Power Quality Acquire of Intelligent Controller based Superior Gain Re-Lift Luo Converter Intended for PV Linked Microgrid Integration

E. RAJENDRAN[1], V. RAJI[2], V. K. DINESH PRABU[3]
[1]Department of Electrical and Electronics Engineering & HOD/ECE,
S. K .P. Engineering College, Tiruvannamalai, Tamil Nadu,
INDIA

[2]Department of Computer Science and Engineering,
S. K .P. Engineering College, Tiruvannamalai, Tamil Nadu,
INDIA

[3]Electrical and Electronics Engineering,
S. K .P. Engineering College, Tiruvannamalai, Tamil Nadu,
INDIA

Abstract: - Power converters-based renewable energy sources such as photovoltaic (PV) and wind energy are more popular for residential and commercial applications. Because, of their eco friendlessness and cost effective operation. A Re-Lift Luo Converter integrated with renewable sources to the utility microgrid along with Intelligent Controller strategies is proposed. The solar photovoltaic system provides voltage to the inverter through a Re-lift Luo converter. The Bidirectional Battery converter along with battery system is used to achieve energy control management for the proposed system. In this paper the grid synchronization with DSTATCOM devices controlled by PI controller with D-Q theory transformation is achieved. Under this work, DSTATCOM has been used to improve the power quality under different loading conditions. The LC filter is employed to develop the output of the inverter. The input of the PV and battery systems are DC bus power source, as well as AC power injected into the grid network. The obtained results indicate that proposed approach delivers better performance with superior efficiency and nominal harmonics. The entire proposed system is validated through a MATLAB simulation and Hardware experimental prototype.

Key-Words: - Photovoltaic (PV), Energy Storage System (ESS), Adaptive Neuro-Fuzzy Inference System (ANFIS), Maximum Power Point Tracking (MPPT), Voltage Source Inverter (VSI), Pulse Width Modulation (PWM).

Received: February 3, 2023. Revised: November 26, 2023. Accepted: December 7, 2023. Published: January 16, 2024.

1 Introduction

The microgrids are playing major role and drawing awareness from engineers and scientists for the period of the last few decades. There could be DC bus as well as AC bus bars running around where the sources and loads with suitable voltage ratings connected. microgrids are generally including renewable energy sources. The renewable energy sources distribute power into the microgrid using power electronic converters. Consequently, that the energy is properly transformed into the bus bars with changed voltage ratings. The stand alone storage system is required in the microgrid. In addition to that, the renewable energy harvested from the solar photovoltaic system can be stored the energy during the periods, at the same time as the solar irradiances are available. The stored energy can be used during the periods whereas the solar energy is not presented, particularly for the period of the night time. While the microgrid include voltage bus bars of DC and AC voltages by way of high and low voltage paths, it is necessary with the intention of multiple output power electronic converters can be employed. As a result, a lot of topological variants for multiple output power conversion systems in addition to control schemes for a variety of applications have been description in the novel, and a few of the milestone contributions are reviewed herein as a result that the research gaps could be identified.

A new DC to DC converter topology by way of a high power conversion efficiency moreover wide range of operation with zero voltage switching as well as lower output inductance has been proposed and validated, [1]. The developed a three port DC to DC converter through high voltage gain. The authors have demonstrated how it could be used for battery charging powered from a solar photovoltaic resource, [2]. The design of a solar photovoltaic simulator as a result that the research activities correlated to solar photovoltaic systems could be carried out effortlessly in a laboratory for the period of day or night. The multiport DC to DC converters have been generally suggested for utilize in microgrids as fine, [3].

A choice of configurations of multiple output DC to DC converters has been discussed in article, [4]. A quadratic boost converter through lofty voltage gain has been presented, [5]. In the research article, [6], the developed a harmonic reduction scheme is a cascaded cell-based islanded microgrid. The developed a high step up DC to DC converter with a Ćuk-derived quadratic boost converter, [7]. A dual-output DC to DC converter among the relift Luo converter as the interior converter has been presented in this article. The proposed system is proved to be more beneficial by way of increased voltage gain, which enables the system to be operational even through low solar irradiance otherwise when the battery state of charge becomes especially low, [8].

An artificial neural network controlled based battery charging scheme has been proposed and validated, [9]. A hybrid energy storage system powered from the solar photovoltaic system has been developed, [10]. Correspondingly, in solar powered battery based energy storage system has been designed for applications in AC low voltage systems and for catering power used for nonlinear load applications, [11]. The detailed study of power electronic conversion systems are powered by a solar photovoltaic source. The author of for this work made the study in the viewpoint of reliability study, [12]. A multifunction converter powered from a solar photovoltaic source primarily for water pumping applications has been developed, [13].

The developed a DC to DC converter through a three winding coupled inductor to facilitate provides non isolation, reduced voltage stress in addition to high voltage gain features. The increased voltage gain and reduced switching losses, least ripple on the output DC voltage and linearity in control for maximum possible range of output voltage as well as loading conditions are several of the basic requirements of a power electronic converter, [14]. In this kindness, several authors have derived new conversion schemes using the traditional converters like the SEPIC converter, Cuk converter and Luo converter. For example in reference, [15], the modified crucial SEPIC topology for getting high voltage gain. Additional, the authors have developed high voltage gain quasi-SEPIC converter.

This paper identified the frequency scope of interactions in a viewpoint of d-q frame impedances in addition to pinpoint that the ac voltage regulation was the major reason of instability, masking the special effects of phase-locked loop on power transmission systems, [16]. The existing a normalized gradient adaptive regularization factor neural filter supported control is presented for a three phase grid connected solar PV battery energy storage microgrid arrangement. Here, a used incremental conductance technique is utilized for the peak power taking out of a PV array, [17].

A matchless control is developed for resynchronization of the grid throughout reconnection of the grid after the mitigation of a failure. The overall system control system is flexible under various practically happening situations such as disconnection of the PV array, battery and the grid from the arrangement, [18]. Based on the above mention survey, the proposed Re-lift Luo converter through Adaptive Neuro-Fuzzy Inference System (ANFIS) algorithm used PV system, the voltage and supplying the reactive power, power quality issues are overcome for microgrid integration. The role of the document is mentioned below,

- To extract the maximum power from PV system using Re-lift Luo converter through Neuro Fuzzy Logic algorithm.
- To achieve the high gain output DC voltage with Proposed MPPT and Re-Lift Luo converter.
- To achieve the power management system for the proposed Bidirectional Battery converter along with battery system.
- To achieve the grid synchronization using D-Q theory and PI controller.

2 Materials and Method

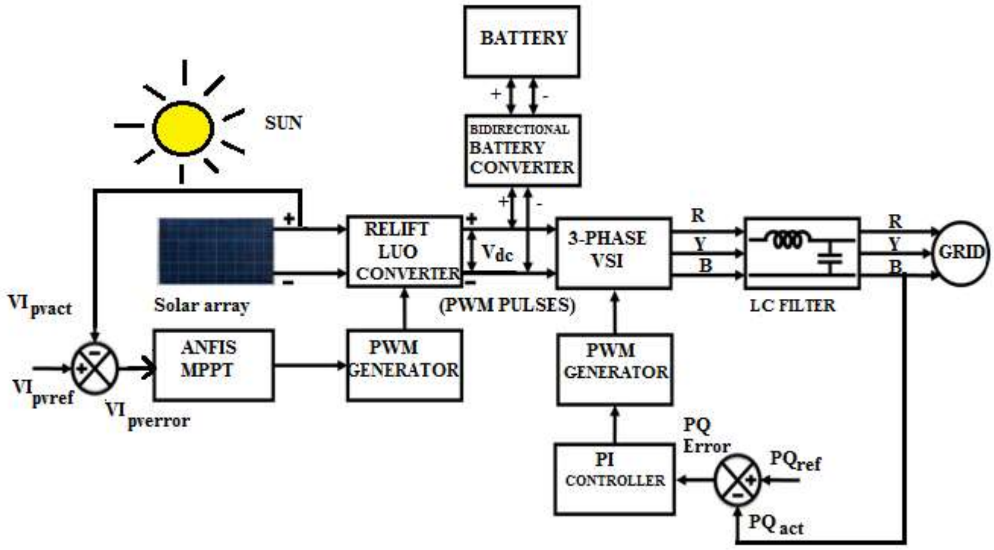

Fig. 1: Proposed Simulation Block Diagram

- To demonstrate the characteristics of the PV and the battery systems are analysed using MATLAB Simulink and hardware model environment.

In this proposed system implementing an innovative DC-DC multi-source converter configuration based grid interactive microgrid consists of Photovoltaic (PV) and Energy Storage System (ESS) is proposed as shown in Figure 1. The planned system design makes use of solar as well as batteries for an efficient storage system. The battery is used to achieve the energy management of the proposed method. The optimal DC voltage is extracted from the PV panel using ANFIS based MPPT is injected into a proposed converter,which helps to improvise the DC voltage. A power output obtained from a PV panel or array is fed into the Re-lift Luo converter and the enhanced output from the converter is converted to AC through a 3 phase Voltage Source Inverter (VSI), which is injected to the grid after suitable synchronization. A PI controller is implemented to maintain the constant voltage of the DC link and enhance the grid's performance. The PWM generators are employed in this method, based on the error signal can able to generate the proper pulses and supplied to the Inverter as well as Re-lift Luo converter. The harmonic present in VSI is rectified using LC filter; thereby the quality power has been safely injected into the microgrid. Under this work, DSTATCOM has been used to improve the quality of power under different loading conditions and also reduces the Total Harmonics Distortion (THD) and satisfies the IEEE harmonics standard level.

2.1 Re-Lift Luo Converter

The Re-Lift Luo converter comprises of three diodes D_1, D_2, D_3; three capacitors C_1, C_2, C_3; three inductors L_1, L_2, L_3; two power switches S_1, S_2 as well as an output capacitor C_0 as shown in Figure 2. The Capacitors C_2 and C_3 acquire a voltage boosting characteristic which makes the capacitor voltage V_C two times upper than the source voltage V_{PV}. The inductor L_3 serves as a ladder joint for connecting the capacitors C_2 and C_3 in order to raise the capacitor voltage V_{C1}.The source instantaneous current $I_{PV}= i_{L1} + i_{L2} + i_{L3} +i_{C2} +i_{C3}$ flows when the power switches S_1 and S_2 are turned ON as illustrated in Figure 3. Meanwhile, the inductors L_1 and L_3 store the energy from the source. The inductor L_2 gets charged with the energy received from both the source and capacitor C_1. The current flowing during the inductors L_1, L_2 and L_3 get to increased.

The source current I_{PV} becomes zero when the power switches S_1 and S_2 are in OFF condition as illustrated in Figure 4. The discharging of inductor L_1 takes place and the inductor current i_{L1} flows via path $C_2 - L_3 - C_3 - D_3 - C_1$ and results in charging of capacitor C_1. For the moment the inductor L_2 discharges energy and the current i_{L2} flows to the load R and output capacitor C_0.The current i_{L1} and i_{L2} reject at this stage. By means of considering capacitors C_2 and C_3 value as very large, during steady state condition $V_{PV}= V_{C2}=V_{C3}$. At the switch ON condition, $V_{L3} = V_{PV}$. The peak-to-peak current ripple of inductor L_3 is expressed by the equation as follows:

$$\Delta iL3 = \frac{VPVK}{L3} \quad (1)$$

At the switch OFF condition,

$$\Delta iL3 = \frac{VL3(1-K)T}{L3} \quad (2)$$

The voltage across the inductor L_3 is given as,

$$VL3 = \frac{k}{1-k}\ VPV \quad (3)$$

During the period kT, the switch is in ON condition as well as the current i_{L1} increases whereas during period (1-K) T, the switch is in OFF condition with the current i_{L1} decreases. V_{PV} and – (V_{C1}- 2V_{PV} - V_{L3}) are the related voltages supplied to the inductor L_1. Thus,

$$KTVPV = (1-K)T\ (VC1 - 2VPV - VL3) \quad (4)$$

Therefore,

$$VC1 = \frac{2}{1-K}VPV \quad (5)$$

Similarly, during the period KT, the switch is in ON condition in addition to the current i_{L2} increases whereas during the period (1-K) T, the switch is in OFF condition and the current i_{L2} decreases. $(VPV - VC1 - V0)$ and $-(V0 - 2VPV - VL3)$ are the related voltages supplied to the inductor L_2.
Thus,

$$KT\ (VC1 + VPV - V0) = (1-K)T\ (VC1 - 2VPV - VL3) \quad (6)$$

Therefore,

$$Vo = \frac{2}{1-K}VPV \quad (7)$$

By taking into account $P_0 = P_{IN}$ i.e., $V_0 I_0 = V_{PV} I_{PV}$, the output current is:

$$Io = \frac{1-K}{2}IPV \quad (8)$$

The value of the inductors L_1, L_2, C_1, C_2, C_3 and C_0 are obtained from the following equations,

$$L1 = \frac{1-KTVPV}{\Delta iL1} \quad (9)$$

$$L2 = \frac{KTVPV}{\Delta iL2} \quad (10)$$

$$C1 = \frac{(1-K)TiL1}{\Delta VC1}$$

$$= \frac{(1-K)KT}{\Delta VC1}IPV \quad (11)$$

$$C2 = \frac{(1-K)T\ (iL1 + iL2)}{\Delta VC2}$$

$$= \frac{IoT}{\Delta VC2} \quad (12)$$

$$C3 = \frac{(1-K)T\ (iL1 + iL2)}{\Delta VC3}$$

$$= \frac{IoT}{\Delta VC3} \quad (13)$$

$$Co = \frac{KT * TVPV}{4\Delta VoL2} \quad (14)$$

The converter voltage output is not stable in addition to it is affected seriously by the non-linear nature of the PV output. The implementation of a valuable controller is crucial to make the converter output constant. In this work, ANFIS is used to control the operation of the re-lift Luo converter as it is capable of enhancing the operation of the converter.

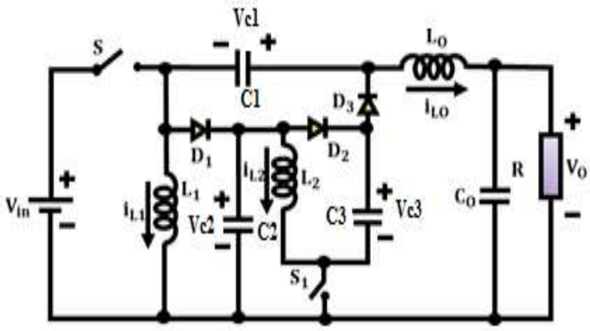

Fig. 2: RE-LIFT LUO Converter Circuit.

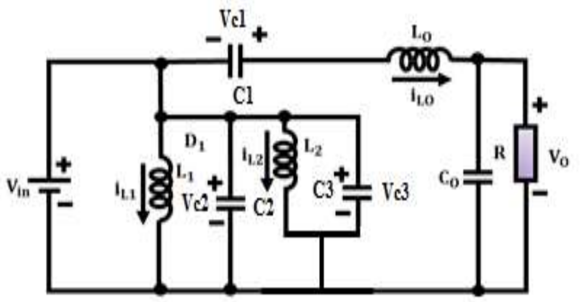

Fig. 3: RE-LIFT LUO Converter is ON Condition

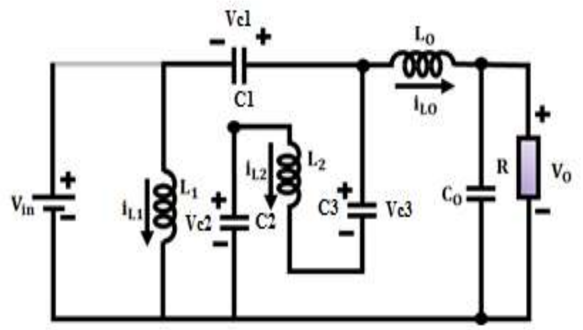

Fig. 4: RE-LIFT LUO Converter is OFF Condition

2.2 ANFIS Based MPPT

An innovative ANFIS based Maximum Power Point Tracking (MPPT) method is proposed to attain as well as tracking the maximum power of the PV module under changing the weather conditions. The proposed input variables are PV voltage (VPV) and PV Current (IPV) and solar cell temperature. The output variable is only duty cycle, which is used to control the DC-DC RE-LIFT LUO Converter in order to keep tracking maximum power. Since the modeling of the conventional Fuzzy Logic Controller is based on trial and error, the probability of obtaining the optimal performance is low. Therefore, obtaining membership functions and fuzzy rules can be prepared through learning using ANFIS.

The ANFIS is able of developing the input-output mapping of training data sets, when it is trained with sufficient number of epochs. By adjusting the standards of membership functions, ANFIS generates the set of fuzzy rules in order to create appropriate output for altered values of inputs. When the parameters of membership functions are adjusted otherwise changed till the error is reduced to least value. Once all the parameters of membership function are in tuned, the ANFIS model becomes learning model which is ready to be used in MPPT control system. But, before using ANFIS learning model for MPPT control, its results are checked by using checking data which is different starting training data. Over if error produced is more than desired value, parameters of membership functions are adjusted to bring down the error. A DC-DC Relift Luo Converter is designed to be placed between solar PV modules as well as load in order to transfer maximum power to load by changing duty cycle of DC-DC Relift Luo Converter.

2.3 Bidirectional Battery Converter

The bidirectional battery converter allows power to flow in both directions between the battery and the load or grid, depending on the needs of the system as shown in Figure 5. During periods of high load or grid demand, the battery can discharge through the DC/AC inverter to provide additional power. During periods of low load or grid demand, excess power from the grid can be used to charge the battery through the AC/DC rectifier.

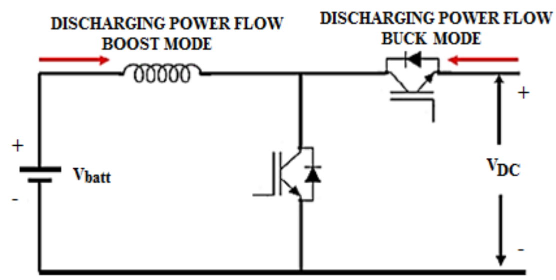

Fig. 5: Bidirectional Battery Converter.

The BDC, during charging mode, operates in buck mode due to the fact that the dc-link serves as its input, while the ESS functions as its load. The capacitor and inductor values during buck mode is estimated as,

$$\mathrm{Lbuck} = \frac{(\mathrm{VDC} - \mathrm{VESS})\mathrm{Dbuck}}{\Delta \mathrm{ILf}} \tag{15}$$

$$\mathrm{Cbuck} = \frac{(1 - \mathrm{Dbuck})}{(8\mathrm{Lbuck}\Delta \mathrm{VEssf} * \mathrm{f})} \tag{16}$$

Where, the ripple current and switching frequency are specified using theterms ΔI_L and f, respectively, while the duty ratio is specified by the term D. In the case of the discharging mode, the conditions are reversed as the BDC is in boost mode, though the ESS operates as the input this time along with the dc-link serves as the load. The capacitor as well as inductor values in this mode are predictable as,

$$\text{Lboost} = \frac{(\text{VESS}) * (\text{Dbuck})}{(\Delta\text{ILf})} \quad (17)$$

$$\text{Cboost} = \frac{(\text{VDC}) * (\text{Dboost})}{(8\text{Ro}\Delta\text{VDCf})} \quad (18)$$

Where, output resistance and ripple voltage are referred as R_0 and ΔV_{DC} respectively.

2.4 Inverter with LC Filter

The DC-DC RE-LIFT LUO Converter in order to keep tracking maximum DC power, which the DC power directly fed to the 3 phase voltage source inverter. This inverter is converts DC to AC, which the AC power fed to the LC filter. Here, LC filter is suppressing the harmonics content present in inverter output. Further, the pure AC power fed to the microgrid. Then the Grid actual real power as well as reactive power compare to reference real power with reactive power. The error signal fed to PI controller, the PI fine tuning the error signal and fed to PWM generator. Based on the PWM signal 3 phase inverter produced the output voltage of the microgrid.

3 Results and Discussion

3.1 Simulation Results Discussion

The proposed effort is implemented in MATLAB simulation as well as the following results are obtained. Solar panel produced DC output voltage is 150V as shown in Figure 6. That the 150V DC is fed to RE-LIFT LUO Converter, it convert 150V to 769V DC as shown in Figure 7. The RE-LIFT LUO Converter output voltage is directly fed to three phase voltage source inverter, it convert 769V to 520V AC as shown in Figure 8 and inverter current is 0.4A as shows the Figure 9. Inverter output voltage is sent to LC filter, filter filtering the harmonic content present in AC output. Further filter output voltage connected in the microgrid network as a result grid voltage is 300V AC and current is 10A as shows the Figure 10 and Figure 11.

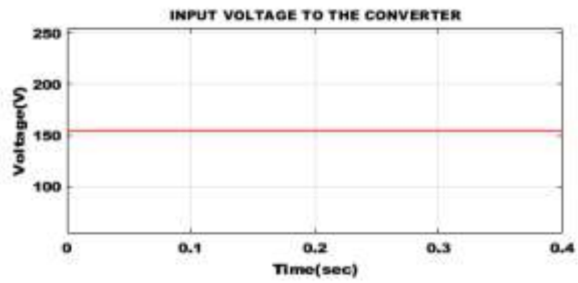

Fig. 6: Solar panel output voltage

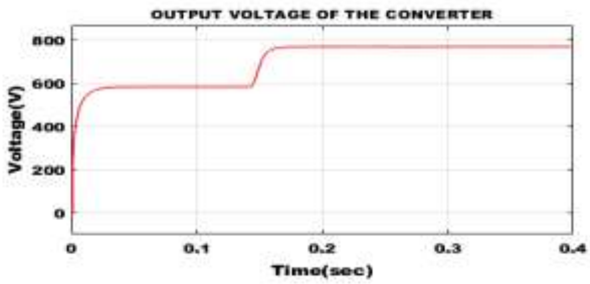

Fig. 7: DC RE-LIFT LUO Converter Output Voltage

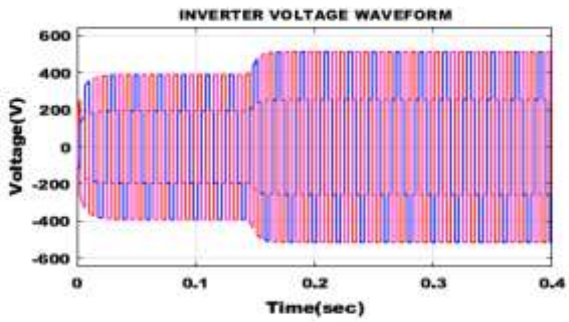

Fig. 8: Inverter Output Voltage

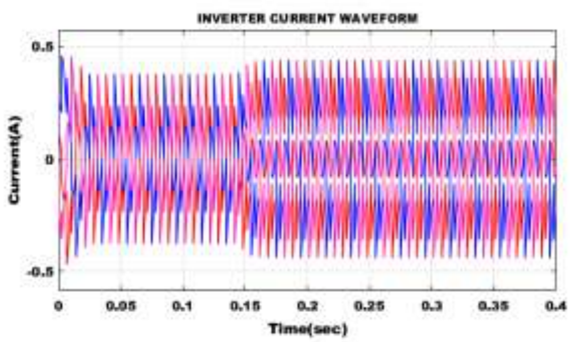

Fig. 9: Inverter Output Current

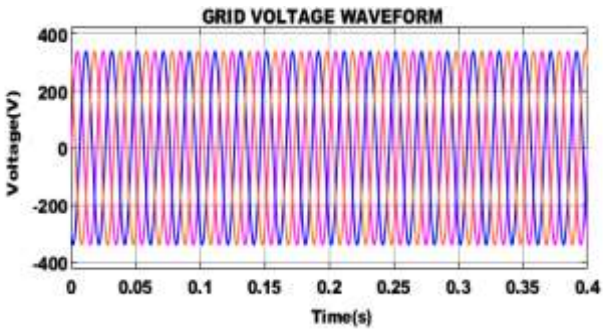

Fig. 10: Grid Output Voltage

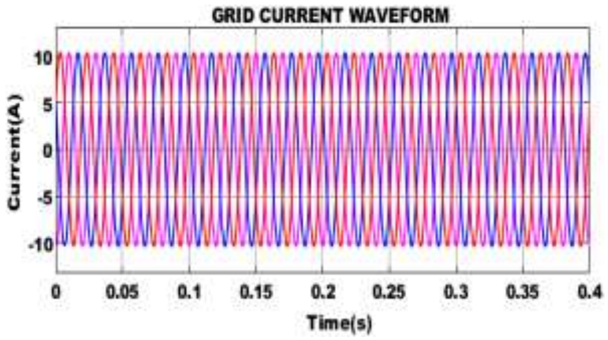

Fig. 11: Grid Output current

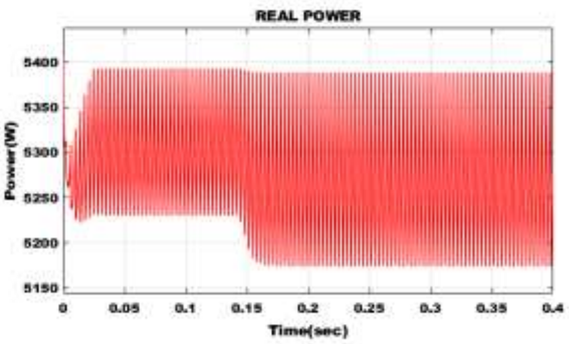

Fig. 12: Real power waveform

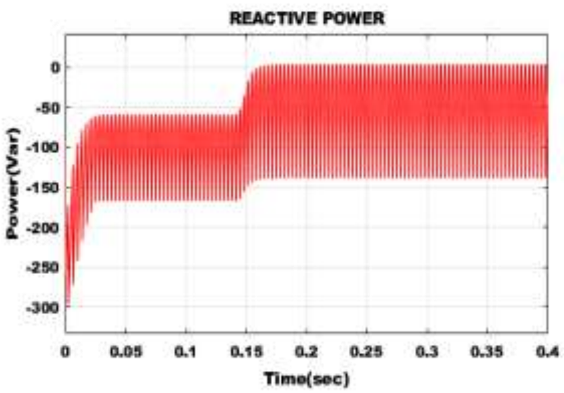

Fig. 13: Reactive power waveform

The Figure 12 and Figure 13 represents the waveforms for real and reactive power of the statcom inverter. The Figure 14 represents the waveforms for Power Factor of the statcom inverter. The graphic shows that there is variation according to the current and voltage the load demands. As a result, the system achieves a unity power factor, demonstrating its effectiveness.

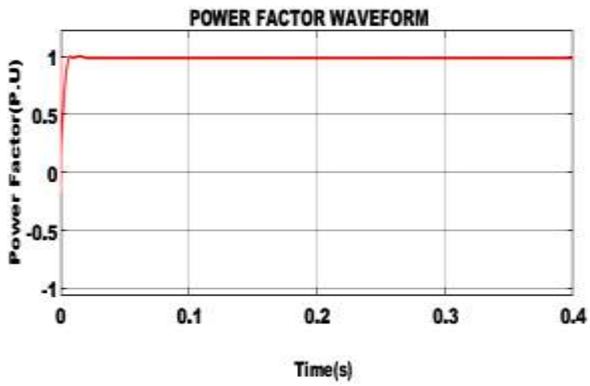

Fig. 14: Power Factor waveform

The Figure 15 represents the waveforms for Voltage and Current IN phase of the statcom inverter. It was discovered that when the voltage and current waveforms were compared, a 360V constant voltage was maintained. An IN phase current, or one that initially increases and then maintains stability while having distortions, is produced in response to the voltage. The Figure 16 represents the total harmonic distortion. The grid current THD obtained by the proposed work is 1.18%, as can be seen from the graph.

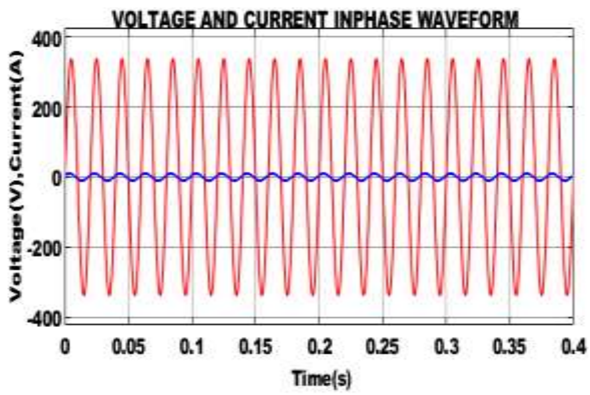

Fig. 15: Inphase voltage and current waveform

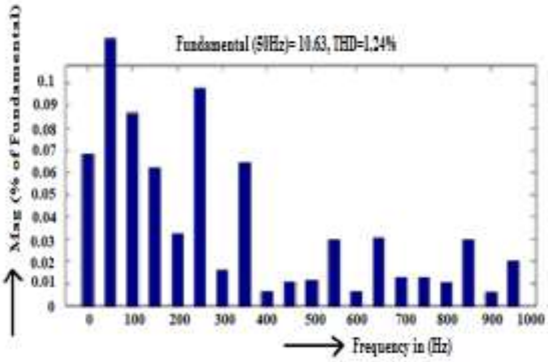

Fig. 16: Total Harmonics Distortion (THD)

3.2 Hardware Results Discussion

Here experimental setup of 3 phase Voltage Source Inverter, rectifier, transformer, RELIFT-LUO Converter, battery, Bidirectional converter and microgrid connected load as shown in the Figure 17. Using step down transformer 230V/12V is step downed. In this 12V AC supply is connected to the single phase diode rectifier circuits. Here, diode rectifier which is converts AC to DC and rectified DC voltage level is 11.2 V. In this 11.2V DC supply is directly fed to the RELIFT-LUO Converter, it can be boosted up to 89.6V DC.

Basically multi port DC-DC converter boost ratio 1:4, but RELIFT-LUO Converter boost ratio 1:16. But, RELIFT-LUO Converter is PWM pulses are applied only 50% as a result achieved 50% output voltage. In this boosted DC voltage is directly fed to the three phase Inverter circuit. This inverter is convert DC to AC and inverter output voltage 86.6V AC. In this circuit LC filter is used, the function of LC Filter is, filtering the harmonics content present in the output power of inverter. As result LC filter output is 90V AC.

To facilitate the LC filters output voltage is fed to the microgrid as shown in the DSO output Figure 18. If the any load demand may be present in the microgrid, the signal conditioner can operated and gives the feedback to DSPIC30F4011 Microcontroller. Based on the feedback, Microcontroller it gives the signal of Pulse driver circuit, the pulse driver supply the firing pluses to the three phase inverter circuit as well as RELIFT-LUO Converter.

Based on the firing pulses inverter and RELIFT-LUO Converter can be operated and improve the power quality. Here, the battery is 12V, suppose solar system power is available, that time bidirectional converter operated at buck mode, battery can get charged. Assume that, the solar system power is not available, that time bidirectional converter operated at boost mode, battery can get discharged. The battery energy is supplied to inverter, the inverter supply grid power.

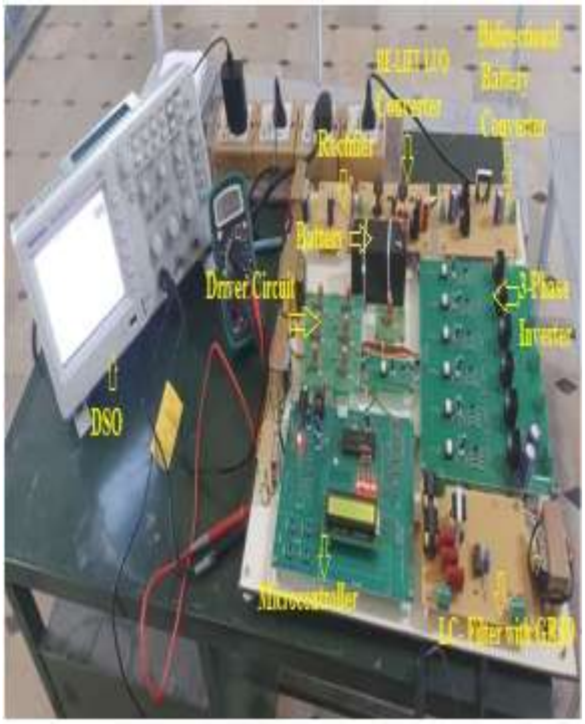

Fig. 17: Hardware Snapshot

Fig. 18: Grid Output Voltage measured by DSO

4 Conclusion

The solar PV energy generating system has come under examination as a key energy system by electric utilities all over the world due to its use of renewable energy sources to produce electricity. Moreover, study is necessary to develop modern technology, such as highly efficient batteries or solar panels, as these sorts of systems become more common in the modern world. In this study, the PV system has a Re-Lift Luo converter, which raises the output voltage gain of the PV system. The converter tracks the maximum power point and utilizes a PWM regulator to improve overall device efficiency. Using ANFIS will improve the MPPT controller's accuracy. The energy management for the proposed system is achieved using a Bidirectional Battery converter along with a battery system. With a three-phase VSI the input DC power is inverted. An LC filter is used to decrease the resulting harmonics. The grid synchronization is achieved using D-Q theory and PI controller. The simulation is run using MATLAB, and a minimal THD value of 1.24% was discovered. Similarly, the experimental hardware model is also verified and results are discussed.

Acknowledgement:
I (Dr.E.Rajendran) would express my sincere gratitude to my beloved Chairman Er.K.Karunanithi for his kind inspiration and supporting in addition to providing necessary infrastructure for completion of this project and research paper work. I would express my sincere gratitude to my beloved CEO Dr.R.Sakthi Krishnan for his kind stimulation and supported to me. I would like to express my hearty appreciation to My Parents Mr.P. Elumalai, Mrs.E.Rukkumani and My Beloved Wife Dr.R.Vijaya Lakshmi,B.S.M.S., and My Sweetheart Sons Mr.R.Renu Prasaath and Mr.R.Sriram. Finally my corresponding authors are grateful to Dr. V.Raji and Mr.V.K.Dinesh Prabu for supporting regularly.

References:
[1] B. R. Lin and C. W. Chu, "Hybrid DC–DC converter with high efficiency, wide ZVS range, and less output inductance," *International Journal of Circuit Theory and Applications,* vol. 44, no. 5, pp. 996–1011, 2016.
[2] Y. M. Chen, A. Q. Huang, and X. Yu, "A high step-up three-port DC-DC converter for stand-alone PV/battery power systems," *IEEE Transactions on Power Electronics,* vol. 28, no. 11, pp. 5049–5062, 2013.
[3] Y. Singh, I. Hussain, B. Singh, and S. Mishra, "Grid integration of single-phase single-stage SPV system using an active noise isolation-based control algorithm," *in 2016 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES),* Trivandrum, India, 2016.
[4] O. Ray, A. P. Josyula, S. Mishra, and A. Joshi, "Integrated dual output converter," *IEEE Transactions on Industrial Electronics,* vol. 62, no. 1, pp. 371–382, 2015.
[5] S.-W. Lee and H.-L. Do, "Quadratic boost DC–DC converter with high voltage gain and reduced voltage stresses," *IEEE Transactions on Power Electronics,* vol. 34, no. 3, pp. 2397–2404, 2018.
[6] V. S. Mahadik and P. K. Katti, "Performance enhancement of SPV based water pumping with multifunction converter," *in 2018 International Conference on Power Energy, Environment, and Intelligent Control (PEEIC),* Greater Noida, India, 2018.
[7] V. F. Pires, A. Cordeiro, D. Foito, and J. F. Silva, "High step-up DC–DC converter for fuel cell vehicles based on merged quadratic boost–Ćuk," *IEEE Transactions on Vehicular Technology,* vol. 68, no. 8, pp. 7521–7530, 2019.
[8] R. Banupriya, R. Nagarajan, 'Performance Analysis of a Relift Luo Converter-Derived Dual-Output DC to DC Converter for Microgrid Applications." *Hindawi International Journal of Photoenergy*, Vol. 2022, https://doi.org/10.1155/2022/8093589.
[9] N. Vázquez, C. M. Sanchez, C. Hernández, E. Vázquez, L. del Carmen García, and J. Arau, "A different three-port DC/DC converter for standalone PV system," *International Journal of Photoenergy,* vol. 2014, Article ID 692934, 13 pages, 2014.
[10] Y. Hu, W. Xiao, W. Cao, B. Ji, and D. J. Morrow, "Three-port DC-DC converter for stand-alone photovoltaic systems," *IEEE Transactions on Power Electronics,* vol. 30, pp. 3068–3076, 2014.
[11] N. R. Nair and P. Kanakasabapathy, "A three-phase grid connected SPV system using synchronverter," *in 2018 8th IEEE India International Conference on Power Electronics (IICPE),* Jaipur, India, 2018.
[12] G. K. Taneja, G. Modi, B. Singh, and A. Verma, "GMCC based adaptive filter for SPV-RES to improve power quality in the distribution grid," *in 2021 4th Biennial International Conference on Nascent Technologies in Engineering (ICNTE),* NaviMumbai, India, 2021.

[13] K. Ravichandrudu, P. S. P. Kumar, and K. Seshu, A high step-up three-port DC–DC converter for stand-alone PV/battery power systems, Department of EEE, NRI Institute of Technology, *International Journal of Science and Research (IJSR),* Guntur, 2020.
[14] E. Babaei, Z. Saadatizadeh, and P. C. Heris, "A new topology for non-isolated multiport zero voltage switching dc-dc converter," *International Journal of Circuit Theory and Applications,* vol. 46, no. 6, pp. 1204–1227, 2018.
[15] Z. Saadatizadeh, P. C. Heris, E. Babaei, and F. Sadikoglu,"Expandable interleaved high voltage gain boost DC Table DC converter with low switching stress," *International Journal of Circuit Theory and Applications,* vol. 47, no. 5, pp. 782–804, 2019.
[16] C. Li, R. Burgos, B. Wen, Y. Tang and D. Boroyevich, Year: 2020, "Stability Analysis of Power Systems with Multiple STATCOMs in Close Proximity," *IEEE Transactions on Power Electronics,* vol. 35, no. 3, pp. 2268-2283, 2020.
[17] S. K. Kuncham, K. Annamalai and N. Subrahmanyam, Year: 2020, "A Two-Stage T-Type Hybrid Five-Level Transformerless Inverter for PV Applications," *IEEE Transactions on Power Electronics,* vol. 35, no. 9, pp. 9510-9521, 2020.
[18] Nupur Saxena, Ikhlaq Hussain, Bhim Singh, Anoop Lal Vyas 'Implementation of a Grid-Integrated PV-Battery System for Residential and Electrical Vehicle Applications,'' *IEEE Transactions on Industrial Electronics,* Vol. 65, Issue: 8, pp. 6592 – 6601, August 2018.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflicts of interest to declare.