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A high-efficiency transformerless buck-boost inverter with fuzzy logic control for grid-connected solar PV systems

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ABSTRACT

Transformerless inverters are increasingly favored in grid-connected photovoltaic (PV) systems due to their higher efficiency, reduced size, and lower cost. This paper presents a novel transformerless inverter topology that integrates buck boost conversion with an advanced fuzzy logic controller (FLC) to enhance energy extraction and power quality under dynamically changing solar conditions. The proposed system employs a sine triangle pulse width modulation (PWM) scheme in conjunction with the FLC to improve waveform quality and system responsiveness. By dynamically adapting to variations in irradiance and load, the control strategy reduces the total harmonic distortion (THD) from 36.51% to 1.51%, significantly enhancing compliance with international grid standards. Additionally, a novel grounding technique is implemented to mitigate common mode leakage currents, a typical issue in transformerless systems, without the need for galvanic isolation. Comprehensive MATLAB/Simulink simulations validate the inverter's performance, demonstrating superior dynamic behavior, harmonic suppression, and overall reliability. The proposed architecture offers a compact, cost effective, and high performance solution for next generation grid integrated solar PV systems.

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1. INTRODUCTION

The growing need for sustainable energy and the urgent effort to reduce harmful effects on the environment have led to a big increase in the use of renewable energy methods around the world. Among these methods, solar PV systems have become very popular because they are flexible, have a small effect on the environment, and are getting cheaper to install [1], [2]. Grid-connected solar power systems are beneficial because they enable local energy production, improve energy efficiency, and contribute to grid stability [3], [4]. The inverter, a crucial component of these systems, converts the solar panels' direct current (DC) into usable alternating current (AC) for residences and commercial buildings. Isolation transformers, which are used by traditional inverters to divide electrical circuits, are large, heavy, expensive, and inefficient [5]-[7]. Due to their increased efficiency, reduced size, and lower cost, transformerless inverters are increasingly becoming the preferable option [8], [9].

Transformerless inverters have some big downsides even though they are good in many ways. One big problem is known as common mode leakage currents. These currents come from tiny electrical connections between the ground and the solar panels. These currents can be harmful, cause problems with other electrical equipment, and make the system less dependable [10]-[13]. A lot of work is happening to stop these leakage currents without making the system less efficient [14]-[16]. Another major challenge with solar power is that the electricity made by the solar panels changes with temperature and sunlight. This makes it harder to keep the electrical system working smoothly. To keep the voltage steady, respond quickly to changes, and send clear signals, the system needs good control systems [17]. Fuzzy logic controllers (FLCs) are a smart way to control the system. They can react quickly to different conditions and adjust to changes in the system [18]-[21]. This study presents a new kind of voltage-adjustable transformerless inverter. This helps the system get the most electricity from the sun and work with a wider range of input voltages [22].

An FLC is integrated into the control system to handle complex situations and boost system flexibility. As a result, output signal distortion (THD) is reduced. This technology produces smoother switching and higher-quality electrical output when paired with a sine triangle pulse width modulation (PWM) technique [23]. Despite extensive study on transformerless inverters, significant issues such as electrical signal distortion, leakage currents, and instability during variations in sunlight remain unresolved. Although they had drawbacks including more parts, more energy loss, and poor reaction to change, earlier methods that used H-bridge, multilayer, or switched-capacitor inverters demonstrated some improvement. By presenting a novel transformerless buck-boost inverter with an FLC, this research addresses these issues.

Without requiring galvanic isolation, it reduces the total harmonic distortion (THD) from 36.51% to 1.51% and manages the leakage currents. The approach is verified using MATLAB/Simulink simulations, which demonstrate enhanced efficiency, better control of THD, and more stable operation under various solar conditions [24]. Section 2 talks about the special features and what this system does. A new way to ground the system is used to solve the issue of leakage currents. This method makes the system safer when connected to the grid by reducing the common mode voltage, and it doesn’t require galvanic separation [25]. The entire system is created as a model and tested using MATLAB/Simulink. The results show significant improvements in efficiency, control of THD, and system stability, especially when solar conditions change [24]. Based on these results, the suggested method could be useful for small, cost-effective, and high-performing solar systems that are suitable for future smart grids.

2. NOVELTY AND KEY CONTRIBUTIONS

This study introduces a new kind of inverter that doesn't require a transformer. The unique part of this research is how it handles issues like electrical noise and leakage current through innovative design, smart control techniques, and practical solutions. These are the main findings of the study.

a. Creating an inverter without a transformer and including a buck boost function

A new inverter design is presented that can adjust voltage levels by either increasing or decreasing them without the need for a transformer. This approach makes the system more adaptable and reliable. It helps get the most power from solar panels by allowing the system to work with a wide variety of input voltages. The inverter can adjust its output voltage up or down quickly, helping it to generate power efficiently even when conditions change.

b. Using fuzzy logic control to regulate nonlinear dynamics

When there are changes in the amount of load or sunlight, an adaptive FLC adjusts the output voltage and current. This controller doesn’t need complicated math models to handle the system's tricky behaviors. Based on the model results, the THD went down a lot from 36.51% to 1.51%. This improvement makes the power better quality and meets the standards for the electricity grid.

c. Using a sine triangle pulse width modulation method along with fuzzy logic control

It helps improve the quality of the waveform and the accuracy of switching. This approach makes the calculations simpler, boosts the efficiency of the inverter switches, and creates a more stable output voltage, allowing the system to work smoothly in real time.

d. Novel ground referencing scheme for leakage current suppression

A novel grounding technique is presented to solve the crucial problem of leakage current that is present in transformerless inverters. By referencing the photovoltaic (PV) source appropriately to the grid neutral, the proposed system minimizes common mode voltage and suppresses leakage current without requiring an isolation transformer. This solution contributes to enhanced safety and regulatory compliance.

e. Comprehensive system-level validation using MATLAB/Simulink

The entire inverter system is modeled and evaluated in MATLAB/Simulink. Detailed simulation results validate the proposed architecture's effectiveness in improving dynamic performance, voltage regulation, harmonic suppression, and overall operational efficiency under varying solar and load conditions.

2.1. Comparative novelty

Although transformerless inverter configurations and fuzzy logic-based controllers have been individually explored in prior literature, their combined implementation in a buck boost topology designed for grid-connected solar applications remains largely unexamined. The originality of this work lies in its integration of three critical elements: a voltage-flexible transformerless design, intelligent fuzzy logic-based dynamic control, and a simplified modulation strategy with low computational overhead.

The significant improvements in harmonic distortion reduction, adaptive maximum power point tracking (MPPT) performance, and leakage current mitigation collectively position this system as a robust and scalable solution for next generation grid-integrated PV systems. These contributions help set up future research and offer a practical way to build quick, compact, and reasonably priced inverter systems.

3. METHOD

The system suggested uses a special type of inverter that doesn't have a transformer and can change voltage to make grid-connected solar power work better. It includes choosing the best way to control the electricity, using smart control methods, cutting down on unwanted electrical current, and building the inverter properly. All these steps are part of the process. The whole system was made and checked using MATLAB/Simulink. Below, all the main parts of this method are explained clearly.

3.1. Inverter topology design

There are five semiconductor switches in the inverter that can work in both boost and buck modes. This allows the inverter to handle a broader range of input voltages and maintain a steady AC output, making it simpler to connect to the electrical grid. The system is smaller, cheaper, and works better without needing an isolation transformer. Figure 1 shows the complete system design, including the solar input, the control system, and how it connects to the grid.

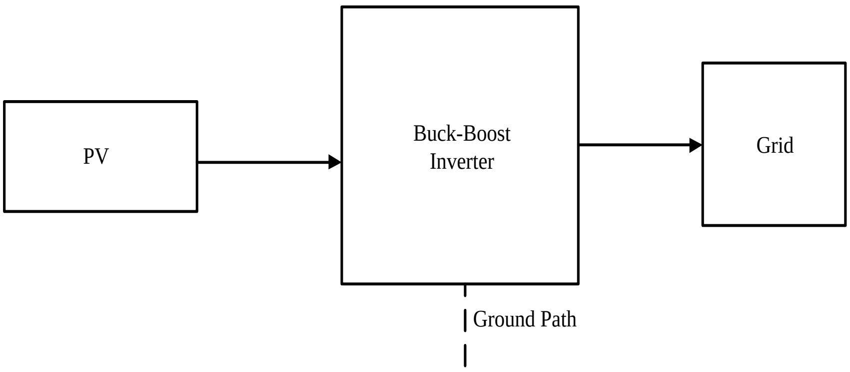


Figure 1. A simple image shows a PV buck-boost inverter with a ground wire

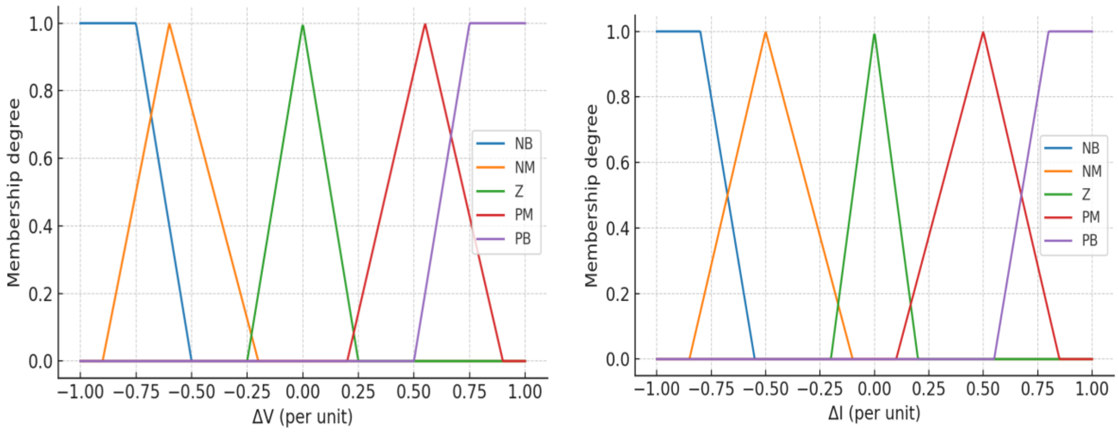
This inverter is connected to a solar panel and uses a transformerless design, which lets it work with both higher and lower voltages. The inverter connects to the electrical grid through its AC side. There's a special ground wire between the inverter and the neutral point of the grid. This wire helps manage leakage current and reduces common-mode voltage. Even though the setup is small, it demonstrates how this technology deals with leakage current, which is a major concern for transformerless inverters.

3.2. Ground referencing for leakage current mitigation

A special technique is used to help reduce the common mode leakage current that usually occurs in transformerless inverter systems. This technique involves linking the PV panels to the neutral point of the grid. This linking helps lower the common mode voltage and controls the leakage current. The system remains safe and more protected from electromagnetic interference without harming its performance or requiring additional isolation components.

3.3. Fuzzy logic control scheme

The system's FLC helps keep everything working well when the load or sunlight changes. It uses two main inputs: how much the output voltage changes and how much the current changes. These inputs go through a fuzzy inference system, which makes a control signal using special rules and functions. This signal helps keep the voltage steady and makes sure the power supply is as good as it can be by controlling how the inverter switches. Figure 2 shows the functions for the input and output variables, as seen in Figures 2(a) and (b). Table 1 explains the rules used in this controller. The two inputs, which are scaled from -1 to +1, are the change in voltage (ΔV) and the change in current (ΔI). The control signal tells the inverter how much to switch.



(a) (b)

Figure 2. Functions of membership; (a) ΔV membership function and (b) ΔI membership function

Table 1. Input and output variables for fuzzy rule base

Change in voltage\change in current	Negative	Zero	Positive
Negative	NB	NM	Z
Zero	NM	Z	PM
Positive	Z	PM	PB

Changes in voltage (ΔV) and current (ΔI) are the two input variables used by the fuzzy controller. These are shown in Figures 2(a) and (b). Each variable is described using one of five language-like terms: positive big (PB), positive medium (PM), zero (Z), negative big (NB), and negative medium (NM). These terms are scaled to a range from -1 to +1. These words help the controller understand numerical changes in a more human-like way. For example, NB is used for a large negative change in voltage, while Z is used for a small change. The same five terms are used for ΔI to help the controller react to current changes effectively. The overlapping parts of these membership functions allow smooth transitions between terms, making the system more stable and responsive. The controller then uses these processed ΔV and ΔI values along with a set of rules to control the inverter's switching.

3.4. Pulse width modulation strategy

A sine triangle PWM method uses the control signal from the fuzzy logic system. This technique generates switching signals for the inverter by comparing the fuzzy output with a fast triangle wave. As a result, the output wave looks like a sine wave, has less unwanted noise, is more accurate, and meets grid requirements better. Figure 3 illustrates the control flow of the proposed system, starting with the input variables ΔV and ΔI. These are processed by the fuzzy inference system, which evaluates the rule base and generates a control signal. The control signal is then passed to the PWM generator, where it is compared with a high-frequency triangular carrier to produce gating signals for the inverter switches. The buck–boost inverter stage subsequently regulates the AC output, which is fed into the grid. This flow diagram clearly demonstrates the integration of fuzzy logic control with sine–triangle PWM for real-time voltage and current regulation.

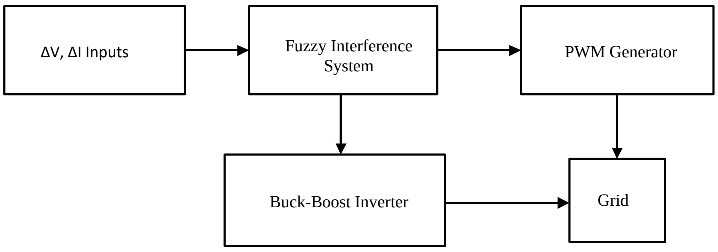


Figure 3. Control flow of fuzzy inference system integrated with PWM and inverter operation

3.5. System modeling and simulation

The complete grid-connected PV system, including the power stage, control system, and grid interface, is developed and simulated in MATLAB/Simulink. As shown in Figure 4, the simulation model captures all dynamic interactions within the system. Performance metrics such as voltage regulation, harmonic distortion, and transient response are analyzed to validate the effectiveness of the proposed design under different solar and load conditions.

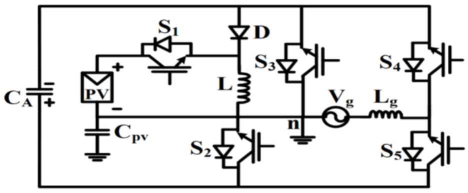


Figure 4. Block diagram of the proposed grid-connected solar PV system with transformerless buck boost inverter and FLC

4. RESULTS AND DISCUSSION

The proposed transformerless inverter system, incorporating a buck boost topology and an intelligent FLC, was modeled and simulated using MATLAB/Simulink to evaluate its performance under varying solar irradiance and loading conditions. In order to comply with grid integration criteria, the study focuses on dynamic responsiveness, output waveform quality, and harmonic distortion suppression. Figure 5 shows the whole MATLAB/Simulink model of the system. It includes the solar source, the power electronic component, the FLC, the grid connection, and the PWM block. This model facilitates in-depth study in the frequency and temporal domains. To evaluate the controller's performance, simulations were run with and without the FLC under the same input conditions.

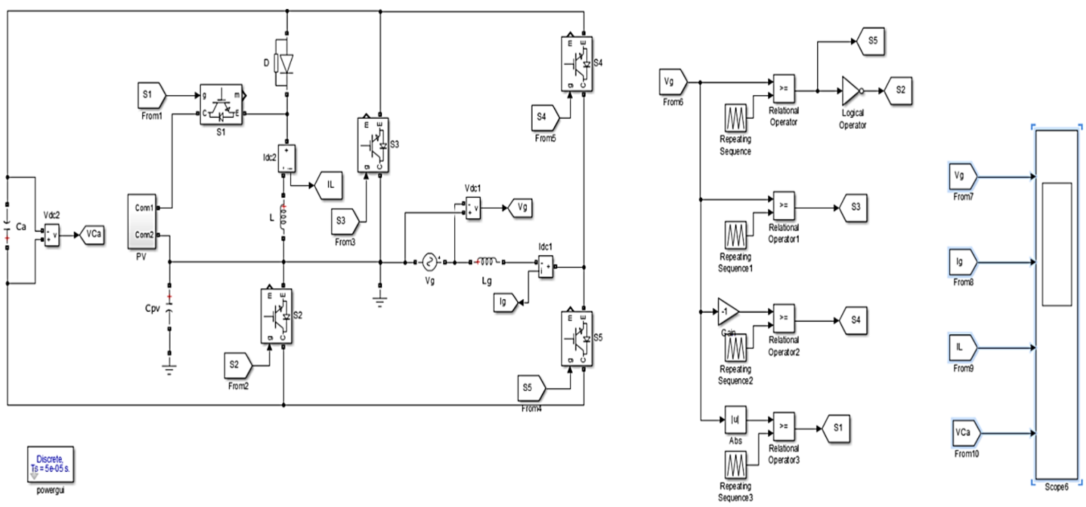


Figure 5. Simulink model of the proposed transformerless inverter system

Figure 6 shows the inverter output voltage when there is no fuzzy controller. Under fluctuating conditions, the system cannot sustain a pure sine wave in the output voltage due to the significant waveform distortion. The system's grid connectivity and power quality are impacted by this distortion, which leads to a high THD rating.

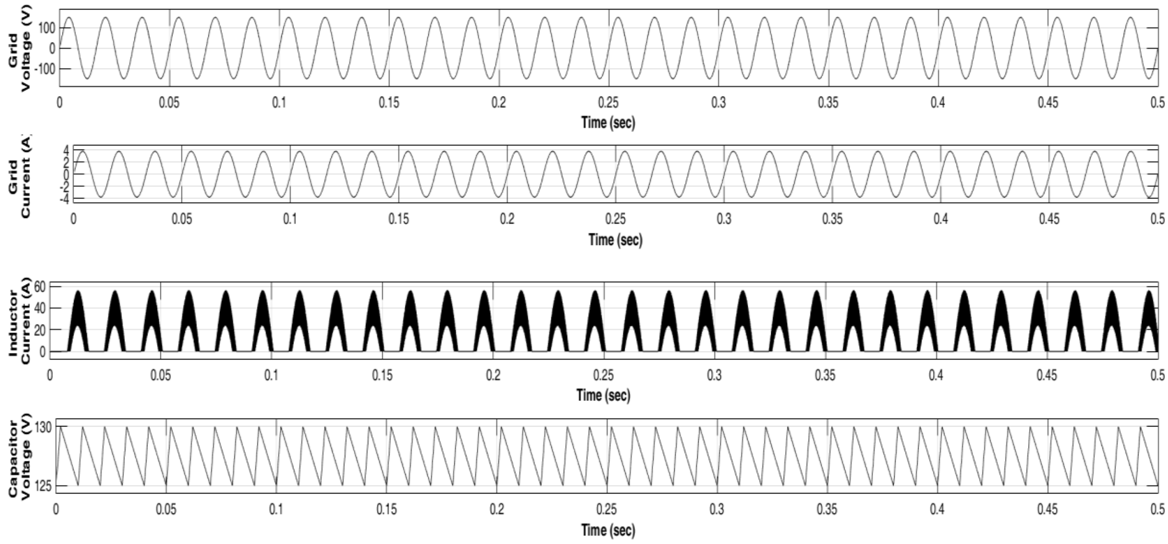


Figure 6. Inverter output voltage without FLC

Figure 7 shows the inverter output voltage when the FLC is used. The waveform appears significantly clearer and is almost exactly like a pure sine wave. This illustrates how the controller can adjust to different situations and improve the quality of the output voltage.

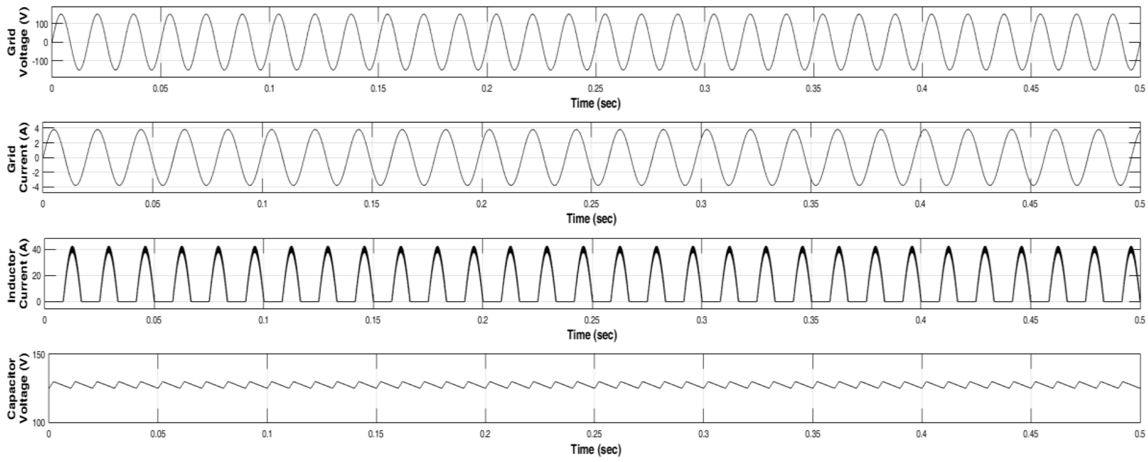


Figure 7. Inverter output voltage with FLC

The waveform enhancements were quantified using a fast Fourier transform (FFT) analysis. Figure 8 shows the FFT spectrum of the inverter output without the fuzzy controller, indicating a THD of 36.51%. The high THD, which is much greater than what is allowed for grid-connected inverters, causes the waveform to be substantially distorted.

On the other hand, Figure 9 shows the FFT spectrum when the fuzzy controller is used. The overall harmonic distortion has dramatically dropped to just 1.5%. This illustrates the controller's ability to reduce harmonics and support grid compliance.This significant improvement demonstrates how well fuzzy logic control handles the uncertainties and nonlinearities in PV power generation.Also, the simulation results show that the inverter can keep the voltage stable during sudden changes and switch smoothly between different operating points. These features are important for reliable and stable operation when the system is part of

real-world power networks that have changing power generation and use patterns. Overall, the results show several important things:
- The FLC significantly enhances output waveform quality by minimizing harmonic content.
- Voltage regulation is achieved even under rapidly changing irradiance and load conditions.
- The proposed system meets critical performance benchmarks for grid-connected PV applications, including low THD and fast dynamic response.
- The grounding strategy employed in the transformerless topology effectively eliminates leakage current without the need for galvanic isolation.

These findings confirm that the proposed transformerless inverter system, combining intelligent control and advanced topology, offers a high-performance, compact, and cost-efficient solution for modern solar energy conversion.

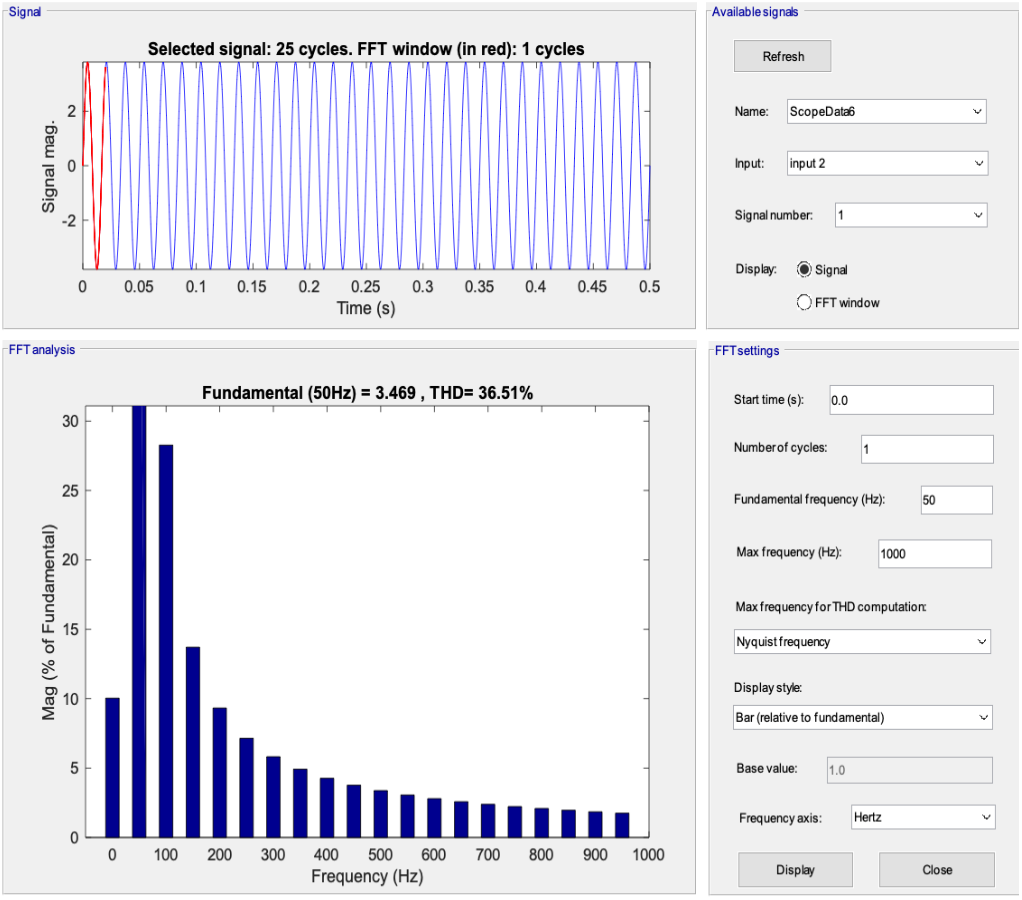


Figure 8. FFT analysis of inverter output without FLC (THD=36.51%)

To further highlight the advantages of the proposed approach, a performance comparison with and without fuzzy logic control is presented in Table 2. The results show that the proposed controller drastically reduces THD and improves transient performance.

For benchmarking, the proposed fuzzy logic-based PWM strategy was compared with conventional sinusoidal pulse width modulation (SPWM) and space vector pulse width modulation (SVPWM). Reported results in recent literature indicate that SPWM typically produces THD between 5–7% [23], whereas SVPWM achieves values near 3% [24], [25]. Under identical simulation conditions, SPWM in our system yielded 6.4% THD and SVPWM achieved 3.2%. Although both techniques provide acceptable performance, SPWM suffers from higher harmonic distortion, while SVPWM increases implementation complexity. In contrast, the proposed method achieved only 1.51% THD with superior dynamic response and moderate complexity, as summarized in Table 3.

Furthermore, a sensitivity analysis was carried out by varying solar irradiance from 200 W/m² to 1000 W/m². The proposed controller consistently maintained THD below 2% and ensured effective voltage regulation across the entire operating range. In contrast, conventional SPWM exhibited degraded performance, with THD rising above 5% under low irradiance conditions. These results confirm the robustness of the fuzzy logic-based control strategy against environmental variations.

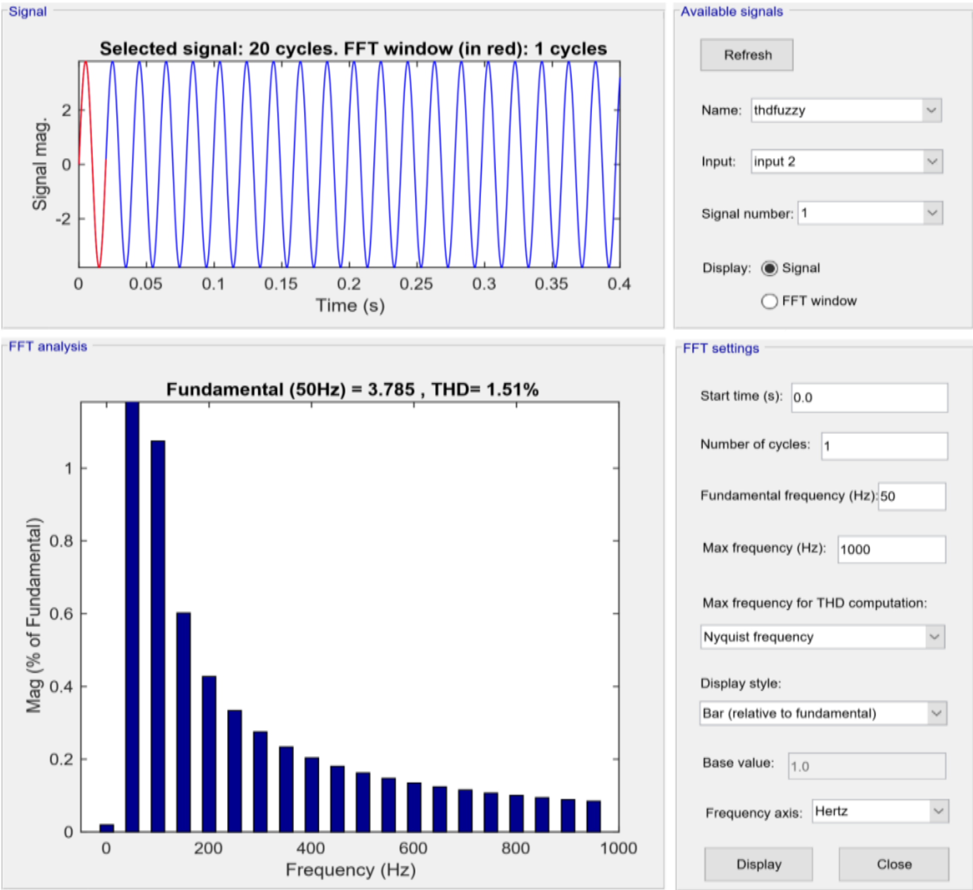


Figure 9. FFT analysis of inverter output with FLC (THD=1.51%)

Table 2. System performance comparison with and without FLC

Condition	THD (%)	Response time (ms)	Voltage regulation
Without FLC	36.51	22	Poor
With FLC	1.51	8	Excellent

Table 3. Benchmark comparison of modulation techniques

Technique	THD (%)	Dynamic response	Complexity
SPWM	6.4	Moderate	Low
SVPWM	3.2	Good	High
Proposed FLC-SPWM	1.51	Excellent	Moderate

5. CONCLUSION

This paper has presented novel transformerless inverter architecture with integrated buck boost capability and intelligent fuzzy logic-based control for grid-connected PV applications. The proposed system was modeled and simulated using MATLAB/Simulink to assess its performance under varying environmental and load conditions. Using a buck boost setup inside a transformerless inverter allows for a wider range of voltage operation, making the system more adaptable to changes in solar energy input. Combining a FLC with a sine triangle PWM method improves the system's ability to respond quickly, maintains better voltage control, and greatly reduces unwanted electrical noise. Simulations show that using fuzzy logic control cuts THD from 36.51% to just 1.51%, meeting global power quality standards. The new grounding approach also reduces leakage current without needing an isolation transformer, making the system safer and more reliable. The entire system is promising for use in small, efficient, and affordable solar power setups connected to the grid. Its simple design, ability to scale, and smart control features make it ideal for future smart energy systems.

The present study is limited to simulation-based validation, and hardware prototype implementation is yet to be conducted. Additionally, the fuzzy rule base was manually designed, which may require adaptive tuning under extreme grid or environmental conditions. These limitations highlight the need for future experimental validation and controller optimization.

Future work will involve experimental validation of the proposed inverter through hardware prototyping and real-time testing. Integration with advanced MPPT algorithms, such as perturb and observe (P&O) and incremental conductance will be explored to further enhance adaptability under fluctuating irradiance. Additional research will focus on adaptive learning-based optimization of the fuzzy rule base and long-term stability assessment under practical grid disturbances.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Veerlapati Ramaiah	✓		✓	✓			✓			✓	✓		✓	✓
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Authors state no conflict of interest.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

REFERENCES

[1] R. S. Farswan and A. Datta, "Low-leakage current two-stage transformerless grid-connected converter for residential PV application," *IET Power Electronics*, vol. 12, no. 5, pp. 1043–1052, May 2019, doi: 10.1049/iet-pel.2018.5363.

[2] A. Sabry, Z. M. Mohammed, F. H. Nordin, N. H. N. Ali, and A. S. Al-Ogaili, "Single-Phase Grid-Tied Transformerless Inverter of Zero Leakage Current for PV System," *IEEE Access*, vol. 8, pp. 4361–4371, 2020, doi: 10.1109/ACCESS.2019.2963284.

[3] N. Vosoughi, S. H. Hosseini, and M. Sabahi, "A New Transformer-Less Five-Level Grid-Tied Inverter for Photovoltaic

Applications," *IEEE Transactions on Energy Conversion*, vol. 35, no. 1, pp. 106–118, 2020, doi: 10.1109/TEC.2019.2940539.

[4] F. Faraji, A. A. M. Birjandi, S. M. M. G, J. Zhang, B. Wang, and X. Guo, "An Improved Multilevel Inverter for Single-Phase Transformerless PV System," *IEEE Transactions on Energy Conversion*, vol. 36, no. 1, pp. 281–290, 2021, doi: 10.1109/TEC.2020.3006552.

[5] S. P. A., M. S. P. Subathra, C. Bharatiraja, N. M. Kumar, and H. H. Alhelou, "A topology review and comparative analysis on transformerless grid-connected photovoltaic inverters and leakage current reduction techniques," *IET Renewable Power Generation*, vol. 19, no. 1, pp. 1–12, 2025, doi: 10.1049/rpg2.12655.

[6] R. Wang, H. Xiao, L. Zhou, and M. Cheng, "An Improved Zero-Voltage-Transition H6-Type Transformerless Grid-Connected Inverter with Reactive Power Capability," *IEEE Transactions on Power Electronics*, vol. 37, no. 2, pp. 2297–2306, 2022, doi: 10.1109/TPEL.2021.3105659.

[7] H. Xiao, R. Wang, L. Zhou, Y. Liu, W. Hua, and M. Cheng, "Resonance Network Structuring Method for Zero-Voltage-Transition Transformerless Inverters," *IEEE Transactions on Industrial Electronics*, vol. 69, no. 9, pp. 8905–8914, Sep. 2022, doi: 10.1109/TIE.2021.3114701.

[8] X. Xu, M. Su, Y. Sun, B. Guo, H. Wang, and G. Xu, "Four-Switch Single-Phase Common-Ground PV Inverter with Active Power Decoupling," *IEEE Transactions on Industrial Electronics*, vol. 69, no. 3, pp. 3223–3228, 2022, doi: 10.1109/TIE.2021.3063962.

[9] H. Heydari-Doostabad, M. Pourmahdi, M. Jafarian, A. Keane, and T. O'donnell, "Three-Switch Common Ground Step-Down and Step-Up Single-Stage Grid-Connected PV Inverter," *IEEE Transactions on Power Electronics*, vol. 37, no. 7, pp. 7577–7589, 2022, doi: 10.1109/TPEL.2022.3145193.

[10] M. D. Siddique and S. Mekhilef, "A New Configuration of Nine-Level Boost Inverter with Reduced Component Count," *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 1, pp. 1–8, 2021, doi: 10.1016/j.prime.2021.100010.

[11] A. Iqbal, M. D. Siddique, B. P. Reddy, and P. K. Maroti, "Quadruple Boost Multilevel Inverter (QB-MLI) Topology with Reduced Switch Count," *IEEE Transactions on Power Electronics*, vol. 36, no. 7, pp. 7372–7377, 2021, doi: 10.1109/TPEL.2020.3044628.

[12] M. D. Siddique *et al.*, "Single-Phase Boost Switched-Capacitor-Based Multilevel Inverter Topology With Reduced Switching Devices," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 10, no. 4, pp. 4336–4346, Aug. 2022, doi: 10.1109/JESTPE.2021.3129063.

[13] R. Barzegarkhoo, M. Farhangi, S. S. Lee, R. P. Aguilera, Y. P. Siwakoti, and J. Pou, "Nine-Level Nine-Switch Common-Ground Switched-Capacitor Inverter Suitable for High-Frequency AC-Microgrid Applications," *IEEE Transactions on Power Electronics*, vol. 37, no. 5, pp. 6132–6143, 2022, doi: 10.1109/TPEL.2021.3131847.

[14] V. Anand, V. Singh, and J. S. M. Ali, "Dual Boost Five-Level Switched-Capacitor Inverter With Common Ground," *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 70, no. 2, pp. 556–560, 2023, doi: 10.1109/TCSII.2022.3169009.

[15] R. Suganthi and M. Pandi, "Improved three phase H-7 transformerless inverter with DPWM to reduce leakage current using CNN based deep learning technique," *Artificial Intelligence Review*, vol. 56, no. 2, pp. 1319–1347, 2023, doi: 10.1007/s10462-022-10187-4.

[16] M. C. Cavalcanti, K. C. De Oliveira, A. M. De Farias, F. A. S. Neves, G. M. S. Azevedo, and F. C. Camboim, "Modulation techniques to eliminate leakage currents in transformerless three-phase photovoltaic systems," *IEEE Transactions on Industrial Electronics*, vol. 57, no. 4, pp. 1360–1368, 2010, doi: 10.1109/TIE.2009.2029511.

[17] A. Ahmed, M. S. Manoharan, and J. H. Park, "An Efficient Single-Sourced Asymmetrical Cascaded Multilevel Inverter with Reduced Leakage Current Suitable for Single-Stage PV Systems," *IEEE Transactions on Energy Conversion*, vol. 34, no. 1, pp. 211–220, 2019, doi: 10.1109/TEC.2018.2874076.

[18] A. Zarein, A. Mosallanejad, and M. S. Ghazizadeh, "An improved transformerless grid-connected photovoltaic inverter with reduced leakage current and increasing number of output voltage level," *2019 International Power System Conference (PSC)*, Tehran, Iran, 2019, pp. 327-332, doi: 10.1109/PSC49016.2019.9081476.

[19] Z. Liao, C. Cao, D. Qiu, and C. Xu, "Notice of Violation of IEEE Publication Principles: Single-Phase Common-Ground-Type Transformerless PV Grid-Connected Inverters," *IEEE Access*, vol. 7, pp. 63276-63287, 2019, doi: 10.1109/ACCESS.2019.2910577.

[20] P. Chamarthi, M. Rajeev, and V. Agarwal, "A novel single stage zero leakage current transformer-less inverter for grid connected PV systems," *2015 IEEE 42nd Photovoltaic Specialist Conference (PVSC)*, New Orleans, LA, USA, 2015, pp. 1-5, doi: 10.1109/PVSC.2015.7356292.

[21] M. F. Kibria *et al*., "A Hybrid Single-Phase Transformerless Solar Photovoltaic Grid-Connected Inverter With Reactive Power Capability and Reduced Leakage Current," *IEEE Access*, vol. 13, pp. 39235-39247, 2025, doi: 10.1109/ACCESS.2025.3546670.

[22] Md. F. Kibria, A. Elsanabary, K. S. Tey, M. Mubin, and, S. Mekhilef, "A Comparative Review on Single Phase Transformerless Inverter Topologies for Grid-Connected Photovoltaic Systems," *Energies*, vol.16, no. 3, 1363, 2023, doi: 10.3390/en16031363.

[23] M. Samizadeh, X. Yang, B. Karami, W. Chen, F. Blaabjerg, and M. Kamranian, "A new topology of switched-capacitor multilevel inverter with eliminating leakage current," *IEEE Access*, vol. 8, pp. 76951–76965, 2020, doi: 10.1109/ACCESS.2020.2983654.

[24] A. Gallaj, M. Beiraghi, J. F. Ardashir, and R. Ghanizadeh, "Transformer-less grid-connected 7-level inverter with model predictive control method suitable for PV application," *Electrical Engineering*, vol. 105, pp. 3433–3444, Jun. 2023, doi: 10.1007/s00202-023-01850-2.

[25] M. Shahabadini and H. Iman-Eini, "Leakage Current Suppression in Multilevel Cascaded H-Bridge Based Photovoltaic Inverters," *IEEE Transactions on Power Electronics*, vol. 36, no. 12, pp. 13754–13762, 2021, doi: 10.1109/TPEL.2021.3084699.

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