International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 14, Issue 2, February 2025)

Single Phase Grid-connected PV system with unfolding Flyback Microinverter for Residential Applications

[1]Raushan Patel, [2]Dr. P. Yadav
[1]*Research Scholar, Dept of Electrical and Electronics Engineering, Millennium Institute of Technology and Science, India*
[2]*Professor, Dept of Electrical and Electronics Engineering, Millennium Institute of Technology and Science, India*

Abstract : This paper presents a comprehensive analysis of a Single-Phase Grid-Connected Photovoltaic (PV) System employing an Unfolding Flyback Microinverter for residential applications. The Flyback topology is widely preferred in microinverter designs due to its cost-effectiveness, electrical isolation, and high efficiency at low power levels. The unfolding stage ensures proper grid synchronization, reducing harmonic distortion and improving the power quality injected into the grid. The proposed system enhances power conversion efficiency, ensures maximum power point tracking (MPPT) for optimal PV utilization, and maintains compliance with grid regulations. The paper explores the control strategies, operational performance, and efficiency improvements of the system, making it an ideal choice for distributed renewable energy generation. Comparative analysis with traditional inverters demonstrates the microinverter's advantages in terms of scalability, modularity, and enhanced safety for residential solar applications.

***Index Terms* – Flyback, Ratio, Micro-inverter, Voltage, Gain.**

I. INTRODUCTION

The increasing global demand for renewable energy has accelerated the adoption of photovoltaic (PV) systems, particularly for residential rooftop solar installations. Among various inverter technologies used for integrating solar power into the grid, microinverters have gained widespread popularity due to their modularity, improved energy harvesting, and ease of installation. Unlike centralized and string inverters, microinverters operate at the module level, allowing independent maximum power point tracking (MPPT) for each panel, thereby enhancing overall system efficiency, especially under partial shading conditions.

One of the most efficient and cost-effective microinverter topologies is the Flyback inverter, which provides galvanic isolation, making it a safer alternative for grid-connected systems. However, traditional Flyback inverters suffer from high switching losses and lower efficiency, particularly at high-frequency operations. To overcome these limitations, an Unfolding Flyback Microinverter is introduced, which employs a low-frequency unfolding circuit instead of a conventional full-bridge inverter. This simplifies the control mechanism, reduces switching losses, and improves power conversion efficiency while maintaining compliance with grid voltage and frequency regulations.

In a grid-connected PV system, effective power injection into the grid requires precise synchronization and control strategies. The Unfolding Flyback Microinverter improves the AC power waveform quality by reducing total harmonic distortion (THD), ensuring a smoother transition between DC-AC power conversion. Moreover, advanced MPPT algorithms are integrated to maximize energy extraction from the PV panels under varying irradiation and temperature conditions.

The proposed system offers multiple advantages over traditional microinverters, including reduced component count, higher efficiency at low power ratings, and enhanced reliability. Since Flyback microinverters operate with high-frequency transformers, they ensure electrical isolation, improving system safety and grid compatibility. Additionally, their modular nature makes them ideal for residential users who prefer scalable solutions for incremental solar power expansion without modifying the entire setup.

Another critical aspect of microinverter design is power quality and grid compliance. The Unfolding Flyback Microinverter efficiently maintains power factor correction (PFC), ensuring minimal reactive power injection into the grid. Moreover, improved voltage regulation techniques prevent grid disturbances, making the system more stable and reliable for residential applications.

This paper focuses on the design, control strategy, and operational performance of the Unfolding Flyback Microinverter in a Single-Phase Grid-Connected PV System. A detailed comparative analysis is presented to highlight the benefits of the proposed system over conventional centralized inverters and other microinverter topologies. The study also explores future advancements, including AI-driven MPPT, wide-bandgap semiconductor adoption, and improved thermal management, to further enhance efficiency and reliability. With the growing shift towards smart energy solutions, the proposed Unfolding Flyback Microinverter provides an optimal balance between efficiency, cost-effectiveness, and ease of deployment, making it a promising technology for residential solar energy applications.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 14, Issue 2, February 2025)

II. PROPOSED MODEL

The present efficient BF/F miniature inverter with non-detached pseudo-DC interface, which comprises of an exceptionally BF/F converter and an unfolding stage. The hybrid BF/F converter is involved a decoupling capacitor Ci, a primary power switch Q1, a resounding capacitor Cs, two power rectifier diodes D1 and D2, two yield filter capacitors C1 and C2, a coupled transformer T that is modeled as a polarizing inductor L m, a leakage inductor Ls, and an ideal transformer with the turns proportion N, and an activity mode progress network that is made out of two switches Q2 and Q3 reciprocally worked at twofold line frequency. The unfolding stage incorporates four switches S1, S2, S3 and S4 worked at line frequency, a filter capacitor Cfand a filter inductor Lf. If the switch Q2 is ON and Q3 is OFF, at that point the miniature inverter is in BF mode, in any case, the miniature inverter is in F mode.

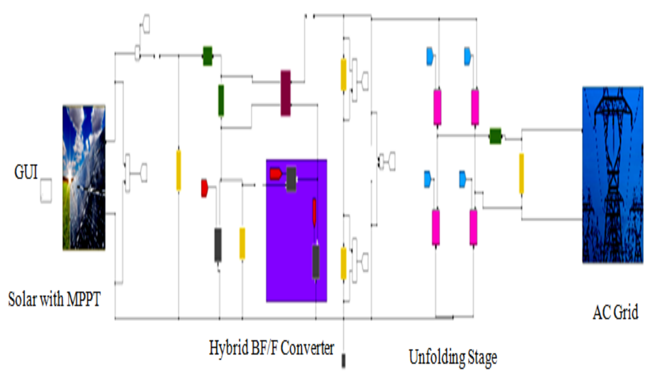
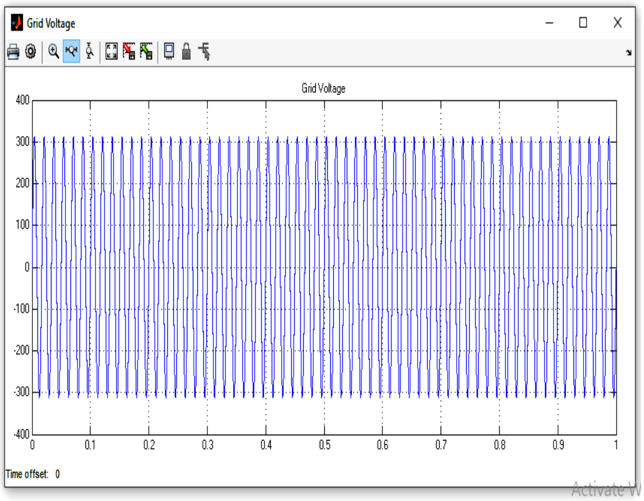


Figure 1: Proposed Model

Figure 2 is showing the present models' details. The BCM activity with top current control is received, since it offers high power thickness and transformation efficiency, and it likewise gives regular soft-exchanging of power gadgets, including ZVS and Versus of the primary switch Q1, and ZCS of the rectifier diodes D1 and D2, with the QR method utilized. The miniature inverter works at BF mode when vo ＞Vi+△V, where vo is the yield voltage of the circuit, Vi is the normal worth of the information voltage vi, and △V is a steady voltage esteem. During this mode, the switch Q2 is consistently ON and the Q3 is OFF, which makes the sub-boost converter effectively share the high prompt power with the sub-flyback converter. The boost inductor and the flyback transformer are coupled into the transformer T, and the yield voltage vo is acquired by falling the yield voltages (vc1, vc2) of the two sub-converters. Therefore, high voltage acquire is achieved with low voltage weight on the principle switch Q1, the two rectifier diodes D1 and D2, and the two yield capacitors C1 and C2. Then again, this mode intrinsically gives a latent snubber, which is made out of the diode D2, and the capacitors Cs and C2. Henceforth, the energy put away in the leakage inductor Ls is reused to the yield side. Then, the voltage overshoot of the fundamental switch Q1 is stifled during the mood killer measure. Since the yield voltage vo can't be controlled lower than the information voltage vi during the BF mode, the F mode is created with the switch Q3 consistently ON and the Q2 OFF.

This mode is around the zero-grid voltage, where the prompt transferred power is low. Therefore, the effect of the leakage inductor can be disregarded. Notwithstanding, because of the fact that the exchanging frequency during this mode is very higher than the BF mode, its term, which is controlled by △ V, should be fittingly confined to the most limited conceivable time. The full capacitor Cs is included corresponding with the fundamental switch Q1 for offering an appropriate QR time. It helps the time deferral of turn-on driving signal be planned flexibly, so the ZVS or Versus turn-on in BCM activity is ensured. In addition, this capacitor effectively improves the mood killer measure by bringing down the rising incline of the voltage across Q1.

III. SIMULATION RESULTS



e

Figure 2: Grid Voltage

Figure 2 is showing the value of grid voltage. It is generated from the overall microinverter system. The value of grid voltage is 320V.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 14, Issue 2, February 2025)

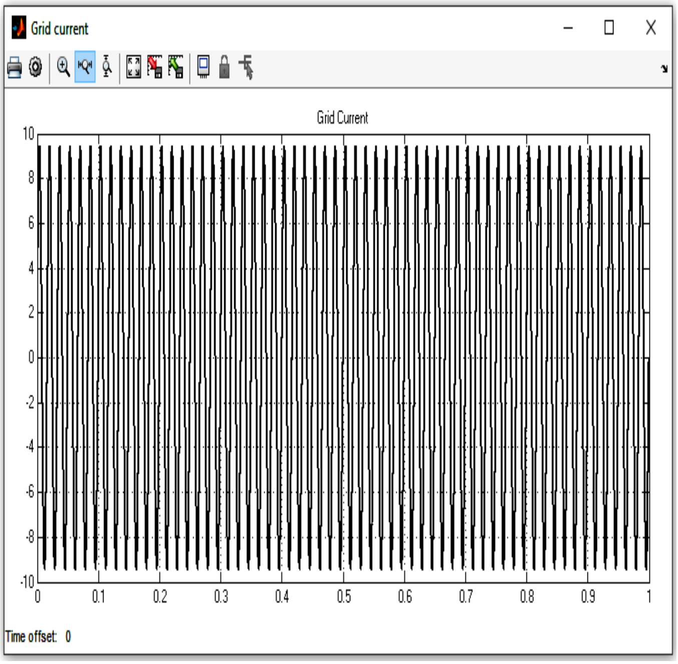


Figure 3: Grid Current

Figure 3 is showing the value of grid current. It is generated from the overall microinverter system. The value of grid current is 9.5A.

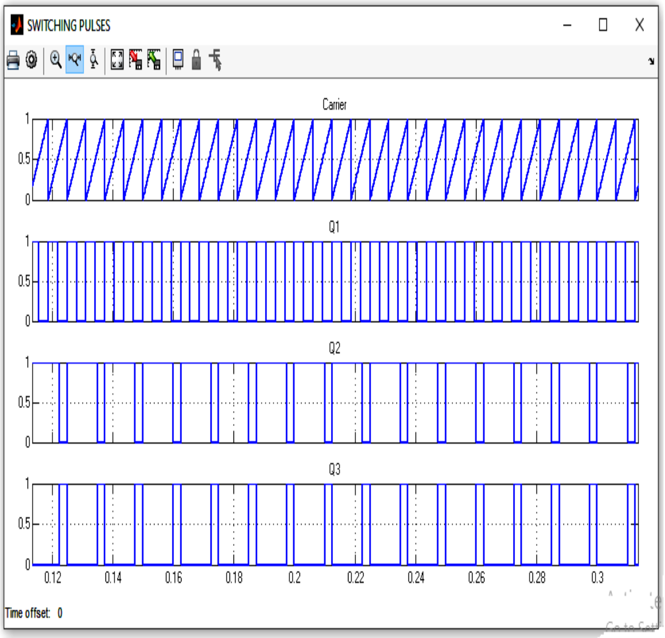


Figure 4: Switching pulse

Figure 4 is showing the switching pulse. The Q1, Q2 and Q3 are the various switches signals and carrier wave. It is used to switching pulse of the signal.

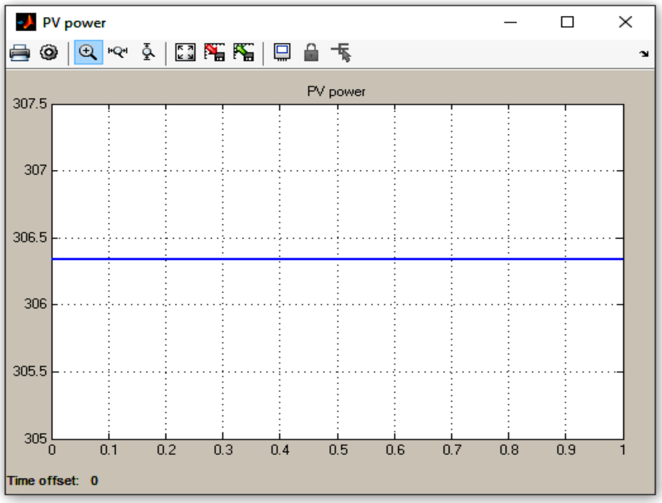


Figure 5: PV Power

Figure 5 is showing the PV power of the present model. The value of the PV power is the 306.4 W.

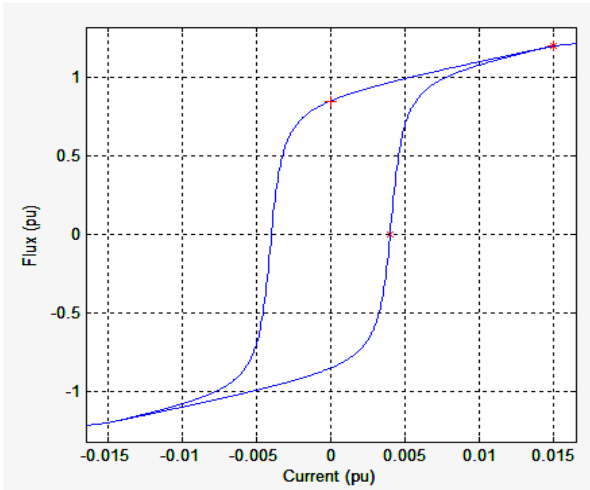


Figure 6: Hysteresis curve

Figure 6 is showing the hysteresis curve regarding the current and flux esteems. A hysteresis circle shows the connection between the incited magnetic flux thickness B and the polarizing force H.

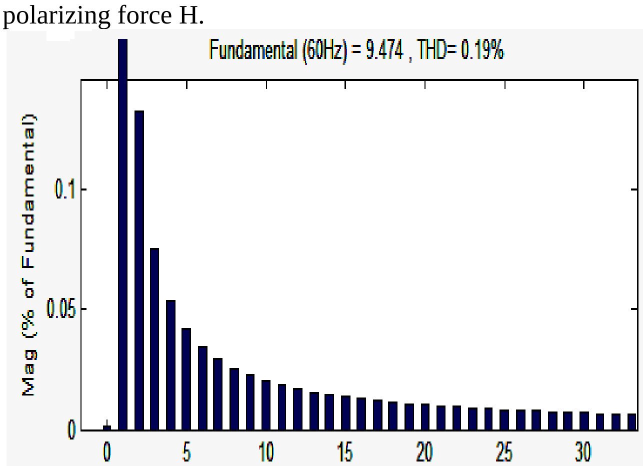


Figure 7: Total Harmonic Distortion

The current model's complete consonant bending in relation to the sound request is illustrated in Figure 7. The value of THD is 0.19%. The fundamental advantage of the THD is provided by the present research. It is defined as the ratio of the powers of all consonant parts to the power of the fundamental frequency and is an estimation of the symphonious contortion present in a signal.

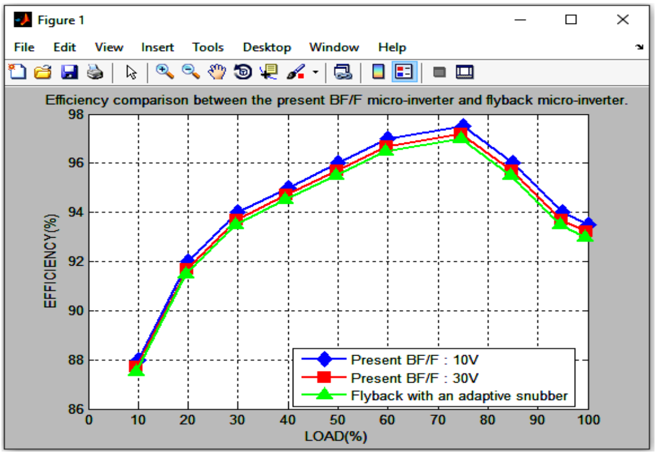


Figure 8: Efficiency comparison between the present BF/F micro-inverter and flyback micro-inverter

The efficacy of the present and past approach is the subject of Figure 8. The current BF/F miniature inverter exhibits superior efficiencies at all heaps in comparison to the flyback miniature inverter. Furthermore, they are further enhanced when the voltage is reduced from 30V to 10V. The current miniature inverter has a maximum efficiency of 97.5% (△V=10V), whereas the flyback miniature inverters have a maximum efficiency of 97%.

Table 1: Results comparison

Sr. No	Parameter	Previous Model	Present Model
1	Grid Voltage	220V	320V
2	Output Power	240W	306.4 W
3	THD	2.175 %	0.19%
4	Efficiency	96.2%	97.5%

Table 1 is showing the results comparison of the previous and present model. The present model grid voltage is the 320V while previously it is 220V.

IV. CONCLUSION

The Single-Phase Grid-Connected PV System with an Unfolding Flyback Microinverter presents an efficient, cost-effective, and modular solution for residential solar energy applications. By leveraging Flyback topology with an unfolding stage, the system reduces switching losses, enhances power conversion efficiency, and ensures grid compliance with minimal harmonic distortion. The integration of advanced MPPT algorithms maximizes energy extraction, while the microinverter's scalability and electrical isolation improve safety and reliability. Comparative analysis demonstrates its advantages over traditional inverters, making it an ideal choice for distributed renewable energy generation. Future advancements in AI-driven MPPT, wide-bandgap semiconductors, and improved thermal management can further enhance system performance, paving the way for more sustainable and intelligent solar power solutions.

REFERENCES

1. J. A. Flores and P. R. Rivera, "Single-Phase Grid-Connected MicroInverter for Low Power Photovoltaic Residential Applications," 2022 IEEE ANDESCON, Barranquilla, Colombia, 2022, pp. 1-6, doi: 10.1109/ANDESCON56260.2022.9989682.
2. S. Pal and S. Chattopadhyay, "Control of a Low-Voltage Microinverter with Secondary Phase-Shift Modulation for Grid-Connected Application," 2022 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), Jaipur, India, 2022, pp. 1-6, doi: 10.1109/PEDES56012.2022.10080693.
3. A. A. Ismail, M. Eldodor and A. A. El-Deib, "Development of a High Frequency Current Controlled Grid-connected Microinverter for PV Applications," 2022 23rd International Middle East Power Systems Conference (MEPCON), Cairo, Egypt, 2022, pp. 1-7, doi: 10.1109/MEPCON55441.2022.10021756.
4. A. A. Mamun, M. I. I. Sakib, K. F. I. Faruque, M. R. Uddin and K. M. Salim, "A Grid-Tie Microinverter Design Based on Dual-Switch Flyback Topology for Solar PV Application," 2022 International Conference on Engineering and Emerging Technologies (ICEET), Kuala Lumpur, Malaysia, 2022, pp. 1-5, doi: 10.1109/ICEET56468.2022.10007209.
5. A. Abu-Humaid, L. Ben-Brahim, A. Gastli and M. Djemai, "Design of Transformerless Microinverter using a High Gain DC-DC Converter and PUC Inverter," IECON 2022 – 48th Annual Conference of the IEEE Industrial Electronics Society, Brussels, Belgium, 2022, pp. 1-6, doi: 10.1109/IECON49645.2022.9968659.
6. J. Roy, A. Gupta and R. Ayyanar, "Discontinuous Conduction Mode Analysis of High Gain Extended-Duty-Ratio Boost Converter," in IEEE Open Journal of the Industrial Electronics Society, vol. 2, pp. 372-387, 2021, doi: 10.1109/OJIES.2021.3077982.
7. A. Bhattacharya, A. R. Paul and K. Chatterjee, "A Coupled Inductor Based Ćuk Microinverter for Grid Connected Photovoltaic Applications," 2020 IEEE

International Conference on Power Electronics, Drives and Energy Systems (PEDES), Jaipur, India, 2020, pp. 1-6, doi: 10.1109/PEDES49360.2020.9379536.

8. A. Tomar, P. H. Nguyen and S. Mishra, "Design & Real-Time Field Implementation of Micro-Inverter for Rural Applications," 2020 IEEE 17th India Council International Conference (INDICON), New Delhi, India, 2020, pp. 1-6, doi: 10.1109/INDICON49873.2020.9342557.
9. Y. Shen, M. D'Antonio, S. Chakraborty and A. Khaligh, "CCM vs. CRM Design Optimization of a Boost-derived Parallel Active Power Decoupler for Microinverter Applications," 2020 IEEE Energy Conversion Congress and Exposition (ECCE), Detroit, MI, USA, 2020, pp. 5393-5400, doi: 10.1109/ECCE44975.2020.9236218.
10. M. D'Antonio, S. Chakraborty and A. Khaligh, "Design Optimization for Weighted Conduction Loss Minimization in a Dual-Active-Bridge-Based PV Microinverter," 2020 IEEE Energy Conversion Congress and Exposition (ECCE), Detroit, MI, USA, 2020, pp. 6008-6015, doi: 10.1109/ECCE44975.2020.9235668.