An Interlinking Converter for Renewable Energy Integration into Hybrid Grids

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Abstract –
Distributed generators (DGs) based on renewable energy sources have grown in significance in the electricity industry as global warming has increased. Microgrids offer a great framework for creating smart grids, which boost system resilience, because of their small size and ability to "island" while supplying the majority of their loads during certain circumstances. Maintaining load-generation balance is a major difficulty because microgrids are dominated by renewable-based DGs, which are characterized by their statistical features and unpredictable power. Even though microgrids are now commonly utilized and studied, there is still a lot of disagreement on whether they should use direct current (DC) or alternating current (AC), with most people favoring a combination of the two.

This article presents an interlinking converter architecture to enable the flexible integration of renewable energy into hybrid grids. With one AC port and two DC ports, the proposed converter can be set up as a DC-DC converter, a DC-AC inverter, or a DC-DC/AC multiport converter, making it a flexible choice for merging numerous DC and AC sources. The concept is supported by the MATLAB/SIMULINK simulation results, which validate features like flexible conversion, high power density, low leakage currents, and customizable power flow.

Keywords - Hybrid DC/AC grid, Interlinking converter (IC), renewable energy integration, flexibility, leakage currents.

I. INTRODUCTION

In order to meet the growing need for energy, reduce CO2 emissions, and address environmental issues, renewable energy is expected to be crucial in the future. It is feasible to integrate this renewable energy at the distribution and transmission levels. Particularly in Europe, wind power plays a significant role at the transmission level. AC or DC cables connect a large number of offshore wind farms in northern Europe to the mainland electricity grid. Due to their intermittent nature, wind farms connected to the grid with PE converters increase grid vulnerability and instability.

Compared to the previous method, freestanding hybrid topologies offer more benefits (such as increased reliability, higher power density, and lower cost for the small number of transfer stages) and more flexibility. Split-source inverters were created to increase characteristics such as small size, high efficiency, flexible power flow, and voltage augmentation; nevertheless, the issue of leakage current was not considered. This is a challenging issue when applied to PV systems. Although they can only convert energy in one direction, standalone converters without a transformer can be used to reduce leakage currents.

The benefits of freestanding hybrid converters, however, conflict with the relatively low power density required by the dual-buck inverter, which calls for the usage of large AC filter inductors.

According to this study, interlinking conversion architecture is a good option for integrating RES into hybrid grids. It beats the competition due to its exceptional durability, easy implementation, and flexible operation. An active switch and a VSI would be used in place of the boost converter's power device in order to implement the recommended architecture. It also makes use of a symmetrical impedance network, which enhances power density, leakage current suppression, and system efficacy. A dedicated modulation technique is shown as an example of how power quality and control flexibility can be enhanced without compromising efficiency.

II. MICROGRID CONCEPT

"The MicroGrid structure envisions a combination of loads and microsources working as a unified system producing electricity and heat," the Consortium for Electric Reliability Technology Solution (CERTS) states. The great majority of microsources will need to be power electronic based in order to provide controlled operation as a single aggregated system. In addition to appearing to the bulk power system as a single regulated entity, the MicroGrid can readily adjust to new microsources and controls to meet the needs of its local consumers. A greater level of reliability and safety in the near area is one of these needs. The Consortium for Electric Reliability Technology Solutions published a white paper on the integration of distributed energy resources. The MicroGrid allows for regulation of power flow and MicroGrid voltage in addition to individual source control.

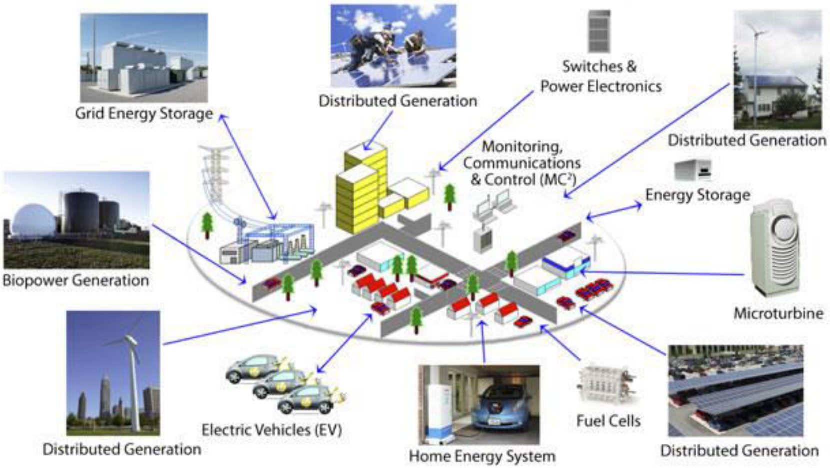


Fig.1: MicroGrid structure

Figure 1 depicts the components of a MicroGrid, which include many consumers and several power generators in a small region. Energy independence for local power producers and customers is made possible by connecting a separate power source to the MicroGrid. Both low and high voltage systems are viable for the MicroGrid. Figure 2 depicts the hybrid system's configuration. The AC & DC bus are associated to the various AC & DC sources & loads. Power inverters and transformers connect the AC to DC bus.

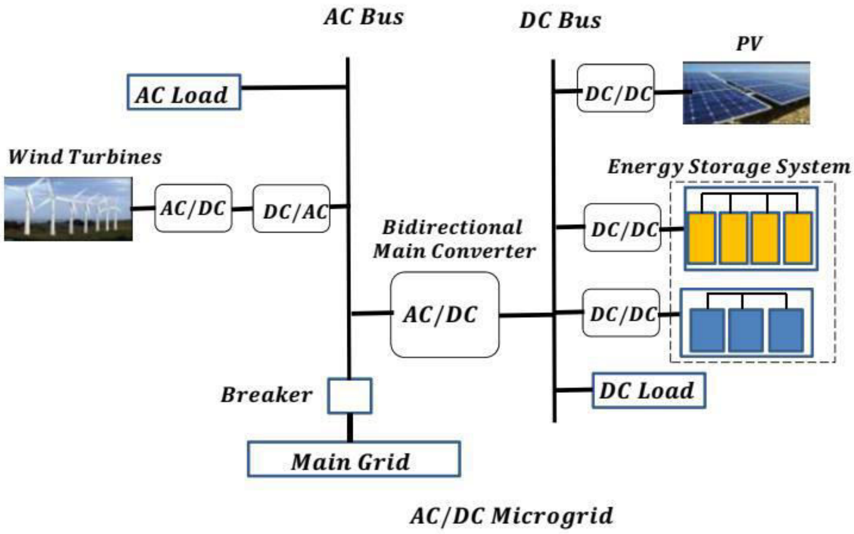


Fig.2: Hybrid AC/DC MicroGrid System

III. PROPOSED INTERLINKING CONVERTER

A. General Concept

The suggested interconnecting converter design for hybrid grids is seen schematically in Fig. 3. Figure 3 shows that the converter has three inputs: two DC ports & one AC port. The AC side may either be an AC load or grid. Importantly, the suggested design would benefit greatly by having bidirectional power conversions at every step. The following factors are important to keep in mind when doing so: To get an alternating current (AC) output, a voltage source inverter (VSI) is used in place of the boost converter's control switch, & the VSI's common-mode voltage (CMV) is clamped. This allows the hybrid converter to perform either boost or buck conversion between the DCL & DCH sides.

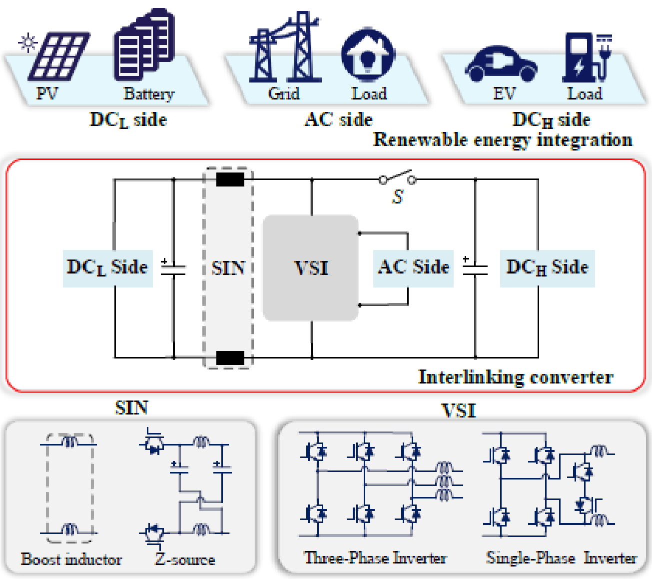


Fig. 3. Proposed architecture.

Since the impedance and VSI are set up symmetrically, the CMV is limited to be equal to half the DCL voltage in this design. In Fig. 4, the CMV clamping is illustrated by illustrating the suggested interlinking converter design with a 1-Φ inverter.

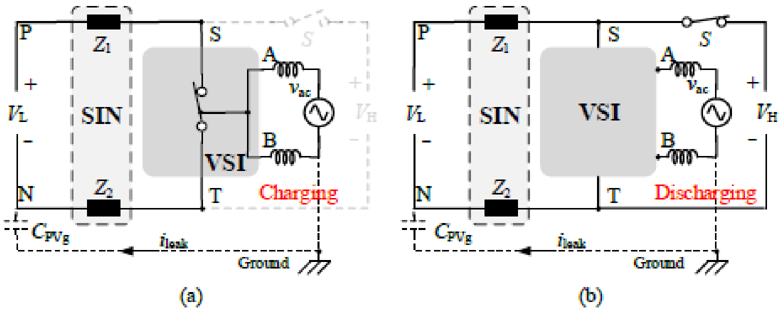


Fig. 4. System stages operation.

According to Fig. 4, the SIN can be in one of two states: a charged condition, as shown, or a discharged state, as shown below. First, as shown in Fig. 4, the active switch S is turned off and the VSI runs in shoot through mode while loading (a). Accordingly, vAN = vBN = VL=2, & the CMV vcm is found by using these values.

$$v_{\mathrm{cm}} = \frac{v_{\mathrm{AN}} + v_{\mathrm{BN}}}{2} = \frac{V_{\mathrm{L}}}{2}$$

S is ON, the VSI is converting DC to AC, and the SIN is releasing, as shown in Fig. 4(b). Considering that the selected VSI fully clamps the CMV, the resulting CMV of the suggested conversion may be calculated as

$$\begin{aligned} v_{\mathrm{cm}} &= \frac{v_{\mathrm{AN}} + v_{\mathrm{BN}}}{2} = \frac{(v_{\mathrm{AT}} - V_{\mathrm{Z2}}) + (v_{\mathrm{BT}} - V_{\mathrm{Z2}})}{2} \\ &= \frac{V_{\mathrm{H}} - (V_{\mathrm{Z1}} + V_{\mathrm{Z2}})}{2} = \frac{V_{\mathrm{L}}}{2} \end{aligned}$$

where VZ1 and VZ2 are the SIN voltages, i.e., VZ1 = VZ2. From the equations, it is clear that the SIN & the VSI with its CMV clamped are utilised in the planned interlinking conversion architecture, allowing it to keep its CMV constant. For this reason, the suggested interconnecting converter is a good fit for PV systems. Keep in mind that the DCL side is the sole place where leakage current reduction is possible. According to the needs of the application, additional isolation hardware at the DCH side may be considered.

B. Operational Flexibility

Power may flow in both directions between the DC ports thanks to the synchronous rectifier switch, as shown in Fig. 3. The power factor of the VSI may be varied between [-1, 1] with the use of a specialised modulation technique, allowing it to accomplish reactive power injection. For integrating RES into hybrid grids, the proposed hybrid converter offers a great deal of controllability and adaptability. The many operation modes, such as the power feed-in mode (Mode I), the power feedback mode (Mode II), and the power factor mode (Mode III) depicted in Fig. 5, demonstrate this adaptability.

(1) When in Mode I, the DCL side acts as a generator (via PV panels, for example) for the DCH side, the AC side, or both. Here, the converter boosts the DC-DC conversion from the

DCL side to the DCH and DC-AC conversion from the DCL side to the AC side. Furthermore, in this mode, power can be transferred from the DCL side to the AC/DCH side.
(2) There are three distinct use-cases for Mode II. First, the converter operates in active rectification for the DCH side and buck DC-DC conversion for the DCL side from the AC side, with the power being fed back to the DCL and DCH sides (i.e., the two DC ports are loads). Second, when just the DCL side is acting as a load, the power feed-back mode is in effect (e.g., charging batteries). What this means is that power is being supplied from both the DC and AC sources. The third issue is that both the DCL and AC sides are acting as loads, when the DCH side should be responsible for the buck DC-DC and DC-AC conversions.
(3) In Mode III, the power factor at the AC side must be regulated flexibly to allow grid-connected applications, regardless of the power flow modes between the DCL and DCH sides. As shown in Fig. 5, this is possible with the proposed converter design when the DC-AC conversion modulation approach includes reactive power injection capabilities.

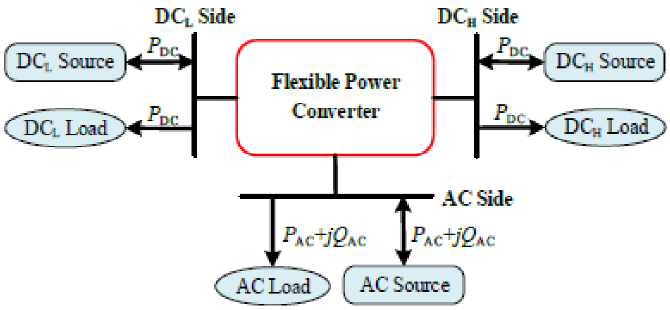


Fig. 5. Proposed modes of operation.

In a combination AC/DC grid, the overall network function is greatly enhanced if the AC & DC ports are coupled to grids. When the AC grid requires help, the power flow from the input DCL side may be modified, & the DCH grid can also provide benefit by supplying power to the AC port. In a similarly, if the DC side experiences steady state difficulties under faults, the AC grid can be run in the correction mode to aid the DC grid in sustaining the fault. Altogether, the proposed energy conversion structure can be a flexible and viable method for integrating RES into hybrid AC/DC grids.

C. Topology and Modulation Example

Moreover, in Fig. 6, a converter is presented that implements the suggested structure by employing a very effective and dependable inverter concept (HERIC) circuit as the VSI & a symmetry inductor network as the SIN, with the modulation method being illustrated on this setup.

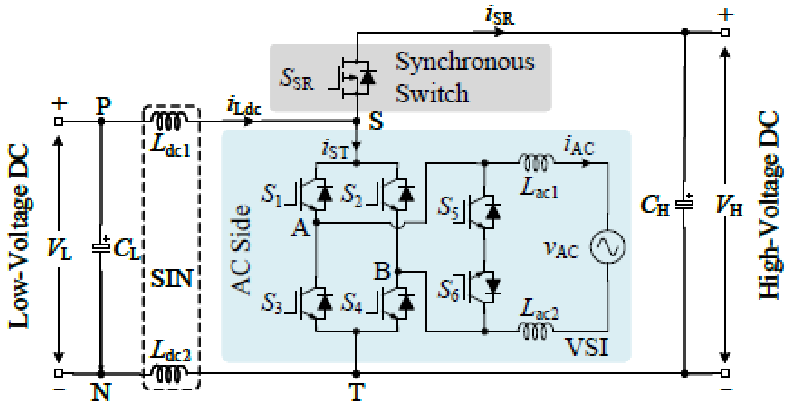
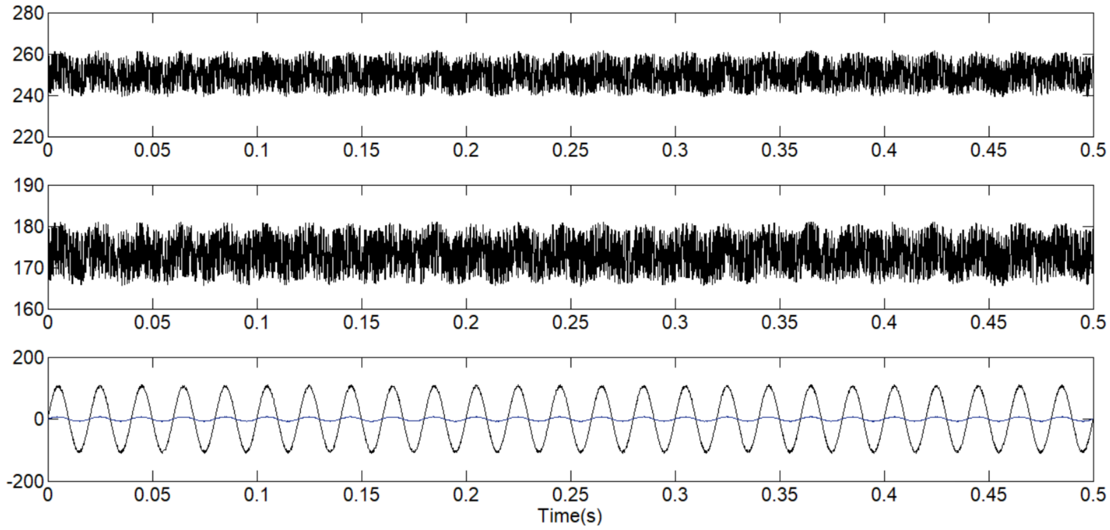


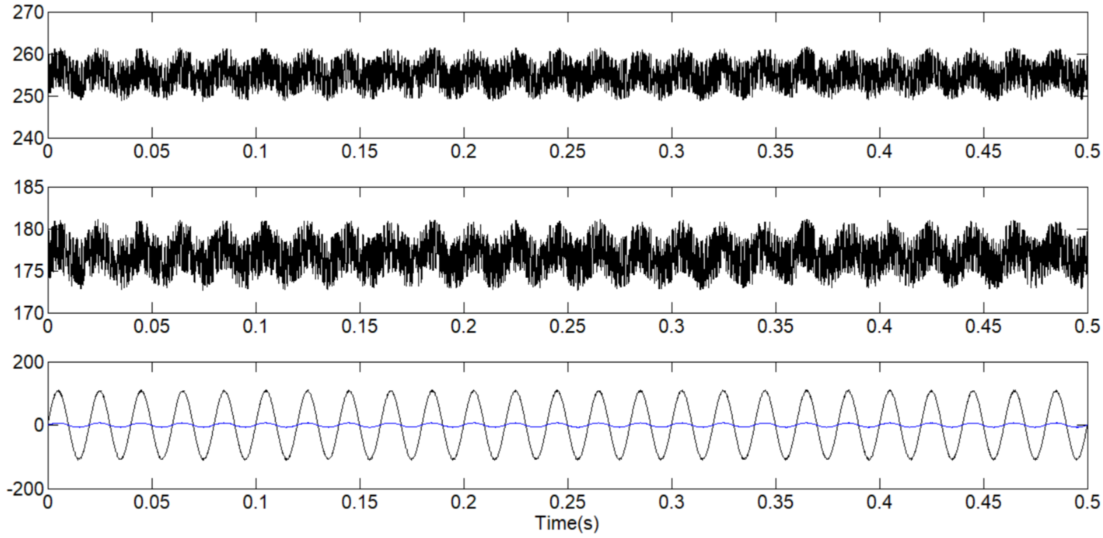
Fig. 6. Proposed architecture.

IV. SIMULATION RESULTS

Case-1:-



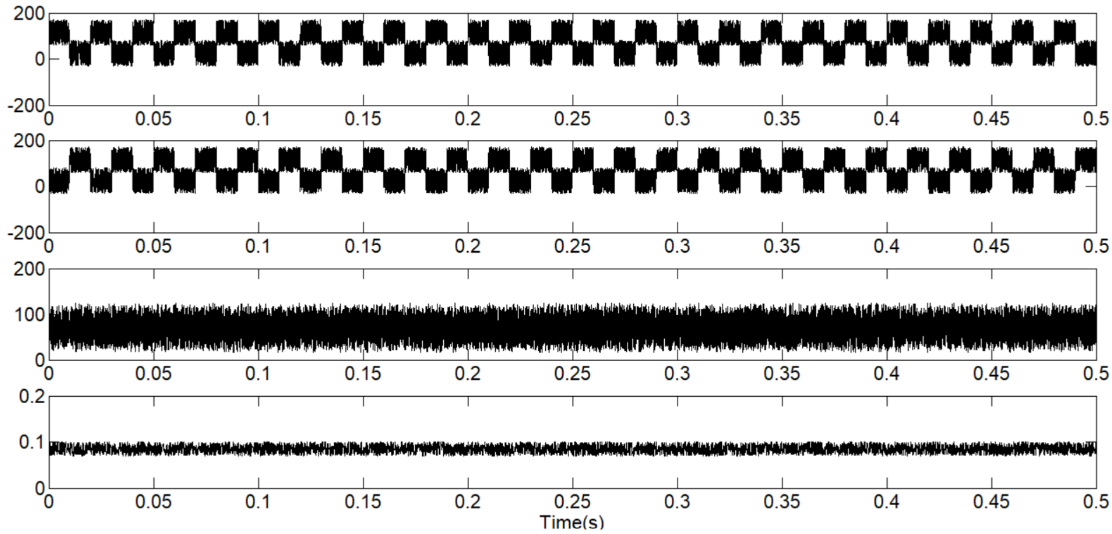
Existing waveforms



Proposed waveforms

Fig:-7. Proposed Mode I waveforms.

For the suggested converter's Mode I operation, seen in Fig. 7, the DCL side supplies energy to the DCH side as well as the AC output. In Fig. 7 we can see that the suggested design can deliver both AC & DC outputs at the same time. According to Fig. 7, ripples can be seen in both DC voltages owing to power connection and the features of the consumer DC source. This can be mitigated by employing power decoupling measures for regular VSIs.



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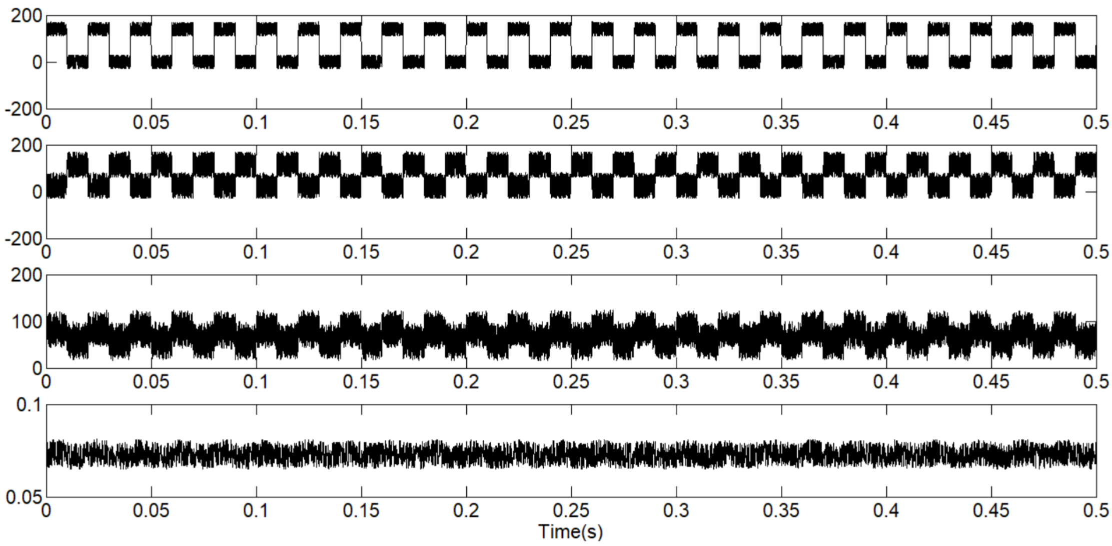
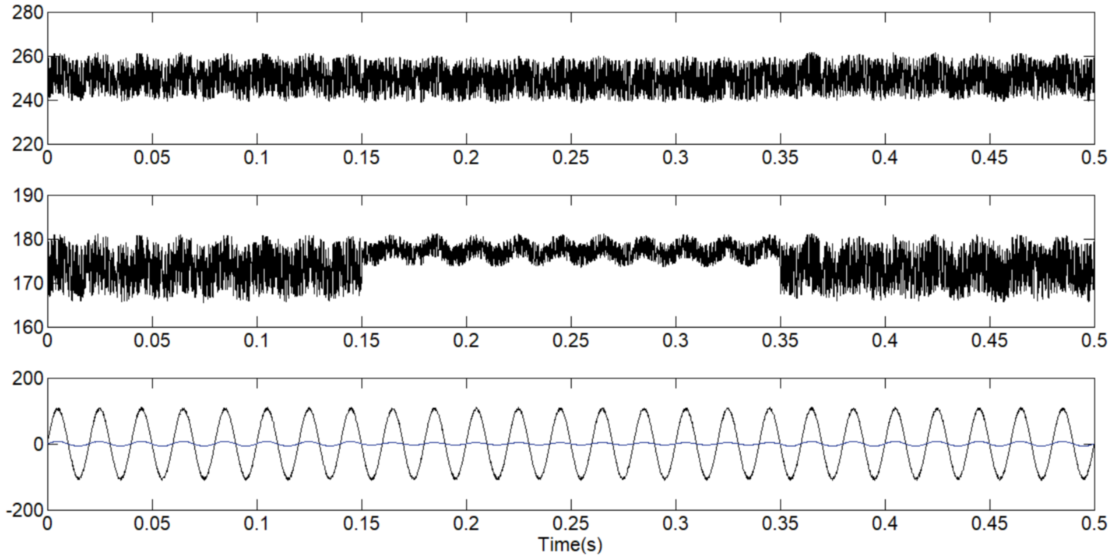


Proposed waveforms

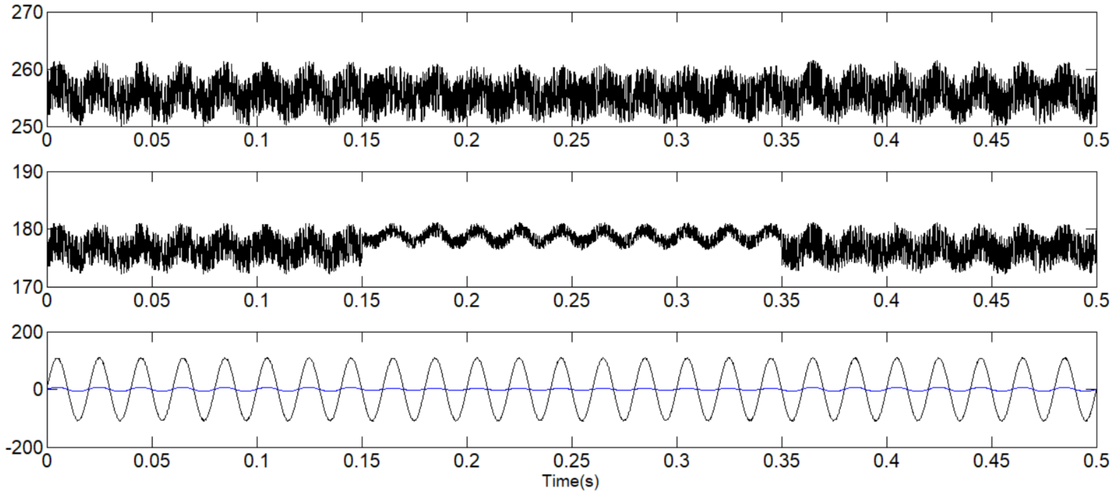
Fig:-8. Proposed system waveforms.

The CMV & leakage currents of the suggested topology for PV applications are shown in Fig. 8. According to Fig. 8, the leakage current ileak is acceptable. The inverter voltages vAN and vBN in Fig. 8 further demonstrate that the proposed modulation approach can match the HERIC's effectiveness when using unipolar PWM. As a result, the suggested converter can keep leakage currents to a minimum while providing clean electricity.

Case-2:-



Existing waveforms

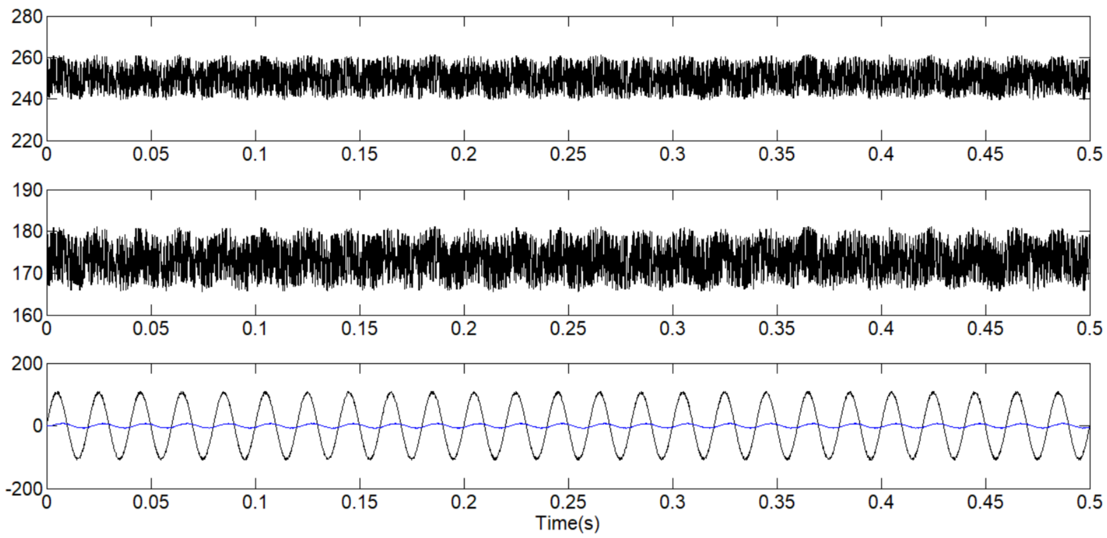


Proposed waveforms

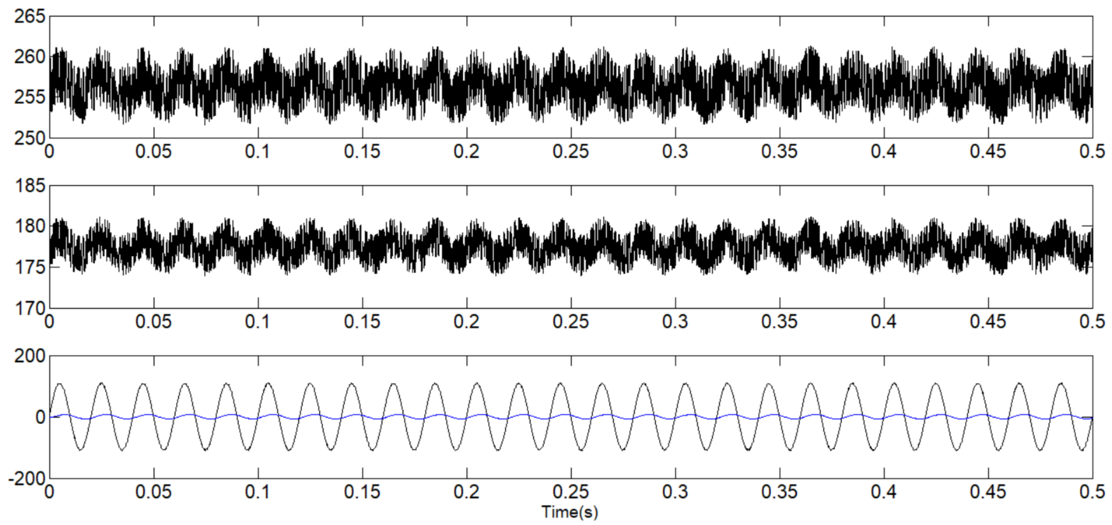
Fig:-9. Mode I waveforms

Moreover, an AC load change test has been conducted to evaluate the converter's system characteristics in Mode I. Figure 9 depicts the results of reducing the grid current amplitude (RMS) to 2.5 A and subsequently increasing it to 5 A. It has been shown experimentally that the suggested converter can maintain stability even when subjected to varying loads. Additionally, the current quality is immune to variations in load because to the independent regulation of the DC-DC and DC-AC conversions.

Case-3:-



Existing waveforms



Proposed waveforms

Fig:-10. Mode III waveforms

The suggested converter's efficacy is confirmed even more by numerical simulations in Mode III, where the DC-AC conversion runs with a non-unity power factor, and the results are displayed in Fig. 10. Based on what we see in Fig. 10, the suggested converter may be useful for the whole system because of its ability to provide adjustable reactive power injection.

CONCLUSION

In this work, a potential approach to the problem of integrating diverse forms of energy into hybrid grids was suggested: an interlinking convert structure. To realise the suggested design, the boost converter's power components are swapped out for a voltage source inverter (VSI) and an operational switch. The suggested interconnected conversion design has the potential for low system losses, highly efficient, excellent power quality, and adaptable regulation of power flow. The effectiveness of the suggested design has been demonstrated using MATLAB/SIMULINK simulations. Flexible power conversion architecture may prove to be a useful connecting component as the need for hybrid energy systems grows.

REFERENCES

[1] I. Batarseh and K. Alluhaybi, “Emerging opportunities in distributed power electronics and battery integration,” IEEE Power Electron. Mag., vol. 7, no. 2, pp. 22–32, Jun. 2020.

[2] B. T. Patterson, “DC, come home: DC microgrids and the birth of the Enernet,” IEEE Power Energy Mag., vol. 10, no. 6, pp. 60–69, Nov. 2012.

[3] A. K. Bhattacharjee, N. Kutkut, and I. Batarseh, “Review of multiport converters for solar and energy storage integration,” IEEE Trans. On Power Electron., vol. 34, no. 2, pp. 1431–1445, Feb. 2019.

[4] Balavenkata Muni, N., Sasikumar, S., Hussain, K., Reddy, K.M. (2022). A Progressive Approach of Designing and Analysis of Solar and Wind Stations Integrated with the Grid Connected Systems. In: Kalinathan, L., R., P., Kanmani, M., S., M. (eds) Computational Intelligence in Data Science. ICCIDS 2022. IFIP Advances in Information and Communication Technology, vol 654. Springer, Cham. https://doi.org/10.1007/978-3-031-16364-7_7.

[5] K.MEENENDRANATH REDDY, & SYED RESHMA. (2022). A Comparative Analysis of Integrated DC Microgrid with Hybrid Power Generation Systems by an Intelligent Control Strategy. International Journal of Recent Research in Electrical and Electronics Engineering, 9(2), 1–10. https://doi.org/10.5281/zenodo.6538769.

[6] J. Ramos-Ruiz, B. Wang, H. Chou, P. Enjeti, and L. Xie, “Power electronics intelligence at the network edge (PINE) – an approach to interface PV and battery energy storage systems at the grid edge,” IEEE J. Emerg. Sel. Top. Power Electron., pp. 1–1, 2020.

[7] D. D’Agostino, P. Zangheri, B. Cuniberti, D. Paci, and P. Bertoldi, “Synthesis report on the national plans for nearly zero energy buildings (NZEBs),” EUR 27804 EN.

[8] Sharabu. Siddhartha Achari, Galigeri. Aravindakumar, Ketha. Govardhan and K.Meenendranath Reddy. Wireless Electrical Power Transmission Using Spark Gap Tesla Coil (SGTC). International Journal for Modern Trends in Science and Technology 2022, 8(07), pp. 38-50. https://doi.org/10.46501/IJMTST0807007

[9] K.Meenendranath Reddy, G.Hussain Basha, Saggi Raj Kumar, V.Srikanth. An Efficient MPPT Technique using Fuzzy/P&O Controller for PV Applications. International Journal for Modern Trends in Science and Technology 2021, 7, pp. 106-111. https://doi.org/10.46501/IJMTST0710017

[10] F. Nejabatkhah and Y. W. Li, “Overview of power management strategies of hybrid AC/DC microgrid,” IEEE Trans. Power Electron., vol. 30, no. 12, pp. 7072–7089, Dec. 2015.

[11] H. Ribeiro, A. Pinto, and B. Borges, “Single-stage DC-AC converter for photovoltaic systems,” in Prof. of ECCE, Sep. 2010, pp. 604–610.

[12] A. Abdelhakim, P. Mattavelli, P. Davari, and F. Blaabjerg, “Performance evaluation of the single-phase split-source inverter using an alternative DC–AC configuration,” IEEE Trans. Ind. Electron., vol. 65, no. 1, pp. 363–373, Jan. 2018.

[13] Dr. P.Sankar Babu, K.Meenendranath Reddy and S.Sneha Madhuri. Improvement of Power Quality in Renewable Energy Integrated Microgrid System Using CMBC. International Journal for Modern Trends in Science and Technology 2021, 7 pp. 299-303. https://doi.org/10.46501/IJMTST0712058.

[14] Kavitha, K., K. Meenendranath Reddy, and Dr. P.Sankar Babu. 2022. "An Improvement of Power Control Method in Microgrid Based PV-Wind Integration of Renewable Energy Sources". Journal of Energy Engineering and Thermodynamics(JEET) ISSN 2815-0945 2 (06):18-28.

[15] P. Naga Sai Charan, & K. Meenendranath Reddy. (2023). An Analysis of Multilevel Converter for Faster Current Control in a DC Microgrid with Extremely Low- Impedance Interconnections. Journal of Image Processing and Intelligent Remote Sensing(JIPIRS) ISSN 2815-0953, 3(01), 18–29. https://doi.org/10.55529/jipirs.31.18.29.

[16] S. S. Lee and Y. E. Heng, "Improved single-phase split-source inverter with hybrid quasi-sinusoidal and constant PWM," IEEE Trans. Ind. Electron., vol. 64, no. 3, pp. 2024–2031, Mar. 2017.

[17] S. S. Lee, A. S. T. Tan, D. Ishak, and R. Mohd-Mokhtar, "Singlephase simplified split-source inverter (S3I) for boost DC–AC power conversion," IEEE Trans. Ind. Electron., vol. 66, no. 10, pp. 7643–7652, Oct. 2019.