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Design and reliability analysis of converter topology for Micro Grid system through optimal switching control

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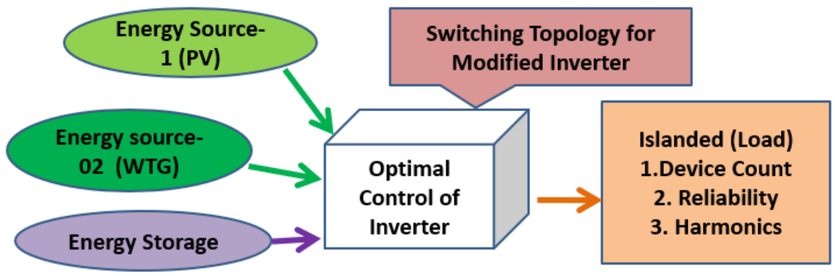
Article

ABSTRACT



Micro grid systems have emerged as a promising solution for integrating renewable energy sources and enhancing the overall reliability and efficiency of power distribution. The design and stability analysis of converter topologies play a crucial role in ensuring the seamless operation of micro grids. This research focuses on the development and optimization of converter topologies through advanced control techniques to enhance the stability and performance of micro grid systems. Special attention is given to the challenges associated with the integration of renewable energy sources, such as variable output and intermittent nature. A novel converter topology is proposed to address these challenges, leveraging advanced power electronics and control methodologies. The stability analysis is conducted using optimal control techniques to ensure robust and reliable operation of the micro grid. Mathematical models and simulation tools are employed to assess the dynamic behavior of the proposed converter topology under various operating change in load conditions. The research explores the potential of micro grid system with the converter topology to enhance the micro grid's overall stability and response to load variations. The results of the stability analysis highlight the improvements achieved in terms of system response, efficiency, and reliability.

Keywords: Micro grid, Modified converter topology, Stability. THD (Total Harmonic distortion), Optimal switching control.

INTRODUCTION

The optimal control of inverters through power electronics switches holds particular significance in the context of micro grid systems, representing a crucial facet of advanced power electronics and control strategies within the realm of distributed energy resources (DERs).[1] Micro grids, characterized by their localized and decentralized energy generation and distribution, rely heavily on inverters for seamless integration, efficient energy conversion, and grid resilience. The optimal control of these inverters, facilitated by power electronics switches, is pivotal for ensuring the reliable and optimal operation of micro grid systems. Micro grids, often composed of renewable energy sources such as solar panels and wind turbines, along with energy storage systems and various loads, require sophisticated control mechanisms to balance supply and demand dynamically. Power electronics switches, including insulated gate bipolar transistors (IGBTs) and metal-oxide-semiconductor field-effect transistors (MOSFETs), play a fundamental role in regulating the flow of energy within the micro grid.[2,3] The optimal control of inverters in micro grid systems encompasses a range of objectives. It involves maximizing the utilization of renewable energy sources, minimizing grid disturbances, enhancing system stability, and ensuring a seamless transition between grid-connected and islanded modes. Additionally, optimal control strategies aim to mitigate issues related to voltage fluctuations, frequency variations, and power quality within the micro grid.[4] Advanced control techniques such as model predictive control (MPC), droop control, and virtual impedance control are applied to achieve optimal performance in microgrid inverters. These strategies consider the variability of renewable energy sources and the dynamic nature of microgrid loads. The integration of power electronics switches in the inverter control architecture enables precise regulation of voltage and

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frequency, seamless switching between different operational modes, and effective energy management.[5–7]

As microgrid systems become increasingly prevalent in addressing energy challenges, including resilience, sustainability, and grid reliability, the optimal control of inverters through power electronics switches emerges as a critical research and application area. This introduction sets the stage for exploring the intricacies of optimal inverter control specifically tailored for micro grid environments, encompassing theoretical foundations, control algorithms, and practical implementations essential for advancing the state-of-the-art in micro grid technology.[8,18]

Literature Survey

The comparison of various converter topologies through optimal switches control are presented table -1. The reliability of micro grid through optimal control of converter topologies through switches are presented.

Table 1. A comparison of recent MLIs for different combination of energy sources reported in literature

Ref	Micro grid Source	Inverter Type	No. of Switches	Voltage Levels	Reliability of Converter	Load Current THD
9	PV and Wind	Conventional	4	3	No	23.1 %
10	PV alone	Voltage Level Boost(VLB)MLI	10	15	No	5.54 %
11	PV, Fuel Cell	Cascaded Multilevel Inverter(CHB)	11	5	NO	4.61 %
12	PV, Wind	Diode Clamped Multilevel Inverter	6	5	NO	2.5%
13	PV alone	Cascade H Bridge Multilevel Inverter	8	5	NO	3.2%
14	PV alone	Modified Cascade Multilevel Inverter	6	7	YES	3.1%
15	PV , Hydrogen	Modular Cascade H bridge Multilevel Inverter	12	7	YES	4.2%
16	Two PV sources	Hybrid Multilevel Inverter	7	7	YES	4.5%
17	PV and Battery	Dual input Converter	7	7	NO	6.1%

Proposed Simulation

The proposed converter is designed for the micro grid systems to ensure the reliability of overall system. Expanding the conventional inverter's levels through an auxiliary circuit and a suggested topology enables the attainment of a seven-output voltage, concurrently diminishing the total harmonic distortion. Further reduction in total harmonic distortion is achievable by augmenting the levels in a multilevel inverter. Integrating a multilevel inverter into a hybrid system yields elevated voltage levels and mitigates total harmonic distortion. This proposed system enhances the voltage gain and profile of the existing conventional inverter, employing multilevel inverters, while concurrently diminishing total harmonic distortion through an increase in the number of levels within the multilevel inverter system. The simulation is performed in PSIM software as presented in figure 1.

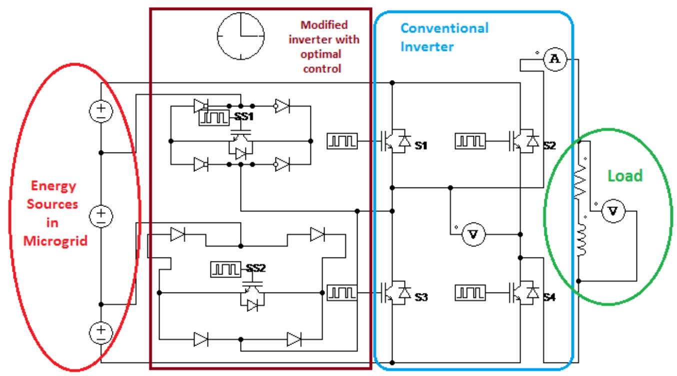

Figure 1. Simulation of Modified converter for micro grid with renewable energy sources

The performance of the converter topology is evaluated through simulation in the PSIM environment. The simulation incorporates three distinct input sources: a solar photovoltaic source, a battery storage system, and a university central bank. Operating in buck-boost mode with continuous conduction, the converter's behavior is analyzed under steady-state conditions. Independent switching techniques generate gate pulses for the converter switches. The switching sequence is given in table 2.

Table2. Switching Sequence

Switches	Firing Angle (in degree)
S1	0 60, 240-300,
S2	240 300, 240 420.
S3	180 240, 360 420
S4	0 240.
S5 or SS1	60 120, 240 300.
S6 or SS2	120 180, 300 360

Adjustments to the duty ratios (D1 to D6) offer a means to control the voltage across the load, influencing the load current. The converter's bidirectional power flow capability makes it suitable for applications with such requirements. Non-ideal behavior, attributed to conduction and switching losses along with voltage drops, leads to slight deviations from idealistic conclusions. The conduction states of the switches are presented in table -3. The simulation parameters are presented in table 4.

Table 3. Switching Topology

Voltage Levels (V)	Conduction States					
	S1	S2	S3	S4	S5	S6
V1+V2+V3	1	0	0	1	0	0
V1+V2	0	0	0	1	1	0
V1	0	0	0	1	0	1
0	0	0	1	1	0	0
-V1	0	1	0	0	1	0
-(V1+V2)	0	1	0	0	0	1
-(V1+V2+V3)	0	1	1	0	0	0

Table 4. Simulation Parameters

S.No.	Components Description	Values
1.	VPV	100V
2.	VW	100V
3.	VB	100V
4.	Load	R=10 ohms, L=0.001 H
5.	Switching frequency	5KHZ
6.	Diodes	Ideal

Results & Discussion

The simulation is performed in PSIM software for the proposed modified inverter for the micro grid. The load waveform voltage is presented in fig. 2, it is observed that the 7 level of voltages are achieved. Also, from the waveforms we can clearly see that the sinusoidal nature of the waveform improves further by increasing the levels in the multilevel inverter system.[18]

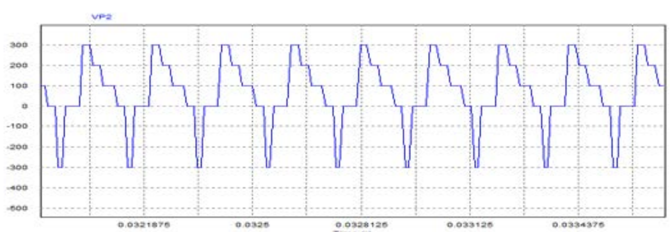

Figure 2. Voltage across Load

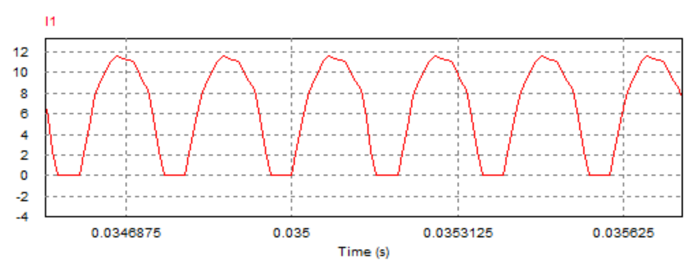

Figure 3. Current through Load

The load current waveform is observed near to sinusoidal i.e. Pulsating D.C. in nature as presented in fig. 3. The magnitude of current peak value of current is 11.8A.

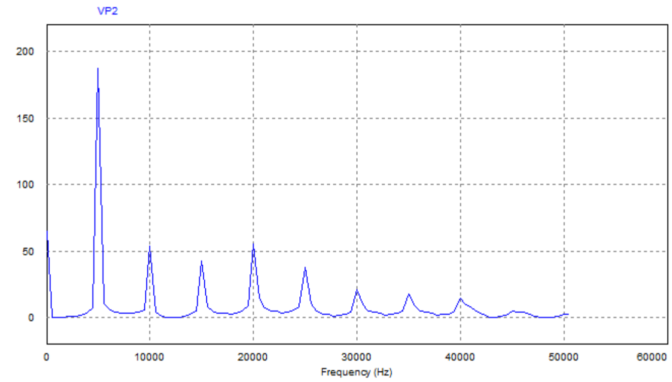

Figure 4. THD across the load voltage

With the help of auxiliary circuit and proposed topology the seven output voltage is achieved and the total harmonic distortion is reduced. This total harmonic distortion can be further reduced by increasing the levels in multilevel inverter. The application of multilevel inverter in the hybrid system generates higher voltage and reduced total harmonic distortion. This is how the voltage gain and profile from the existing conventional inverter system can be improved using proposed system with the help of multilevel inverters and also the total harmonic distortion is reduced by increasing the number of levels in the multilevel inverter system. The seven level output voltage is achieved through properly applying the switching topology and also the THD of load voltage is 5.9 % of the fundamental frequency as shown inn figure 4.

The proposed modified inverter for microgrid system along with the optimal switching control is capable to increase the voltage gain to tripple level ie. +/- 3Vdc. Also through optimal switching of power electronics switches the switching losses are low compared to conventional inverter. The voltage stress is also reduced across the swicthes. The over all device count is reduced to six including convernitonal inverter swicthes. In case of switch faliure the proposed converter is cable to provied power to the load with low voltage level.

Conclusion

This work has outlined the aspects of multilevel inverters to highlight the need to produce new inverters or modified combinations of inverters for Micro grid system. MLIs have been elaborated in various aspects, such as classifications and their abilities to enhance energy conversion in modern energy systems. Based on this review, a modified approach using MLIs for different levels should employ standard MLIs to reduce the switching count. Modified MLIs are promising solutions for PV and other renewable energy systems in terms of size, cost, less THD, and high efficiency energy conversion. Besides, the most recent MLIs grid-connected PV systems, and the minimizing current leakage suppression methods were highlighted in this work. Lastly, the challenges and practical recommendations for developing an efficient system were highlighted to motivate and guide society to focus on inventing an efficient and economic MLIs grid-connected system that combines most of the used and reported inverters' capabilities. A Multilevel inverter structure must be proposed to cater the power from different energy sources with reduced THD, device count and desired voltage levels.

Conflict of Interest Statement

Authors do not have any financial or academic Conflict of Interest for publication of this work.

References

1. A. Dwivedi, Y. Pahariya. Design and Analysis of Hybrid Multilevel Inverter for Asymmetrical Input Voltages. *J. Electr. Eng. Technol.* **2021**, No. 0123456789.
2. R. Sundar, C. Gnanavel, P. Muthukumar. A Unique Single Source Nine Level Inverter with Reduced Switching Devices for Single Phase AC Applications. *Int. J. Eng. Adv. Technol.* **2019**, 9 (2), 4098–4101.
3. M. Keddar, M.L. Doumbia, M. Della Krachai, K. Belmokhtar, A.H. Midoun. Interconnection performance analysis of single-phase neural network based NPC and CHB multilevel inverters for grid-connected PV systems. *Int. J. Renew. Energy Res.* **2019**, 9 (3), 1451–1461.
4. A. Dwivedi, Y. Pahariya. Design and Analysis of 1.4 MW Hybrid Saps System for Rural Electrification in Off-Grid Applications. *Int. J. Energy …* **2017**, 11 (11), 1068–1072.
5. C. Gupta, V.K. Aharwal. Optimizing the performance of Triple Input DC-DC converter in an Integrated System. *J. Integr. Sci. Technol.* **2022**, 10 (3), 215–220.
6. H. Armghan, M. Yang, A. Armghan, et al. Design of integral terminal sliding mode controller for the hybrid AC/DC microgrids involving renewables and energy storage systems. *Int. J. Electr. Power Energy Syst.* **2020**, 119 (November 2019), 105857.
7. C. Gupta, V.K. Aharwal. Design and simulation of Multi-Input Converter for Renewable energy sources. *J. Integr. Sci. Technol.* **2023**, 11 (3), 514.
8. A. Dwivedi, Y. Pahariya. Techno-economic Feasibility Analysis of Optimized Stand-alone PV and Hybrid Energy Systems for Rural Electrification in India. *J. Inst. Eng. Ser. B* **2023**, 104 (4), 911–919.
9. B. Liu, L. Wang, D. Song, et al. Input Current Ripple and Grid Current Harmonics Restraint Approach for Single-Phase Inverter under Battery Input Condition in Residential Photovoltaic/Battery Systems. *IEEE Trans. Sustain. Energy* **2018**, 9 (4), 1957–1968.
10. J. Chattoraj, A. Dwivedi, Y. Pahariya. Enhancement of Power Quality in Saps System With Multilevel. *Int. J. Eng. Sci. Res. Technol.* **2017**, 6 (5), 779–788.
11. N.H. Samrat, N. Ahmad, I.A. Choudhury, Z. Taha. Technical study of a standalone photovoltaic-wind energy based hybrid power supply systems for island electrification in Malaysia. *PLoS One* **2015**, 10 (6).
12. A. Dwivedi. Management. **2012**, 2 (1), 62–65.
13. K.K. Gupta, A. Ranjan, P. Bhatnagar, L.K. Sahu, S. Jain. Multilevel inverter topologies with reduced device count: A review. *IEEE Trans. Power Electron.* **2016**, 31 (1), 135–151.
14. S.P. Gautam, L. Kumar, S. Gupta. Hybrid topology of symmetrical multilevel inverter using less number of devices. *IET Power Electron.* **2015**, 8 (11), 2125–2135.
15. A.K. Sadigh, V. Dargahi, K.A. Corzine. New Multilevel Converter Based on Cascade Connection of Double Flying Capacitor Multicell Converters and Its Improved Modulation Technique. *IEEE Trans. Power Electron.* **2015**, 30 (12), 6568–6580.
16. V.V.S. Pradeep Kumar, B.G. Fernandes. A Fault-Tolerant Single-Phase Grid-Connected Inverter Topology with Enhanced Reliability for Solar PV Applications. *IEEE J. Emerg. Sel. Top. Power Electron.* **2017**, 5 (3), 1254–1262.
17. H. Luo, Y. Dong, W. Li, X. He. Module multilevel-clamped composited multilevel converter (M-MC2) with dual T-type modules and one diode module. *J. Power Electron.* **2014**, 14 (6), 1189–1196.
18. J. Cruz-Cozar, A. Medina-Garcia, D.P. Morales, N. Rodriguez. Resonant hybrid flyback: A novel topology with wide voltage range for DC microgrid applications. *Energy Reports* **2023**, 9, 3222–3234.