltaic systems." *IEEE Transactions on Power Electronics* 30.4 (2014): 1779-1783.

[29] Xiao, Hua F., Ke Lan, and Li Zhang. "A quasi-unipolar SPWM full-bridge transformer less PV grid-connected inverter with constant common-mode voltage." *IEEE Transactions on Power Electronics* 30.6 (2014): 3122-3132.

[30] Guo, Xiaoqiang, et al. "New inverter topology for ground current suppression in transformer less photovoltaic system application." *Journal of Modern Power Systems and Clean Energy* 2.2 (2014): 191-194.

[31] Xiao, Hua F., Xi P. Liu, and Ke Lan. "Zero-voltage-transition full-bridge topologies for transformer less photovoltaic grid-connected inverter." *IEEE Transactions on Industrial Electronics* 61.10 (2014): 5393-5401.

[32] Anand, Sandeep, Saikrishna Kashyap Gundlapalli, and B. G. Fernandes. "Transformer-less grid feeding current source inverter for solar photovoltaic system." *IEEE Transactions on Industrial Electronics* 61.10 (2014): 5334-5344.

[33] Gautam, Vasav, Ashok Kumar, and Parthasarathi Sensarma. "A novel single stage, transformer less PV inverter." *2014 IEEE International Conference on Industrial Technology (ICIT)*. IEEE, 2014.

[34] Freddy, Tan Kheng Suan, et al. "Comparison and analysis of single-phase transformer less grid-connected PV inverters." *IEEE Transactions on Power Electronics* 29.10 (2013): 5358-5369.

[35] Buticchi, Giampaolo, et al. "A nine-level grid-connected converter topology for single-phase transformer less PV systems." *IEEE Transactions on industrial electronics* 61.8 (2013): 3951-3960.

[36] Saridakis, Stefanos, Eftichios Koutroulis, and Frede Blaabjerg. "Optimal design of modern transformer less PV inverter topologies." *IEEE transactions on energy conversion* 28.2 (2013): 394-404.

[37] Zhou, Yufei, et al. "A transformer less grid-connected photovoltaic system based on the coupled inductor single-stage boost three-phase inverter." *IEEE Transactions on Power Electronics* 29.3 (2013): 1041-1046.

[38] Ming, Wen-Long, and Qing-Chang Zhong. "Synchronverter-based transformer less PV inverters." *IECON 2014-40th Annual Conference of the IEEE Industrial Electronics Society*. IEEE, 2014.

