iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** VIII **Month of publication:** Aug 2023

DOI: https://doi.org/10.22214/ijraset.2023.55386

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VIII Aug 2023- Available at www.ijraset.com

Transformerless Grid-Connected Inverters: Advancements, Challenges, and Future Prospects

Sharvendra Kumar Omre[1], Ashutosh[2], Ankit Kumar Sharma[3], Mitali Thakur[4]
[1, 2, 3, 4]*Department of Electrical Engineering, NITTTR, Chandigarh*

Abstract: The rapid growth of renewable energy sources and the increasing demand for efficient power conversion have spurred significant advancements in grid-connected inverter technology. Among these, transformerless grid-connected inverters have emerged as a prominent solution due to their compact size, reduced cost, and enhanced efficiency. This review paper provides a comprehensive analysis of transformerless grid-connected inverters, focusing on their operational principles, key topologies, benefits, challenges, and potential future developments. Through a systematic exploration of recent research and industry trends, this paper aims to offer a comprehensive understanding of the state-of-the-art in transformerless grid-connected inverter technology.
Keywords: Transformerless inverters, grid-connected inverters, renewable energy, power conversion, topologies, efficiency, challenges, future prospects.

I. INTRODUCTION

In recent years, the increasing global demand for clean and sustainable energy sources has led to a significant upsurge in the integration of renewable energy systems into the power grid. Solar photovoltaic (PV) and wind power installations, in particular, have witnessed remarkable growth due to advancements in technology and favourable regulatory policies. As these renewable energy sources generate direct current (DC), efficient conversion to alternating current (AC) is essential for seamless integration with the grid as shown in fig.1. Transformerless grid-connected inverters have emerged as a pioneering solution in this context, offering compactness, cost-effectiveness, and enhanced efficiency compared to their transformer-based counterparts [1].

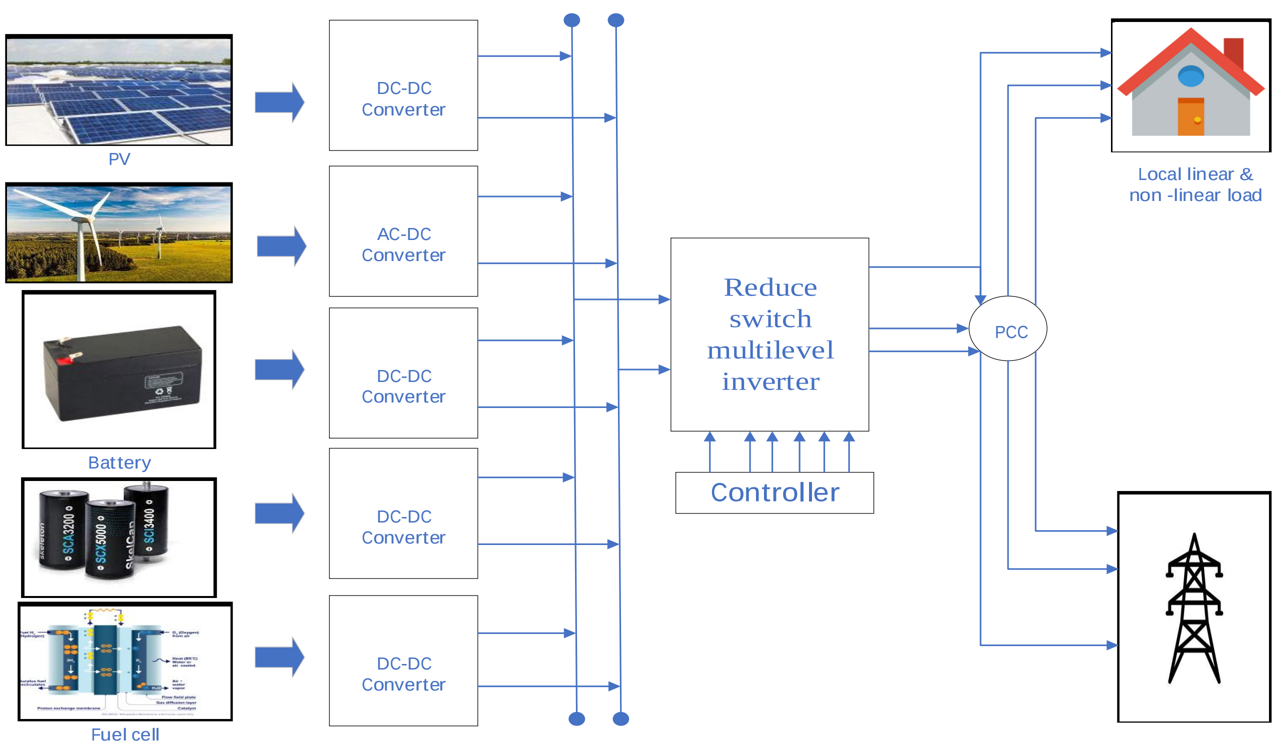


Fig.1 Energy source integration with MLI

To prevent electrical shocks and other risks, isolation transformers have long been used in grid-connected inverters to isolate the DC input from the AC output. However, these transformers increase the system's weight, cost, and losses. However, grid-connected inverters that do not need isolation transformers are possible thanks to cutting-edge circuit topologies and control methods. The absence of these components results in a decrease in size, weight, and cost, making them competitive in many grid-connected uses.

This review paper aims to provide a comprehensive overview of transformerless grid-connected inverters, delving into their operational principles, various topologies, benefits, challenges, and the potential future directions in this rapidly evolving field [2] [3]. By synthesizing recent research findings, industry developments, and technological trends, this paper seeks to offer a holistic understanding of the advancements and challenges associated with transformerless grid-connected inverter technology. Moreover, it aims to shed light on the critical role that these inverters play in enabling the seamless integration of renewable energy sources into the modern power grid.

In the subsequent sections, the paper will explore the operational principles that underlie transformerless grid-connected inverters, presenting an array of innovative circuit topologies that have been developed to achieve efficient power conversion. The benefits of these inverters, including reduced size, improved efficiency, and enhanced power density, will be examined in detail [4]. Challenges such as safety concerns, leakage current issues, and grid interaction will also be discussed, along with potential mitigation strategies.

Furthermore, the paper will explore the future prospects and research directions of transformerless grid-connected inverters, considering the ongoing advancements in semiconductor technology, control strategies, and emerging wide-bandgap devices. As the global energy landscape continues to shift towards sustainable and decentralized solutions, transformerless grid-connected inverters are poised to play a pivotal role in facilitating the seamless integration of renewable energy into the grid.

II. LITERATURE SURVEY

The transformerless cascaded multilevel inverter used by Rajasekar Selvamuthukumaran et al., which uses a hybrid multicarrier pulse width modulation (H -MCPWM) method, is effective in reducing leakage current. Leakage current may be drastically decreased using the modulation approach without the need for any additional components. The proposed H-MCPWM method provides reduced leakage current in the transformerless PV inverter system since it uses fewer carriers and is easy to install as a modulation technique. [5]. Phani Kumar Chamarthi et al. have described and verified the 3-CHB inverter architecture for the PV-fed grid-connected system through computation and experimentation. The suggested modulation approach for the 3-CHB MLI architecture greatly decreased leakage current. It was also established that the reduced leakage current (VDE012601-01) was generally acceptable [6]. In order to give the proposed inverter desirable characteristics like high efficiency and boosting capability during single stage operation, N. Vosoughi et al. presented a series-parallel switching conversion of the integrated switched-capacitor module in a packed unit. Using a common grounding method has the added benefit of reducing leakage current. [7]. A five-level common ground transformerless inverter for PV systems is recommended by Felipe Bovolini Grigoletto. Its output harmonic content is lower. The suggested inverter delivers a maximum dc-voltage utilisation and can manage reactive power, in contrast to half-bridge-based topologies. [8].

G. Veera Bharath et al. introduced multiple transformerless switched capacitor (TSC5LI) topologies for photovoltaic (PV) applications. Maintaining constant grid frequency voltage at PV parasitic capacitors, the four inverter topologies in the proposed family (H8, H8-UPF, H10, and H10-UPF) are able to decrease leakage current even when switch terminal capacitances are included. [9]. Reza Barzegarkhoo and coworkers have shown a unique five-level grid-connected inverter that does not need a transformer. The leakage current problem may be addressed by using the recommended topology, which has a common-grounded layout. Because of its two-fold voltage-boost capabilities and well-balanced active and passive components, it is well-suited for use in PV string applications. The following method for regulating the injected current involves a phase-locked-circuit (PCC). [10].

N. Vosoughi et al. have introduced a novel method for a grid-connected inverter, which eliminates the need for a single-phase transformer. The series-parallel switching conversion utilising the integrated switched-capacitor module in a compact unit demonstrated several attractive characteristics, including an impressive overall efficiency exceeding 97%, the capability to perform dual boosting within a single stage, and the near elimination of leakage current through the implementation of the common grounding technique. The use of a peak current controller technology is employed for the purpose of activating the gates of power switches and effectively regulating both the active and reactive powers [11]. Xiaoqiang Guo et al. conducted an investigation on the relationship between leakage current, common-mode voltage, and differential mode voltage. The issue is resolved by the implementation of a novel three-phase cascaded H5 grid-connected inverter and its corresponding modulation scheme [12].

Reza Barzegarkhoo and colleagues used the SC approach to introduce a novel CG-based TL-inverter structure. Higher voltage gain and output voltage levels can be generated using the converters. [13]. It is more difficult to solve the switching angles due to the asymmetric selective harmonics elimination (SHE) equation that is produced by the asymmetric multilevel inverter (AMLIs) in the cascaded H-bridge (CHB), according to K. yang et al. Results demonstrate the accuracy of this unified SHE approach for CHB AMLIs [14].

III. CONVENTIONAL TOPOLOGIES AND ARCHITECTURE

Multilevel inverters (MLIs) are suitable for high-voltage applications due to their ability to generate output voltage waveforms with enhanced harmonics spectrum and reach greater voltage levels while adhering to the maximum device rating limitations. The user's text is not sufficient to be rewritten in an academic manner. Please provide more by appropriately configuring power switching semiconductor devices and voltage sources, it is possible to generate a multilayer output.

Multilevel inverters (MLI) may be classified into following three overarching categories:

1) Diode-Clamped (neutral-point-clamped)
2) Flying Capacitor
3) Cascaded H-Bridge.

A. Diode -Clamped (Neutral Point Clamped)

Three power electronic switches and two DC voltage sources make up a three-level inverter, also referred to as a neutral-point-clamped (NPC) or diode-clamped MLI. The DC voltage sources are connected in series with a midpoint neutral point, and the switches are connected in a three-phase bridge configuration. Five voltage levels, including zero, positive, negative, and two intermediate voltage levels, can be produced with this design here fig.2 shows a diode-clamped (Neutral point clamped) multilevel inverter.

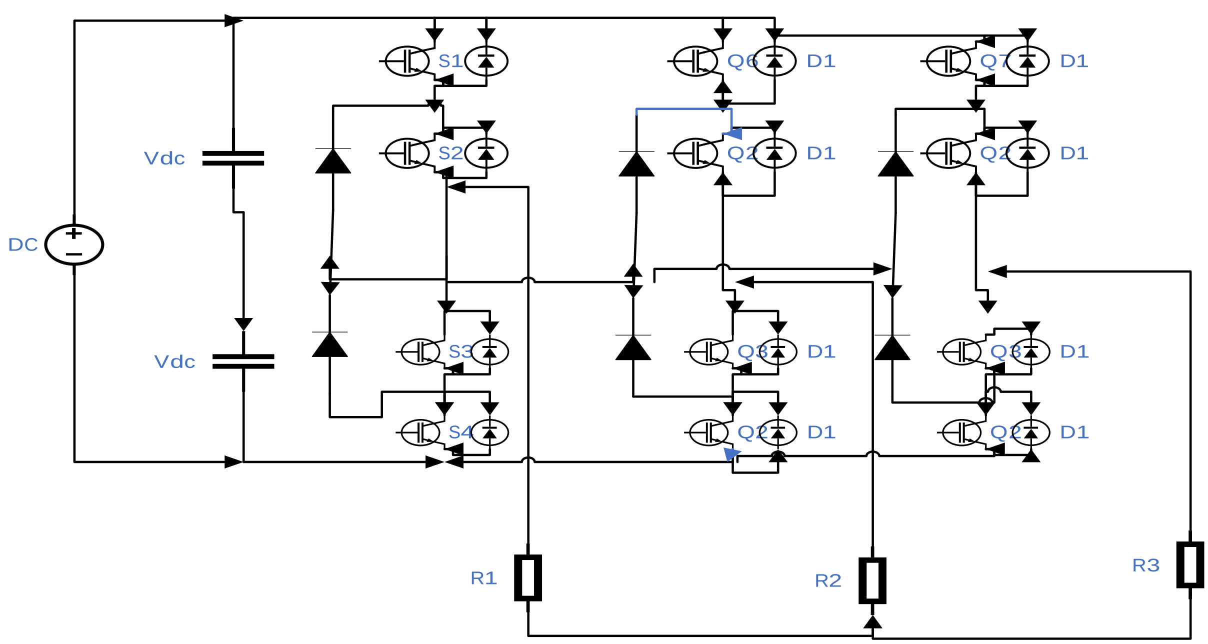


Fig.2 Diode-clamped (Neutral point clamped)

1) *Limitations*

- For higher level generation, large number of capacitors and clamping diodes are required.
- Voltage balancing is difficult.

2) *Applications*

- Low- medium voltage
- Ac motor drive applications and PV.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VIII Aug 2023- Available at www.ijraset.com

B. *Flying Capacitor MLI*

Flying capacitor MLI generates voltage levels using capacitors rather than DC voltage sources. It is made up of a centre point and a series of capacitors, each of which is connected to two power electronic switches shown in fig.3. Comparatively speaking, this topology can generate more voltage levels than the diode-clamped MLI.

1) *Limitations*

- Involves large number of capacitors to get higher levels
- The structure becomes bulky & expensive for high power application.

2) *Applications*

- Low-medium voltage
- Drives application

C. *Cascaded H-Bridge MLI*

Multiple H-bridge cells are connected in series to form a cascading H-bridge MLI. Four power electronic switches and a DC voltage source make up each H-bridge cell shown in fig.4. The number of cells can be raised to achieve larger power levels, and this topology can generate a wide range of voltage levels.

The advantages of MLI over typical two-level inverters are lower harmonic distortion, less electromagnetic interference, lower voltage stress on the switches, and increased efficiency. However, MLIs require sophisticated control algorithms to ensure optimal performance and are more expensive and complex than two-level inverters.

1) *Limitations*

- More number of semiconductor switches are involved.
- Requires a number of isolated dc sources.

2) *Applications*

- Medium – high voltage
- Drives, electric vehicle
- Renewable energy

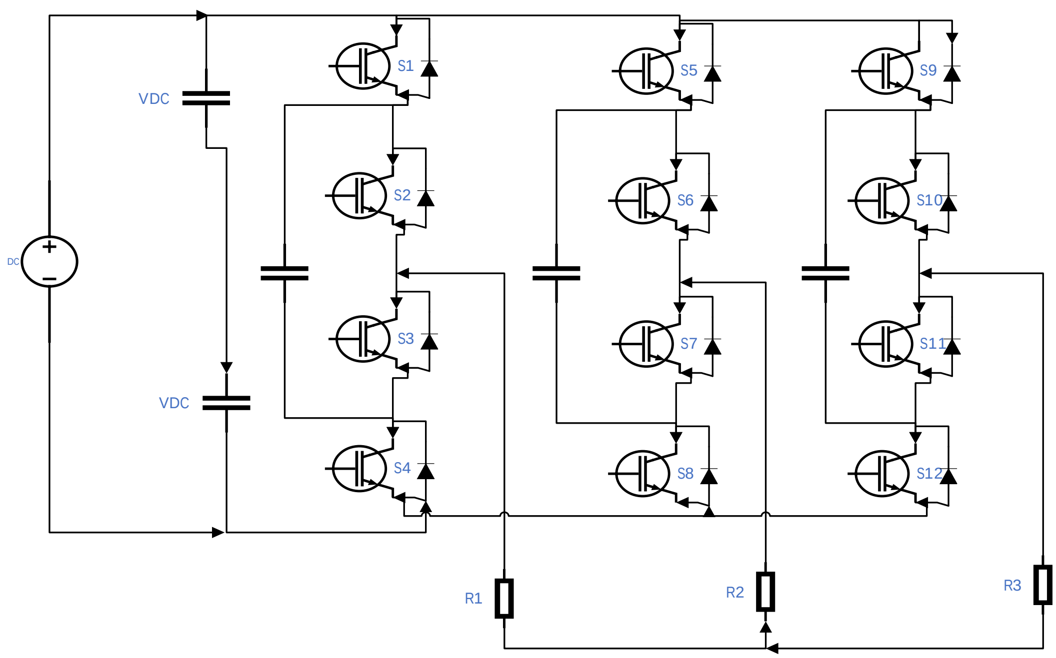


Fig.3 Flying Capacitor MLIs

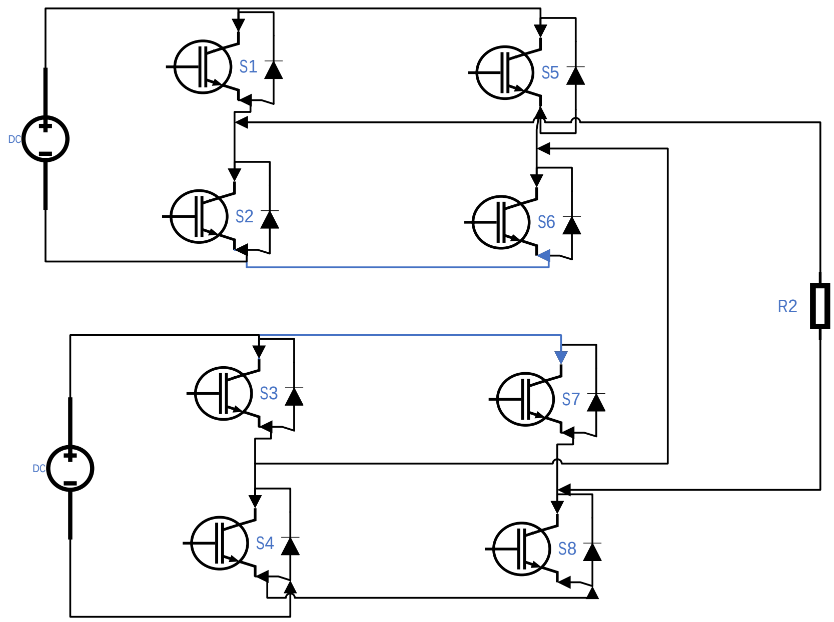


Fig.4 Cascaded H-Bridge MLIs

.

IV. BENEFITS AND CHALLENGES OF TRANSFORMERLESS GRID- CONNECTED INVERTERS.

A transformerless grid-connected inverter is a type of inverter used in photovoltaic (PV) systems that eliminates the need for a traditional transformer for grid integration. Instead of using a transformer to match the voltage levels, transformerless inverters directly convert the DC power generated by the PV panels into AC power for grid injection or consumption.

While transformerless grid-connected inverters offer various advantages, they also have some potential disadvantages and considerations that need to be taken into account. Here are a few disadvantages of transformerless grid-connected inverters.

It is important to address these disadvantages through proper design, implementation, and adherence to safety standards and regulations. Transformerless grid-connected inverters require careful consideration of grounding techniques, leakage current mitigation methods, insulation monitoring, and control strategies to ensure safe and reliable operation. Consulting with experts and following best practices is essential when implementing transformerless grid-connected inverters in PV system. Table.1 is describing the benefits and limitation of grid-connected inverters.

Table.1 Benefits and Limitation of Grid-Connected Inverters

S.No.	Benefits	Limitation
1	Increased Efficiency	Increased Risk of leakage current
2	Reduced size and weight	Lack of Ground Fault Protection
3	Cost saving	Challenging voltage level matching
4	Enhanced response time	Limited voltage boosting capability.
5	Simplified design and maintenance	Grid Compatibility and power quality concerns
6	High frequency operation	Sensitive to Grid disturbances

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VIII Aug 2023- Available at www.ijraset.com

Table.2 Comparison Study of Different Grid Connected Inverter

Type of Converter	Total no. of components				No. of on state switches	Output Filter			Vin(V)	Boosting feature	No. of Output Levels	Leakage Current	Reported Efficiency%	Overall** system efficiency%
	S	**D**	**C**	**L**		**Lf1**	**Lf2**	**Cf**						
H5[16-17]	5	0	1	0	3	3mH	3mH	0.47uF	400	No	3	Non-Zero	98.5(0.5kw)	0.95*0.985=%93.5
OH5[17]	6	0	2	0	3	4mH	4mH	6.6uF	400	No	3	Non-Zero	97.2(1kw)	0.95*0.972=%92.3
H6[18-19]	6	2	2	0	3	3mH	3mH	0.47uF	400	No	3	Non-Zero	97.4(1kw)	0.95*0.974=%92.5
HERIC	6	2	1	0	2	3mH	3mH	2.2uF	400	No	3	Non-Zero	97(1kw)	0.95*0.97=%92.1
Active NPC [20]	6	0	2	0	2	NA	NA	NA	800	No	3	NA	97.34(10kw)	0.95*0.973=%92.4
HB-ZVR [21]	5	5	2	0	2	1.8mH	1.8mH	2uF	400	No	3	Non-Zero	94.88(2.8kw)	0.95*0.948=%90.13
Karschny [22]	5	2	1	1	3	NA	NA	NA	400	No	3	zero	NA	NA
[23]	5	0	2	0	2	8mH	0.8mH	0.34uF	400	No	3	zero	95.20(0.5kw)	0.95*0.95=%90.25
[24]	4	2	2	0	2	4mH	2mH	2.2uF	400	No	3	zero	97.50(0.5kw)	0.95*0.975=%92.62
[25]	2	0	2	1	1	1mH	1mH	2.2uF	400	No	2	zero	96.00(0.2kw)	0.95*0.975=%91.2
[26]	5	0	2	1	2	0.3mH		3.3uF	100	Yes	3	zero	92.50(0.2kw)	92.50%
[27]	5	0	1	0	3	3mH	3mH	2.2uF	400	No	3	Non-Zero	98.00(1kw)	0.95*0.98=%93.1
[28]	6	3	2	0	3	1mH	1mH	2.2uF	400	No	3	Non-Zero	98.5(0.6kw)	0.95*0.98=%93.57
[29]	6	6	1	0	3	2mH	2mH	2.2uF	400	No	3	Non-Zero	98.4 (0.51kw)	0.95*0.984=%93.48

V. MODULATION TECHNIQUES USED IN ML-GCI

The four kinds of ML-MFGCI modulation techniques are (i) SPWM, (ii) Hysteresis, (iii) Selective Harmonic Elimination, and (iv) SVPWM as shown in fig. 5.

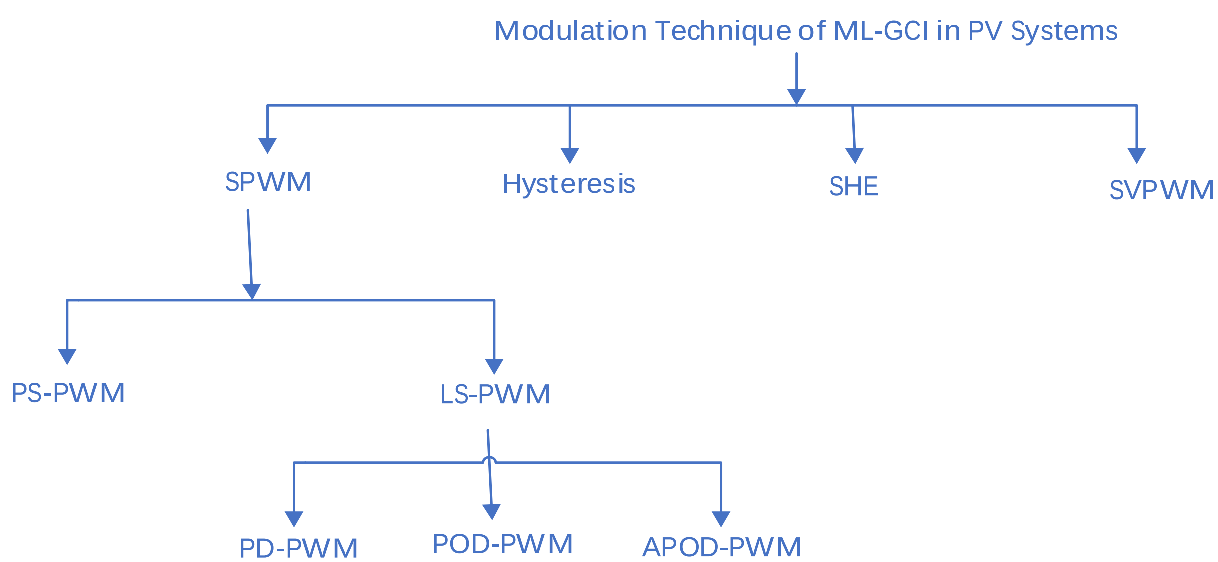


Fig.5 Classification of ML-GCI based on modulation techniques.

A. Sinusoidal Pulse Width Modulation (SPWM)

Power dissipation is one of the most crucial difficulties in high power PV systems, where a sinusoidal reference voltage waveform is compared with a triangular carrier waveform to generate gate signals for the inverter switches. To reduce switching losses, the fundamental frequency SPWM control approach was suggested. The phase shifted (PS) control technique is used for horizontal arrangements, while the multi-carrier SPWM control methods are classified as level shifted (LS-PWM), which includes phase disposition (PD-PWM), phase opposition disposition (POD-PWM), and alternative phase opposition disposition (APOD-PWM), and have been used to improve the performance of multilevel inverters. In actuality, PS-PWM is only useful for cascaded H-bridges and flying capacitors, whereas PD-PWM is more useful for NPC and is more useful for cascaded H-bridges and flying capacitors. Fig. 5 provides illustrations of each of the aforementioned multi-carrier SPWM control techniques.

Ref [30] created a better phase disposition PWM (PD-PWM) for use with an ML-GCI in a PV system. This novel modulation approach is based on selective virtual loop mapping (SVLM), which permits dynamic capacitor voltage balancing without an extra compensation signal. First, virtual submodules (VSMs) are established, and then the loop mapping relationships between the VSMs and the actual submodules are modified to provide the desired voltage balance between the capacitors in the upper and lower arms. Due to the fact that this method merely determines the MIN and MAX capacitor voltage's index and does not need sorting voltages from highest to lowest, it is well-suited for a modular multilevel converter with numerous submodules in one arm. When compared to carrier PS-PWM, this technique facilitates the management of circulating current, is simpler to apply in FGPAs, and provides far stronger dynamic regulation capabilities.

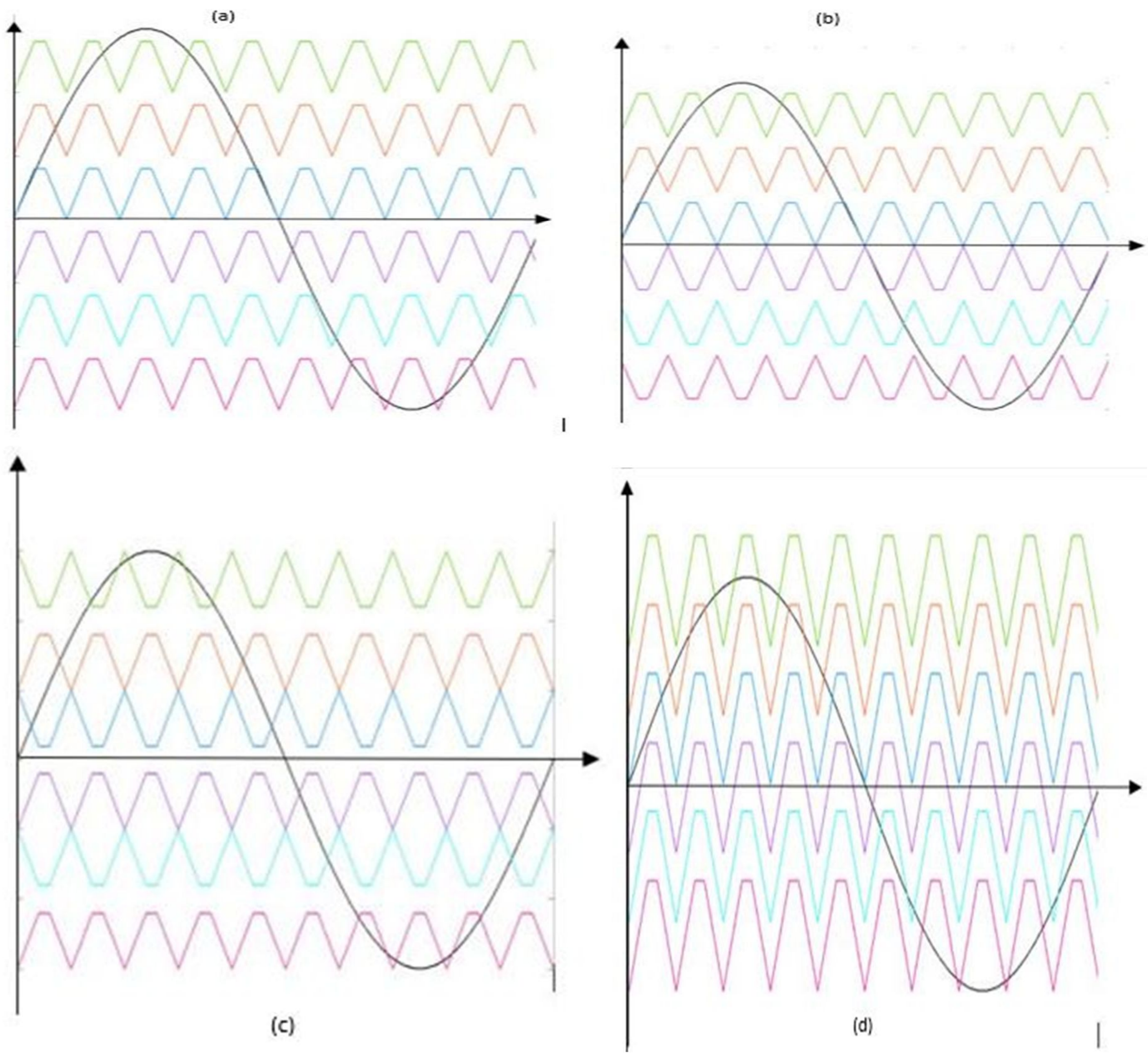


Fig.5 Multi-carrier SPWM controls strategies: (a) PD, (b) POD, (c) APOD, (d) PS.

B. Hysteresis Technique

The switching signals are calculated by comparing the current error signal with a hysteresis band of constant width. This approach is very stable, has fast dynamics, and can restrict current automatically. Some drawbacks of this method include the formation of fluctuating modulation frequencies for active power filters, the complexity of constructing the input filters to active power filters, and the possibility for the generation of undesirable resonance on utility grids [30]. Using active power filters in systems with isolated neutrals is problematic because of the unfavourable effects of phase current interactions and current coupling on filter performance. There have been several suggested solutions to the underlying issue.

C. Selective Harmonic Elimination PWM (SHE-PWM)

The SHE-PWM approach is predicated on the removal of certain harmonic orders and relies on fundamental frequency switching. The idea behind this technique is to eliminate the fundamental component and obtain the fourier coefficient or harmonic components of the predefined switching waveform with unknown switching angles, all while maintaining the fundamental component at the desired reference amplitude [30]. The low switching frequency required by three-level inverters to reduce semiconductor losses makes SHE a promising option.

D. Space Vector PWM(SVPWM)

Determine the suitable switching state and their duty cycle in accordance with a specific modulation scheme is the goal of space vector modulation (SVM). The six sectors of the SVM's complex operating plane are divided into turn-on and turn-off switching states in the power circuits [30]. The turn-on time for each switch is calculated by locating two consecutive switching-state vectors using the reference vector. SVM has a poor response time because of the intrinsic calculation delay even if digital control techniques have superior dependability and flawless anti-jamming. It is advised that deadbeat control be improved upon and that the reactive system components be slightly oversized in order to address this problem.

VI. CONCLUSION

In this article from the fundamental AC-DC and DC-DC converters that underpin energy conversion to the sophisticated multilevel inverters and advanced modulation techniques enhancing power quality, the topologies and architectures in power electronics showcase an intricate tapestry of innovation. These diverse solutions cater to a wide spectrum of needs, from motor drives and industrial automation to renewable energy systems and grid stabilization.

In conclusion, the realm of power electronics stands as a cornerstone of the modern energy landscape, bridging the gap between generation and consumption. Its diverse topologies, intelligent control strategies, and adaptable architectures play an instrumental role in shaping the energy systems of tomorrow. As the world marches toward a more sustainable and interconnected future, the fusion of power electronics with visionary thinking is poised to reshape the very foundation of how we harness and utilize electrical power.

VII. FUTURE SCOPE

The future of transformerless grid-connected inverters holds great promise as these innovative devices continue to shape the integration of renewable energy sources and the advancement of power electronics technology. Ongoing research aims to enhance the efficiency of transformerless inverters through optimized circuit topologies, reduced switching losses, and the utilization of advanced semiconductor materials like wide-bandgap devices (SiC and GaN). The following key areas represent the future scope for transformerless grid-connected inverters: Efficiency Enhancement, Advanced Control Strategies, Higher Power Density, Voltage Boosting Techniques, Harmonic Mitigation, Safety and Isolation.

In conclusion, the horizon for transformerless grid-connected inverters shines bright as ongoing endeavors focus on achieving heightened efficiency, enriched control capabilities, and expanded applications. As the global drive towards cleaner energy intensifies, transformerless inverters are poised to facilitate the seamless integration of renewable energy sources into the grid, thereby propelling the transition to a more sustainable and resilient energy landscape.

REFERENCES

[1] P. R. Bana, K. P. Panda, R. T. Naayagi, P. Siano and G. Panda, "Recently Developed Reduced Switch Multilevel Inverter for Renewable Energy Integration and Drives Application: Topologies, Comprehensive Analysis and Comparative Evaluation," in IEEE Access, vol. 7, pp. 54888-54909, 2019, doi: 10.1109/ACCESS.2019.2913447.

[2] P. R. Bana, K. P. Panda, R. T. Naayagi, P. Siano and G. Panda, "Recently Developed Reduced Switch Multilevel Inverter for Renewable Energy Integration and Drives Application: Topologies, Comprehensive Analysis and Comparative Evaluation," in IEEE Access, vol. 7, pp. 54888-54909, 2019, doi: 10.1109/ACCESS.2019.2913447.

[3] H. Xiao, "Overview of Transformerless Photovoltaic Grid-Connected Inverters," in IEEE Transactions on Power Electronics, vol. 36, no. 1, pp. 533-548, Jan. 2021, doi: 10.1109/TPEL.2020.3003721.

[4] X. Guo, J. Zhou, R. He, X. Jia and C. A. Rojas, "Leakage Current Attenuation of a Three-Phase Cascaded Inverter for Transformerless Grid-Connected PV Systems," in IEEE Transactions on Industrial Electronics, vol. 65, no. 1, pp. 676-686, Jan. 2018, doi: 10.1109/TIE.2017.2733427.

[5] R. Selvamuthukumaran, A. Garg and R. Gupta, "Hybrid Multicarrier Modulation to Reduce Leakage Current in a Transformerless Cascaded Multilevel Inverter for Photovoltaic Systems," in IEEE Transactions on Power Electronics, vol. 30, no. 4, pp. 1779-1783, April 2015, doi: 10.1109/TPEL.2014.2345501.

[6] P. K. Chamarthi, A. Al-Durra, T. H. M. EL-Fouly and K. A. Jaafari, "A Novel Three-Phase Transformerless Cascaded Multilevel Inverter Topology for Grid-Connected Solar PV Applications," in IEEE Transactions on Industry Applications, vol. 57, no. 3, pp. 2285-2297, May-June 2021, doi: 10.1109/TIA.2021.3057312.

[7] S. Mondal, S. P. Biswas, M. R. Islam and S. M. Muyeen, "A Five-Level Switched-Capacitor Based Transformerless Inverter with Boosting Capability for Grid-Tied PV Applications," in IEEE Access, vol. 11, pp. 12426-12443, 2023.

[8] N. Vosoughi, S. H. Hosseini and M. Sabahi, "A New Transformer-Less Five-Level Grid-Tied Inverter for Photovoltaic Applications," in IEEE Transactions on Energy Conversion, vol. 35, no. 1, pp. 106-118, March 2020, doi: 10.1109/TEC.2019.2940539.

[9] F. B. Grigoletto, "Five-Level Transformerless Inverter for Single-Phase Solar Photovoltaic Applications," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 8, no. 4, pp. 3411-3422, Dec. 2020, doi: 10.1109/JESTPE.2019.2891937.

[10] G. V. Bharath, A. Hota and V. Agarwal, "A New Family of 1-φ Five-Level Transformerless Inverters for Solar PV Applications," in IEEE Transactions on Industry Applications, vol. 56, no. 1, pp. 561-569, Jan.-Feb. 2020, doi: 10.1109/TIA.2019.2943125.

[11] N. Vosoughi, S. H. Hosseini and M. Sabahi, "A New Single-Phase Transformerless Grid-Connected Inverter with Boosting Ability and Common Ground Feature," in IEEE Transactions on Industrial Electronics, vol. 67, no. 11, pp. 9313-9325, Nov. 2020, doi: 10.1109/TIE.2019.2952781.

[12] M. S. Irfan, A. Ahmed and J. -H. Park, "Power-Decoupling of a Multiport Isolated Converter for an Electrolytic-Capacitorless Multilevel Inverter," in IEEE Transactions on Power Electronics, vol. 33, no. 8, pp. 6656-6671, Aug. 2018.

[13] T. -K. T. Nguyen, N. -V. Nguyen and N. R. Prasad, "Eliminated common-mode voltage pulse width modulation to reduce output current ripple for multilevel inverters," in IEEE Transactions on Power Electronics, vol. 31, no. 8, pp. 5952-5966, Aug. 2016.

[14] N. -V. Nguyen, T. -K. Tu Nguyen and H. -H. Lee, "A Reduced Switching Loss PWM Strategy to Eliminate Common-Mode Voltage in Multilevel Inverters," in IEEE Transactions on Power Electronics, vol. 30, no. 10, pp. 5425-5438, Oct. 2015.

[15] K. K. Gupta, A. Ranjan, P. Bhatnagar, L. K. Sahu and S. Jain, "Multilevel Inverter Topologies With Reduced Device Count: A Review," in IEEE Transactions on Power Electronics, vol. 31, no. 1, pp. 135-151, Jan. 2016, doi: 10.1109/TPEL.2015.2405012.

[16] M. Victor, F. Greizer, S. Bremicker and U. Hubler, "Method of converting a direct current voltage from a source of direct current voltage more specifically from a photovoltaic course of direct current voltage into a alternating current voltage", Dec. 2005.

[17] H. Xiao, S. Xie, Y. Chen and R. Huang, "An optimized transformerless photovoltaic grid-connected inverter", IEEE Trans. Power Electron., vol. 58, no. 5, pp. 1887-1895, May 2011.

[18] B. Yang, W. Li, Y. Gu, W. Cui and X. He, "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.

[19] B. Ji, J. Wang and J. Zhao, "High-efficiency single-phase transformerless PV H6 inverter with hybrid modulation method", IEEE Trans. Ind. Electron., vol. 60, no. 5, pp. 2104-2115, May 2013.

[20] T. Brückner, S. Bernet and H. Güldner, "The active NPC converter and its loss-balancing control", IEEE Trans. Ind. Electron., vol. 52, no. 3, pp. 855-868, Jun. 2005.

[21] J. Ketterer, H. Schmidt and C. Siedle, "Inverter for transforming a DC voltage into an AC current or an AC voltage", May 2003.

[22] Karschny, D. "Flying inductor topology." German Patent DE19642522C1 15 (1998).

[23] Y. Gu, W. Li, Y. Zhao, B. Yang, C. Li and X. He, "Transformerless inverter with virtual dc bus concept for cost-effective grid-connected PV power systems", IEEE Trans. Power Electron., vol. 28, no. 2, pp. 793-805, Feb. 2013.

[24] J. F. Ardashir, M. Sabahi, S. H. Hosseini, F. Blaabjerg, E. Babaei and G. B. Gharehpetian, "A single-phase transformerless inverter with charge pump circuit concept for grid-tied PV applications", IEEE Trans. Ind. Electron., vol. 64, no. 7, pp. 5403-5415, Jul. 2017.

[25] N. Vázquez, M. Rosas, C. Hernández, E. Vázquez and F. Perez-Pinal, "A new common-mode transformerless photovoltaic inverter", IEEE Trans. Ind. Electron., vol. 62, no. 10, pp. 6381-6391, Apr. 2015.

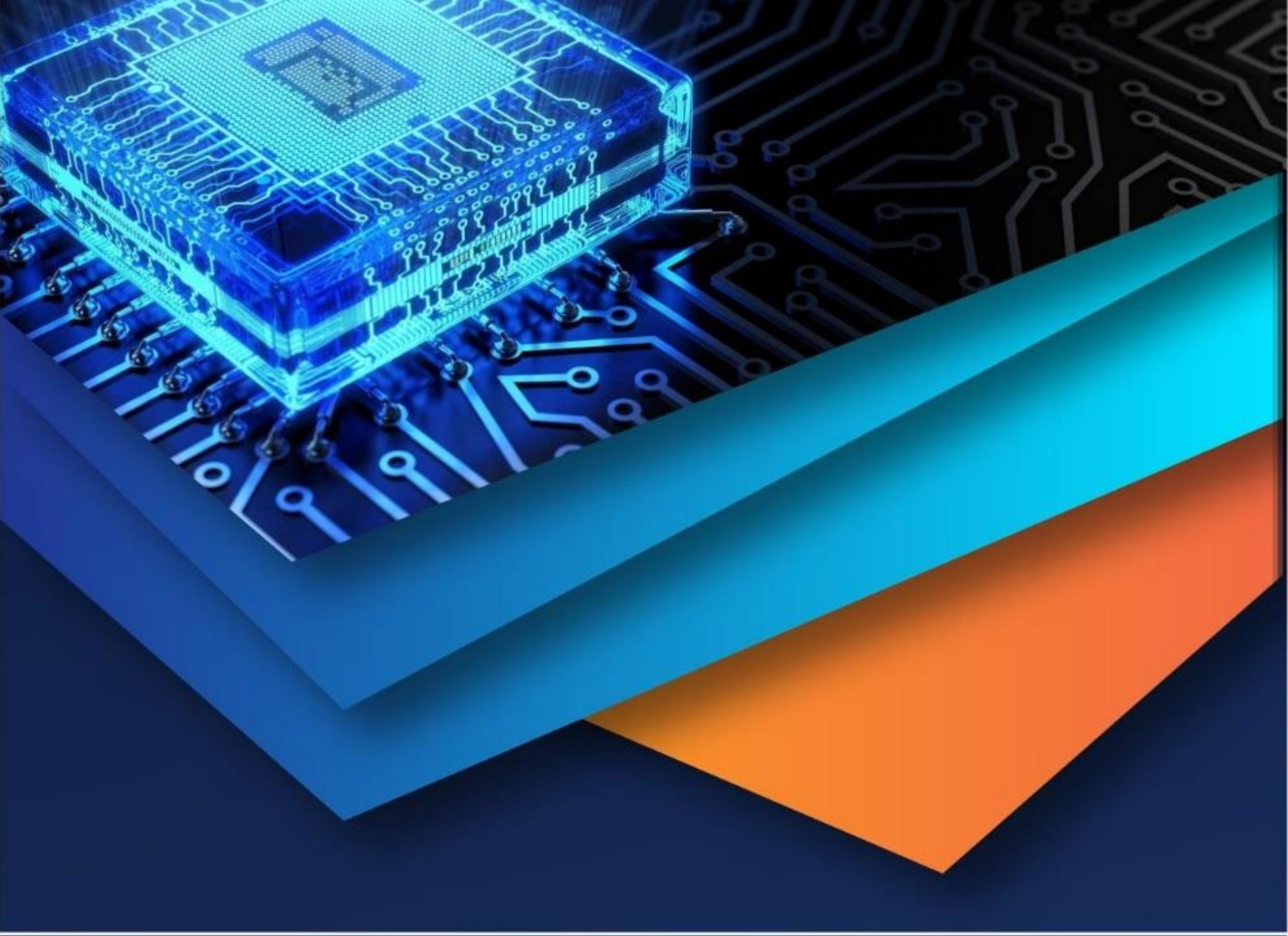
[26] M. T. Azari, M. Sabahi, E. Babaei and F. A. A. Meinagh, "Modified single-phase single-stage grid-tied flying inductor with MPPT and suppressed leakage current", IEEE Trans. Ind. Electron., vol. 65, no. 1, pp. 221-231, Jan. 2018.

[27] 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.

[28] M. Islam and S. Mekhilef, "Efficient transformerless MOSFET inverter for a grid-tied photovoltaic system", IEEE Trans. Power Electron., vol. 31, no. 9, pp. 6305-6316, Sep. 2016.

[29] M. Islam, N. Afrin and S. Mekhilef, "Efficient single-phase transformerless inverter for grid-tied PVG system with reactive power control", IEEE Trans. Sustain. Energy, vol. 7, no. 3, pp. 1205-1215, Jul. 2016.

[30] Latran, M.B. and Teke, A., 2015. Investigation of multilevel multifunctional grid connected inverter topologies and control strategies used in photovoltaic systems. Renewable and Sustainable Energy Reviews, 42, pp.361-376.



10.22214/IJRASET

INDEX COPERNICUS

45.98

ISRA JIF

IMPACT FACTOR: 7.129

SJIFactor

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY