Single-Stage Single-Phase Reconfigurable Inverter Topology for Solar Powered Hybrid AC/DC Home

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ABSTRACT

This paper suggests a reconfigurable single-phase inverter topology for a hybrid ac/dc solar powered home. This inverter possesses a single-phase single-stage topology and the main advantage of this converter is that it can perform dc/dc, dc/ac, and grid tie operation, thus reducing loss, cost, and size of the converter. This hybrid ac/dc home has both ac and dc appliances. This type of home helps to reduce the power loss by avoiding unnecessary double stages of power conversion and improves the harmonic profile by isolating dc loads to dc supply side and rest to ac side. Simulation is done in MATLAB/Simulink. Such type of solar powered home equipped with this novel inverter topology could become a basic building block for future energy efficient smart grid and micro grid.

Keyword mitigation, hybrid ac/dc home, single-phase single-stage inverter, solar photovoltaic (PV).

1. INTRODUCTION

Solar power is fast growing and one of the most important renewable energy; this hugely increases global energy consumption rate in India [1]. Photovoltaics (PV) system is belonging to research and technology related application of solar cells. The solar energy is the energy converting sun energy with sun light and ultraviolet radiation convert directly into electricity using solar cell [2]. The aim of this research work is to increase the power output and efficiency of the PV system. It is also needing of the constant voltage be supplied to the load irrespective of the variation in solar temperature and irradiance. Parallel and series combination of PV arrays are used to generate electricity depending upon the environmental effects (e.g. temperature and solar irradiation) [3]. In solar PV module the efficiency is low [4]. It is necessary to operate on peak power point so that the maximum power can be delivered to the load. The effects of varying temperature and solar irradiation conditions [4]. To increase the efficiency of the system and tracking the maximum power point (MPP) of a photovoltaic (PV) array. The by MPPT techniques is to automatically find the maximum voltage point or maximum current point at which a PV array should obtain the maximum power output under the effects given by temperature and irradiance [5]. The many MPP tracking (MPPT) methods have been developed and implemented. MPPT is a fully electronic system that varies the electrical operating point of the module it capable to deliver maximum available power to the load [6]

To improve the productivity and comfortability, the modern household adds more and more nonlinear equipment, which are also main source of generating harmonics current in distribution feeder. This further adversely affects power quality, power losses and creating a significant challenge for electrical engineers. Modern household loads have different characteristics compared to loads present in earlier stage. However, harmonic mitigation and/or its minimizations are big challenges in distribution system. Many literatures works have been reported to address aforementioned problems as follows. Harmonic mitigation in the distribution system using solar inverter by virtual harmonic damping impedance method is discussed in literature [2]. In [3], PV-battery storage system is used to control the voltage stability in distribution system. The control of solar powered grid connected inverter for electric vehicle charging is suggested in [4]. Patterson [5] has proposed the dc micro grid and shown its advantages and challenges of making a complete dc home micro grid. Further, this paper has analyzed by considering all buildings in 2050, 80% of buildings are already built. So, focus is more on improving the efficiency of existing buildings than making a new complete dc home. Vossos *et al.* [6] has analyzed the efficiency of residential building when it is converted into dc house over the conventional ac distribution house. They analyzed the data of 14 states in the USA, which used 380- and 24-V voltages for dc distribution in homes. There is a 33% savings when the ac equipment is replaced with dc equipment. But replacing all existing home appliances with its dc equivalent is not possible due to the high price and unavailability of the required standards/flexibilities of equipment. Sasidharan *et al.* [7] propose a novel solution to mitigate some of the harmonics related problems and efficiency issues by proposing a hybrid ac/dc home grid system. A solar home is discussed as a case study and a 12% improvement in efficiency and a 20% reduction in harmonics are achieved by shifting dc loads to the dc supply side. Conventional grid connected inverter uses high dc link voltage, which will be the peak magnitude of the line–line grid voltage [8]. For this particular purpose, two stage conversions are required to boost up the dc voltage and to invert it. However, this will increase the cost, size, and loss of the system. To avoid this, single-phase single-stage topologies of inverter are suggested in [9]– [12]. In the single-phase inverter topology

Transformer less inverter gained significant research interest as suggested in [13]. Transformer less inverter has the advantage of low size and cost by avoiding the transformer but this will eliminate the galvanic isolation and inverter will become very sensitive to grid disturbances. The solar PV is limited by its inherent intermittency aspects and, hence, battery storage (assumed here) is required to supply the power when there are not enough solar radiations. But having a separate converter for battery's power management system will increase the cost and size of the converter as well. Hence, a three-phase topology of reconfigurable solar inverter is introduced in [14] and [16] for utility PV system with battery storage. This reconfigurable system is suitable to solar and wind farm applications. This topology is tested with a new algorithm and validated the results. Normally, every solar powered household have a battery system to provide a reliable supply system. These batteries are charged when connected to ac system or they need a separate converter to manage the charging operations when it connected to dc supply side. Though Parkhideh and Kim [16] provide very brief info but no details/outcomes are available about single-phase single-stage topology, which can supply both ac and dc loads in literature Therefore, the main contribution of this paper is to implement a single-phase single-stage solar converter called **reconfigurable solar converter (RSC**) in the solar powered hybrid ac/dc residential building with energy storage devices. The basic concept of the RSC is to use a single power conversion system to perform different operational modes such as **solar PV to grid (Inverter operation, dc–ac), solar PV to battery/dc loads (dc–dc operation), battery to grid (dc–ac), battery/PV to grid (dc to ac) and Grid to battery (ac–dc) for solar PV systems with energy storage**. This inverter is tested in a solar powered hybrid ac/dc home, which contains both ac and dc household loads. Individual appliances are selected according to the harmonic contributions they are injecting to the distribution grid from a typical modern house. Apart from the aforementioned, other additional contributions are as follows. The electrical components and sensors are different from [14], and normal inductor only used for dc/dc operation. The variation in solar radiation is also considered and solar PV-battery operation is verified. The circulation current is mitigated due to operation of the switches in the topology for dc/dc operation. Control logic and sampling of input quantities are also different in this paper

Due to increasing power demand many new alternatives of power generation are used effectively. Out of all these photovoltaic generation is effective and can easily be implemented. The power from the PV system have different outputs depending on the condition of temperature and irradiance. To extract maximum power from PV array different MPPT algorithms are available such as, perturb and observe (P&O), incremental conductance (INC) and many more. Out of all these INC have some advantages and commonly implemented in many PV applications. This mppt controller is used to extract maximum power under all the irradiance conditions using boost converter. The output of PV system serves as DC link for the inverter. A power controlling method is employed to synchronize the PV system with grid. Generally, there are 2 main power stages in a grid tie PV system. First is DC link voltage control stage that maintains constant DC link voltage across inverter input and second stage consist of inverter current control that controls the current injected into the grid. Current control can be employed in many reference frames such as, stationary reference frame (α-β), synchronous reference frame (d-q) and natural reference frame (a-b-c). In the proposed system synchronous reference frame is employed using proportional integral (PI) controller.

2. LITERATURE SURVEY

2.1 Literature Review

Current century has witnessed an unprecedented evolution and growth of renewable energy worldwide. There has been a substantial increase in the capacity and production of all renewable technologies and also growth in supporting policies. Between 2009 and 2013, solar photovoltaic (PVS) experienced the swiftest growth rate in added power capacity among all the renewable.

In particular, rooftop solar PV are gaining more popularity in distribution system due to reduction in cost of solar panel, appropriate government policies such as feed in tariffs promoting renewable energy utilization, modularity, less maintenance, etc. However, the intermittent nature of the renewable causes the significant stability and reliability issues in the distribution system. The restructuring of the electric supply industry has prompted the situation, where customer is a critical business player. To mitigate the uncertainty in solar PV generation, storage options such as battery system and fuel cells, etc., are introduced.

2.1 Existing system

A novel solution to mitigate some of the harmonics related problems and efficiency issues by proposing a hybrid ac/dc home grid system. Conventional grid connected inverter uses high dc link voltage, which will be the peak magnitude of the line–line grid voltage. For this particular purpose, two stage conversions are required to boost up the dc voltage and to invert it. However, this will increase the cost, size, and loss of the system. Transformer less inverter gained significant research interest such that Transformer less inverter has the advantage of low size and cost by avoiding the transformer but this will eliminate the galvanic isolation and inverter will become very sensitive to grid disturbances. The solar PV is limited by its inherent intermittency aspects and, hence, battery storage (assumed here) is required to supply the power when there are not enough solar radiations. Hence, a three-phase topology of reconfigurable solar inverter for utility PV system with battery storage. This reconfigurable system is suitable to solar and wind farm applications. This topology is tested with a new algorithm and validated the results. Normally, every solar powered household have a battery system to provide a reliable supply system. These batteries are charged when connected to ac system or they need a separate converter to manage the charging operations when it connected to dc supply side

Dis-advantages: -

• Having a separate converter for battery's power management system

• Increase the cost and size of the converter as well.

2.2 Proposed system

The main contribution of this paper is to implement a single-phase single-stage solar converter called reconfigurable solar converter (RSC) in the solar powered hybrid ac/dc residential building with energy storage devices. The basic concept of the RSC is to use a single power conversion system to perform different operational modes such as solar PV to grid (Inverter operation, dc–ac), solar PV to battery/dc loads (dc–dc operation), battery to grid (dc–ac), battery/PV to grid (dc to ac) and Grid to battery (ac–dc) for solar PV systems with energy storage. This inverter is tested in a solar powered hybrid ac/dc home, which contains both ac and dc household loads. Vossos *et al.* [6] has analyzed the efficiency of residential building when it is converted into dc house over the conventional ac distribution house. They analyzed the data of 14 states in the USA, which used 380- and 24-V voltages for dc distribution in homes. There is a 33% savings when the ac equipment is replaced with dc equipment. But replacing all existing home appliances with its dc equivalent is not possible due to the high price and unavailability of the required standards/flexibilities of equipment. Sasidharan *et al.* [7] propose a novel solution to mitigate some of the harmonics related problems and efficiency issues by proposing a hybrid ac/dc home grid system. A solar home is discussed as a case study and a 12% improvement in efficiency and a 20% reduction in harmonics are achieved by shifting dc loads to the dc supply side. Parkhideh and Kim [16] provide very brief info but no details/outcomes are available about single-phase single-stage topology, which can supply both ac and dc loads in literature Therefore, the main contribution of this paper is to implement a single-phase single-stage solar converter called reconfigurable solar converter (RSC) in the solar powered hybrid ac/dc residential building with energy storage devices.

3. PROJECT DESCRIPTION

3.1 Solar Photovoltaic Array

A single-phase inverter and boost converter using modelling. The panel output is given to the boost converter after boosting the voltage is connected to invert and then supply to load. In this MPPT algorithm switching pulse generated and given to the boost converter for varying the duty cycle of the boost converter. The interfacing with renewable energy sources is also possible for different solar panels can be feed to the inverter as a dc source [8]. The power coming from battery backup is given to inverter through a bi-directional dc-dc converter; the controlled flow of electrical power in either direction is possible by varying duty cycle.

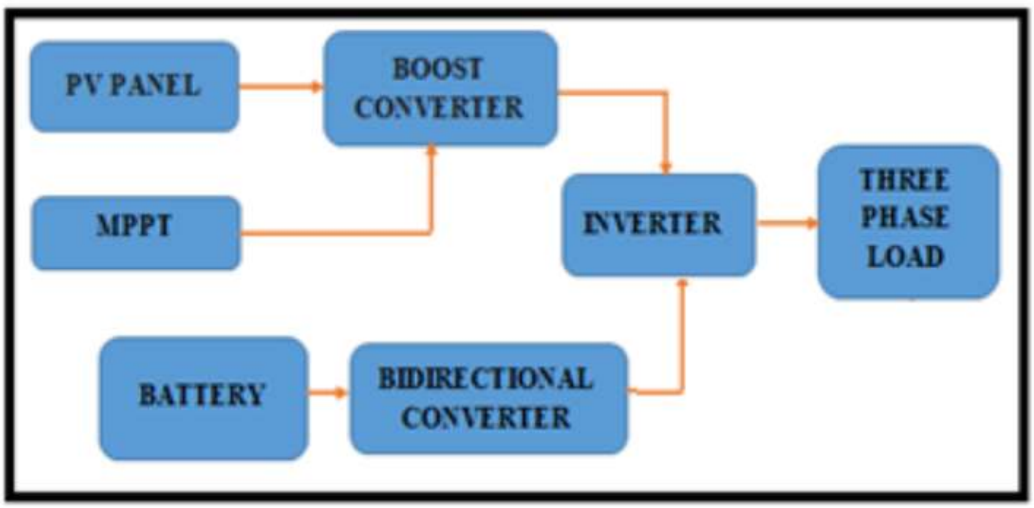

Fig.1 Block Diagram of MPPT Techniques based Photovoltaic System

The Solar Photovoltaic Array is formed by connecting several solar panels in series and parallel combination to generate the required power. The smallest component of the solar photovoltaic array is called photovoltaic (PV) cell. The ideal solar photovoltaic cell is represented by the equivalent circuit shown in Fig 2. These cells are connected in series of 36 or 72 cells to form one module. Similarly, several modules are assembled into a single structure to form array. Finally, assembly of these photovoltaic arrays are connected in parallel to obtain the required power. In PV module, series resistance (Rs) is comparatively more predominant and Rsh is considered equal to infinity ideally. The open circuit voltage (Voc) of the PV cell is directly proportional to solar irradiation and Voc is inversely proportional to the temperature.

The PV Array is characterized based on the I-V and P-V characteristic. As we can see from Fig.3, the variation in irradiation result variation in the current and the curves of I-V characteristic vary largely for different level of irradiation. The irradiation directly affects the PV Array current while the change of temperature directly affects the voltage generated by the PV Array.

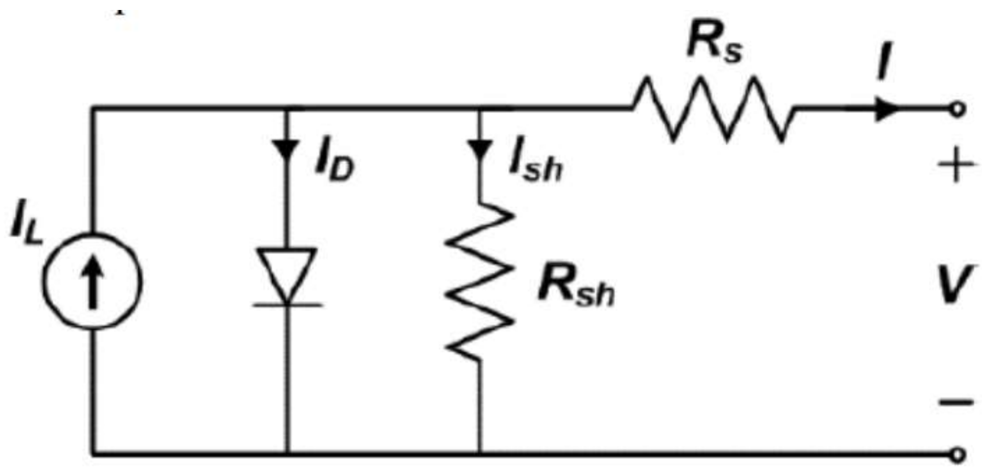

Fig 2: Equivalent circuit of PV cell

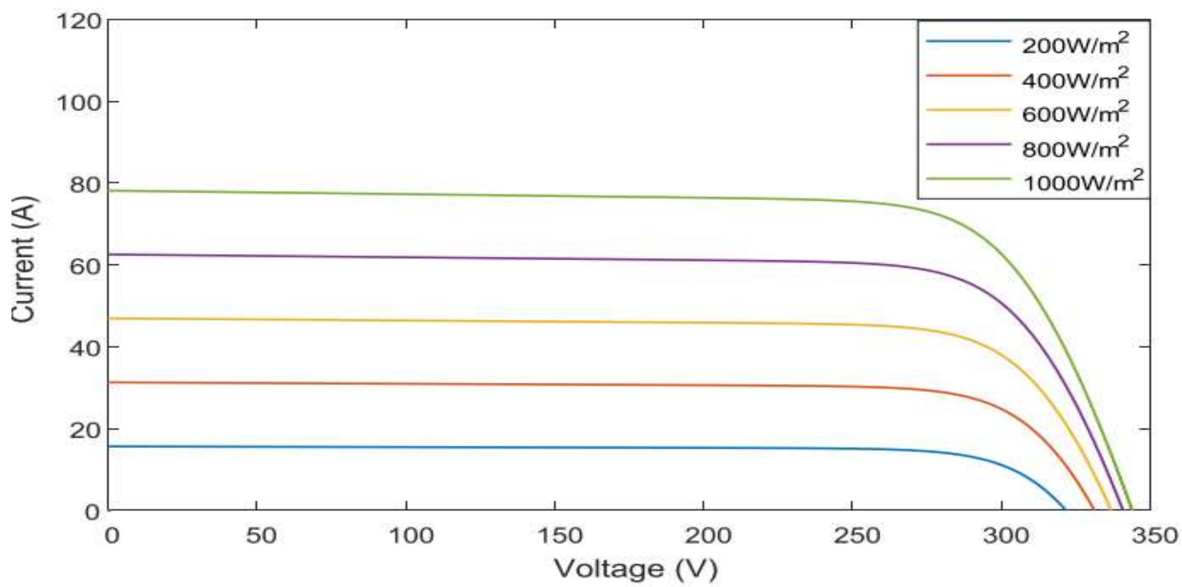

Fig 3: I-V characteristics of 20kW PV Array at different irradiation levels

Single-Stage Solar PV Inverter for Small-Scale Systems Compared to the single-stage one, the multistage power conversion is somewhat more expensive and affects the efficiency of the PV inverter. To reduce the volume and weight as well as the power conversion loss and cost, a hybrid PV battery-powered DC bus system was proposed in 2009 [2]. The DC to AC conversion stage less DC bus system is very applicable to electronic equipment and appliances with high system efficiencies. The PV-batterypowered DC bus system is shown in Fig. For AC systems, a single-stage PV inverter was proposed in [2], and the circuit topology of single-stage inverter is shown in Fig. The proposed inverter performs a dual function: MPPT and outputting a sinusoidal current, which makes the control circuit complex. In [2], an alternative control technique was developed to reduce the complexity of the control circuit. However, the common-mode issue was not considered in the proposed single stage inverter systems. The neutral point clamped (NPC) converter topology has the opportunity to connect the grid neutral point to middle point

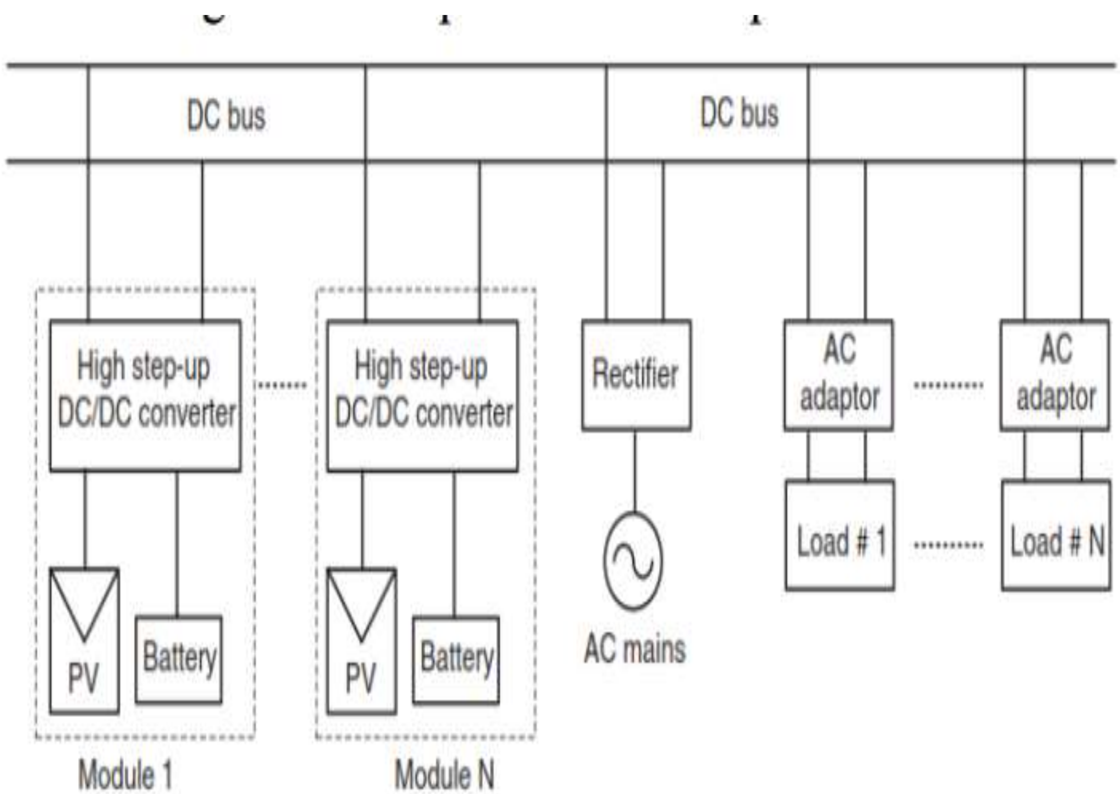

Fig 4 PV-battery-powered DC bus system

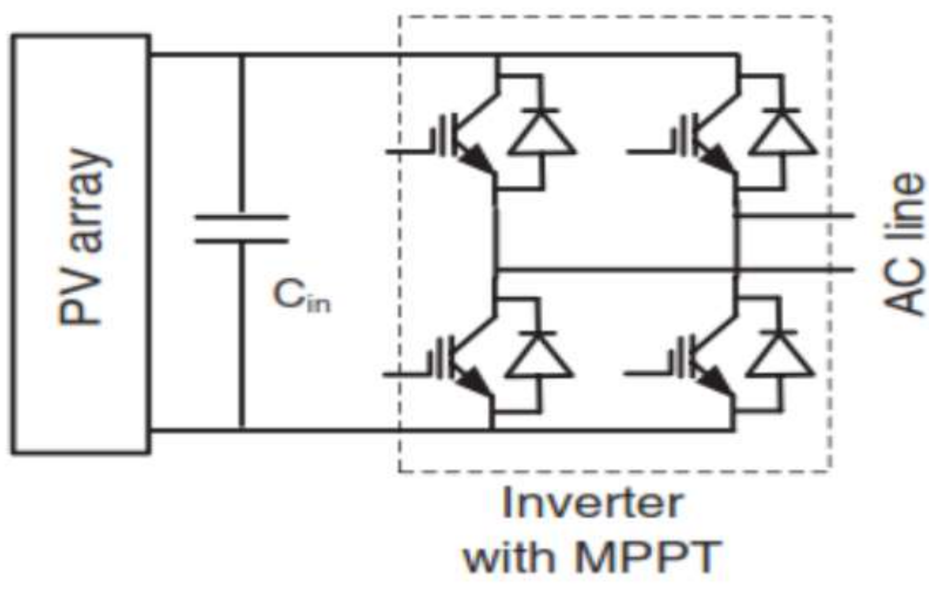

Fig 5 Full-bridge with MPPT-based circuit topology of single stage inverter

Of the DC link, reducing the ground leakage currents. In this context, an NPC topology-based single-phase PV inverter as shown in Fig. 6 and a three phase PV inverter system in Fig. 6. Since the presented circuits are run as buck converters, the PV array voltages should be greater than the peak values of the output AC voltages. If V is the inverter output AC voltage and R is the reservation factor, the minimum array voltage can be calculated as

$$V_A = \sqrt{2} V_{rms} R. \quad \text{……………………(1)}$$

Therefore, a few PV arrays in series connection are necessary to obtain the desired voltage. From the available literature, several single-stage topologies have been proposed based on either boost or buck–boost configurations. An integrated (boost converter and full-bridge inverter) PV inverter circuit topology shown in Fig. was presented in [3]. The output power quality and the efficiency of the inverter are limited by the fact that the boost converter cannot generate the output voltage lower than the input voltage. A universal single-stage PV inverter shown in Fig. was presented in that can operate as a buck, boost, or buck–boost converter. This inverter can operate with a wide range of input voltage, improving the power quality and the efficiency. Using the integrated buck–boost and inversion functions, several modified configurations have been presented in [3]. However, these topologies are only suitable for small-scale (e.g., <100 kW) PV systems, where the PV array normally interconnects with a low-voltage public network.

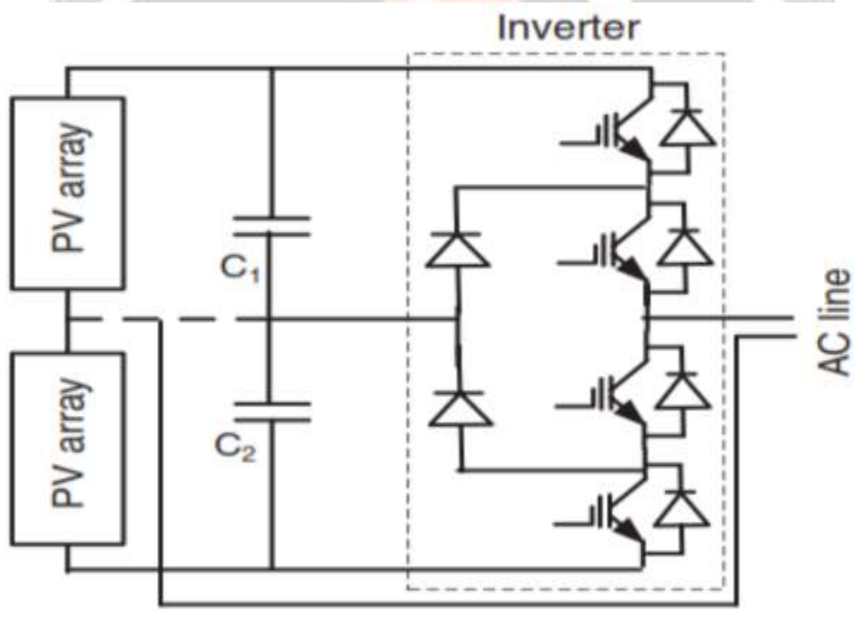

Fig 6 Single-stage power circuit with boost converter

In PV modeling, the generation of electrical power is directly converted from sun energy by photovoltaic cell. The panel used in PV modelling works under the photoelectric effect the modeling of photovoltaic system is done by connecting a current source in parallel and inverted diode connected along with a series and a parallel resistance as shown in Fig.7.

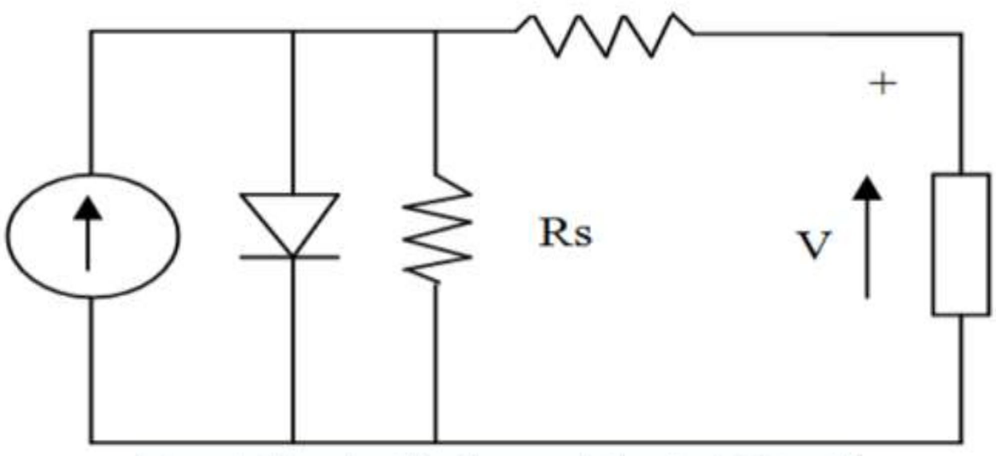

Fig. 7 Single diode model of a PV cell

3.2 Topology of RSC

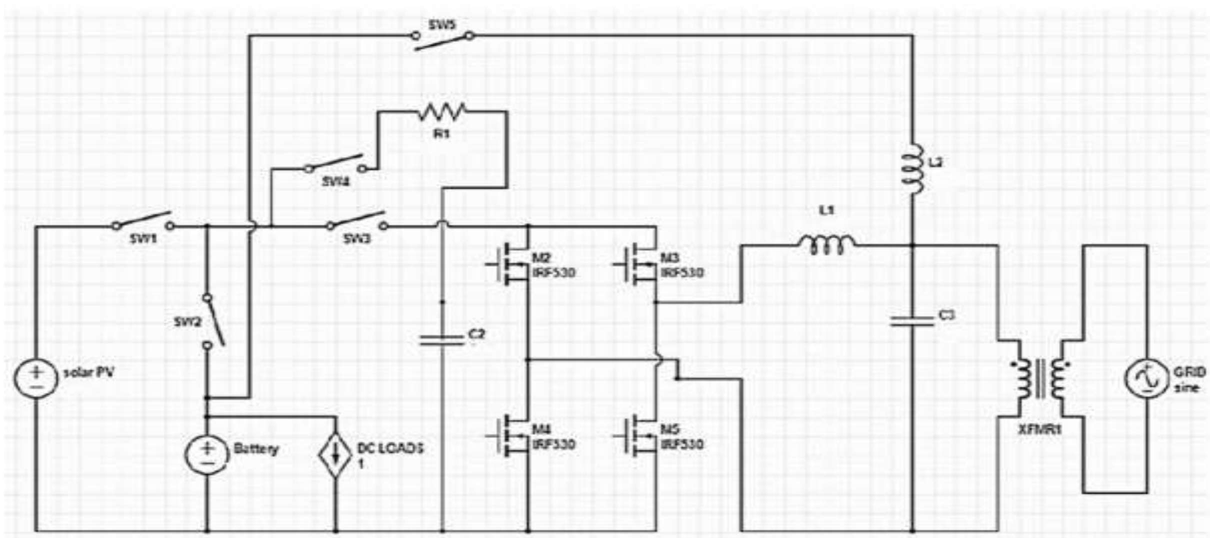

Fig.8. Schematic of the proposed RSC circuit.

The circuit diagram of reconfigurable solar inverter is given in the Fig. 8. Though it will reduce the no of power conversion stages but mechanical switches and cable requirement are more for this topology. The modes of operations of the proposed single-phase single-stage converter are given in Table I. In addition, different operations modes are given in Figs. 9–12.

TABLE-1 MODES OF OPERATION

Modes of operation	ON switches	Off switches
PV-GRID	SW1 SW3 SW 4	SW2 SW 5
PV-BATTERY-GRID	SW1 SW2 SW3 SW4	SW5
PV- BATTERY	SW1 SW3 SW5	SW2 SW4
BATTERY-GRID	SW2 SW3	SW1 SW4 SW5

3.2.1 Modes of operations

A. Mode-1

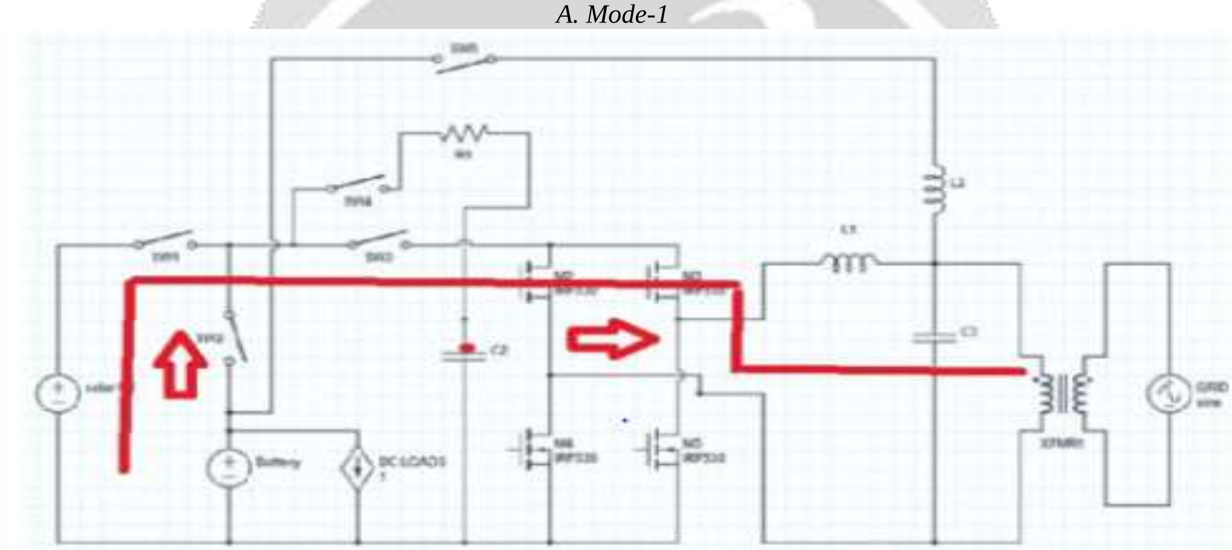

Fig.9. PV to grid

The mode of operation as shown in Fig. 9 is directly connects PV to the grid. Maximum power point tracking (MPPT) controller is used to extract maximum power from the solar panel. Inverter controller is used to synchronize with grid and transfer active power to the grid.

B. Mode-2

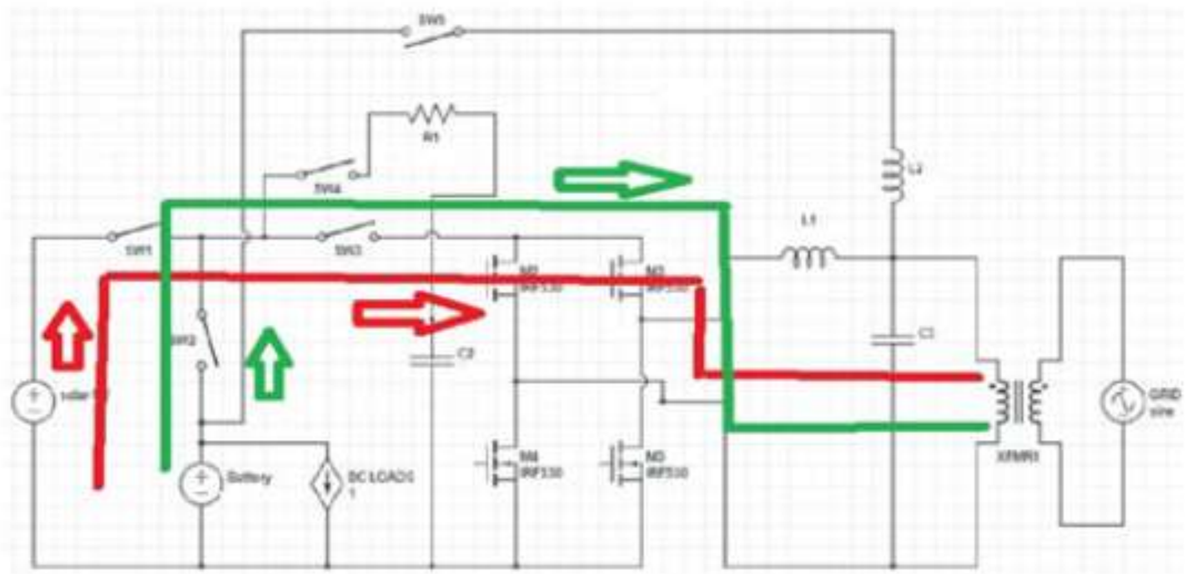

Fig.10. PV-battery to grid

In Fig. 10, the mode of operation is to supply power to the grid from both solar PV and battery. This mode operates when there is a shortage of power from the solar PV due to external conditions, e.g., weather, etc. One of the drawbacks of this connection is that the battery voltage and PV voltage should always be matching each other. Since battery voltage is stiff, MPPT controller cannot be used for this configuration.

C. Mode-3

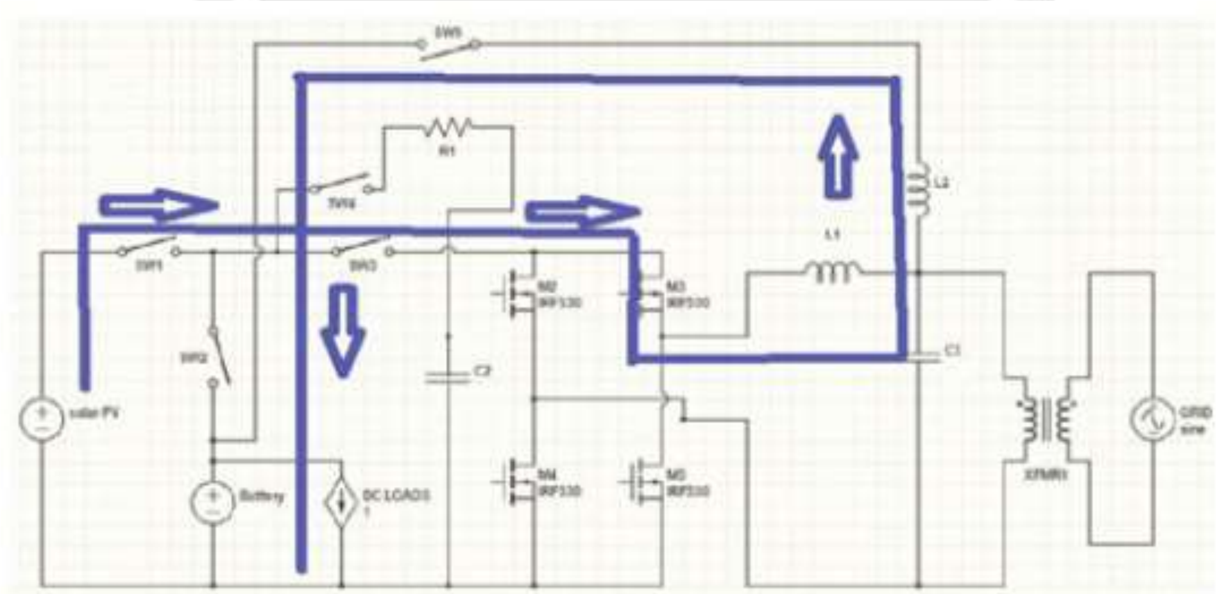

Fig.11. PV to battery charging

Fig. 11 shows dc/dc operation of the proposed topology, where battery is charged by a chopper action of the converter. The extra inductor is optional to reduce ripple in the charging current further. When there is an excess energy available, the battery is charged for the night time usage.

D. Mode-4

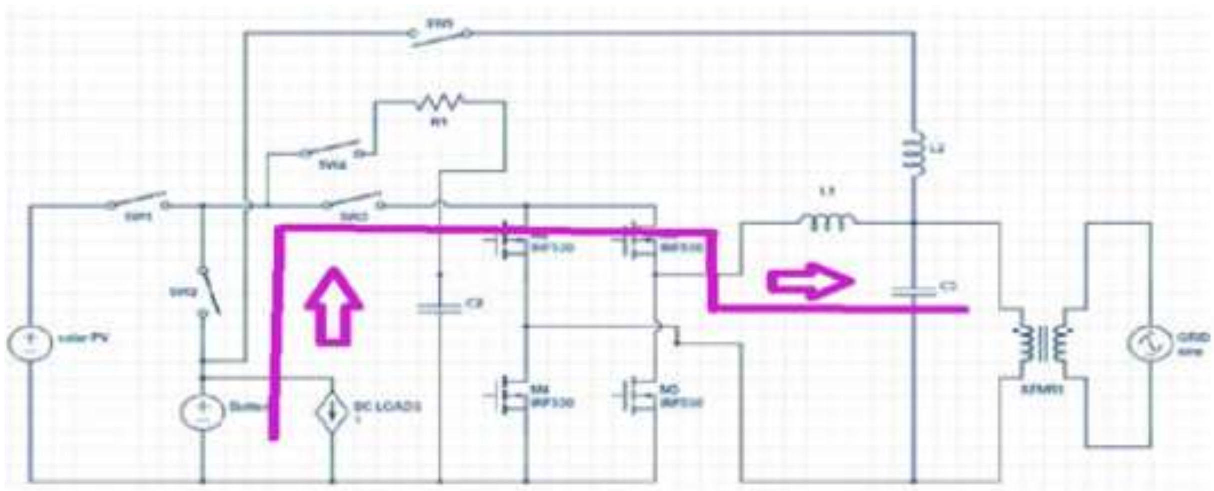

Fig.12. Battery to grid.

From Fig. 12, the energy stored in battery can be released to the appliances or grid during the night hours or when there is no solar radiation due to clouds or rainy conditions. Battery can supply stable power to the inverter. Thus, it can be very helpful in power quality improvement and ancillary services provision.

3.3 Control of the Proposed Converter

For controlling this proposed single-phase inverter, PQ controller is used considering the advantage that it will control the active and reactive power according to the reference signal.

Since the controlling elements for the ac system are very difficult due to their time-varying nature, the ac control variables are converted to a stationary reference frame from a rotating reference frame for effective control [15]. Let $F\alpha$ and $F\beta$ be the rotating reference frame variables, which can be voltage or current, whereas Fd and Fq be the stationary variables. In rotatory reference frame, the active and reactive powers can be calculated by using

$$P = 1/2[vd \times id + vq \times iq] \quad (1)$$

$$Q = 1/2[vd \times iq - vq \times id] \quad (2)$$

Where v and i are the instantaneous values of voltage and current, respectively. When the inverter is synchronized to the grid, the value of vq becomes 0, and (1) and (2) becomes

$$P = 1/2[vd \times id] \quad (3)$$

$$Q = 12[vd \times iq] \,. \quad (4)$$

The active and reactive reference currents are given in (5) and (6) as

$$id = 2 \times \hat{P}vd \quad (5)$$

$$iq = 2 \times \hat{Q}vd \quad (6)$$

Where $\hat{P}$ and $\hat{Q}$ are the reference power signals of active and reactive power, respectively. Calculated values of *id* and *iq* are converted into stationary reference frame and given as signal to PQ controller to produce reference signals for the sinusoidal pulse width modulation controller. Synchronizing the solar inverter with grid requires the knowledge of the magnitude and phase of the grid supply voltage. Phase lock loop (PLL) will track the phase of the grid and help to synchronize with the grid. To obtain maximum power from the solar panel, according to maximum power transfer theorem, the panel resistance should be equal to the load resistance, which is connected to this panel. To achieve this, a hill climbing MPPT algorithm is used. This technique will equalize the resistances and extract maximum power from the solar panel

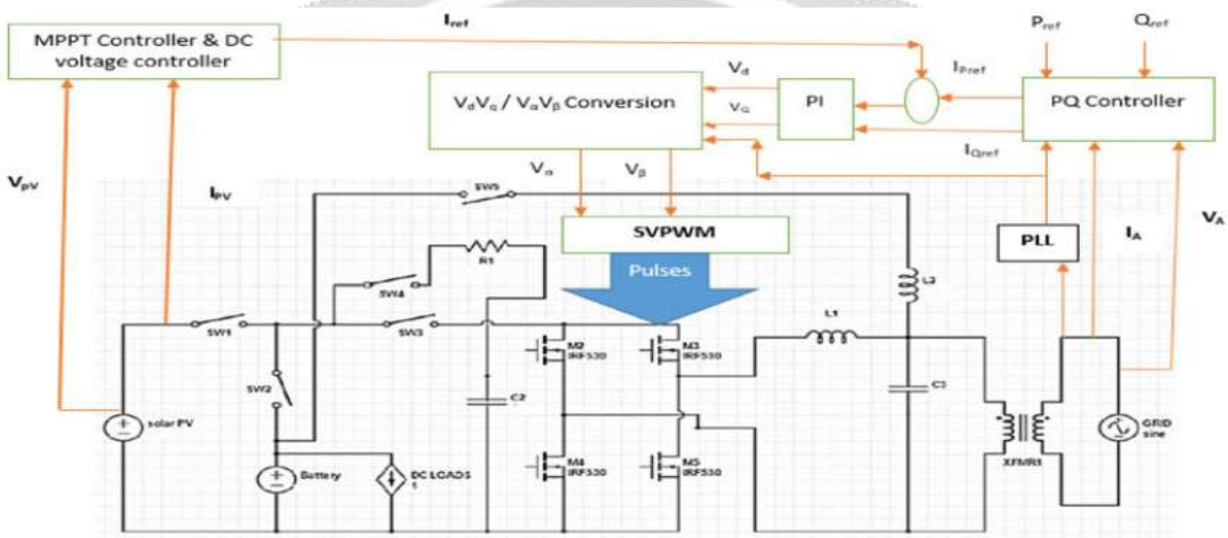

Fig. 13. DC/AC inverter operation

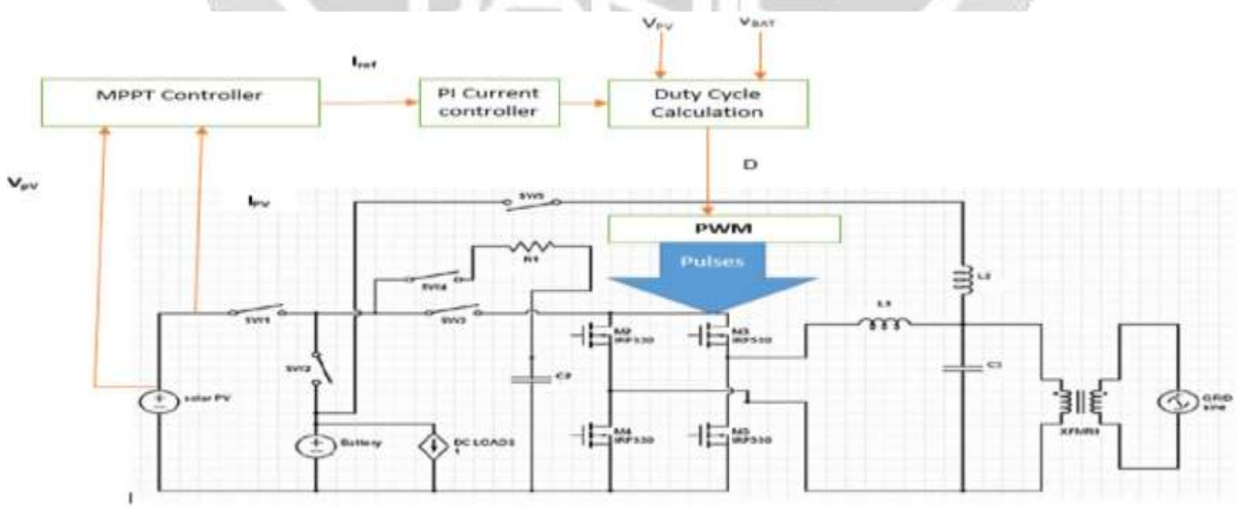

Fig. 14. DC/DC chopper operation.

The control diagram for different modes of operations of the RSC is given in Figs. 13 and 14. In Fig. 13, the inverter operation of the RSC is explained. From voltage and current measurement from the solar panel, voltage is set to extract maximum power from the panel using MPPT algorithm. This voltage is compared with the set dc-link voltage and error is given to a PI controller for DC link voltage regulation. This PI controller will produce reference current, which is compared with reference current produced using PQ controller, which is given in (5) and (6). This error is given to a PI controller, which will generate reference voltage for active power control. Reactive power is separately controlled using another PI controller. These reference voltages are converted to rotating reference frame voltages and given to space vector pulse width modulation (PWM) to drive the inverter. Battery is charged from solar panel using dc/dc conversion mode of RSC, which is given in Fig. 14. One of the MOSFET
switch is used to obtain required voltage level for the battery. Here, constant voltage charging is used. MPPT controller will produce the required current which is given to a PI controller to produce the reference voltage. This voltage is compared with the battery voltage and duty cycle is generated. From this duty cycle, PWM pulses are generated, which is given to the MOSFET switch. Thus, both ac and dc loads are given supply using a single reconfigurable inverter. Simulation of the proposed converter is done in MATLAB/Simulink. The parameters used for the simulation are given in Table II. The radiation is kept at maximum at 1000 W/m2. Inbuilt PLL and PWM pulse generator blocks in MATLAB/Simulink are used for controlling the inverter. The design is done for 500-W inverter topology.
In order to synchronize the solar inverter with grid, the magnitude and phase of the grid supply voltage must be known. PLL is system which will track a signal with other signal system.

3.4 Modeling and Simulation

TABLE II
SIMULATION PARAMETERS

Components	Parameters
Battery	12 V, 9 Ah
Filter capacitor (C1)	47 μF
Filter inductor (L1)	2.3 mH
Switching frequency	4000 Hz
DC link capacitor (C2) 2 nos.	2200 μF, 16 V
Resistance (R1)	1 kΩ
Solar panel details	
No of cells per module	36
Open circuit voltage (V)	22.09
Short circuit current (A)	8.36
Voltage at maximum power (V)	17.7
Current at maximum power (A)	7.62
diode quality factor	1.25
number of series-connected module per module	1
number of modules per string	3
Series resistance (ohm)	0.165
Parallel resistance (ohm)	80

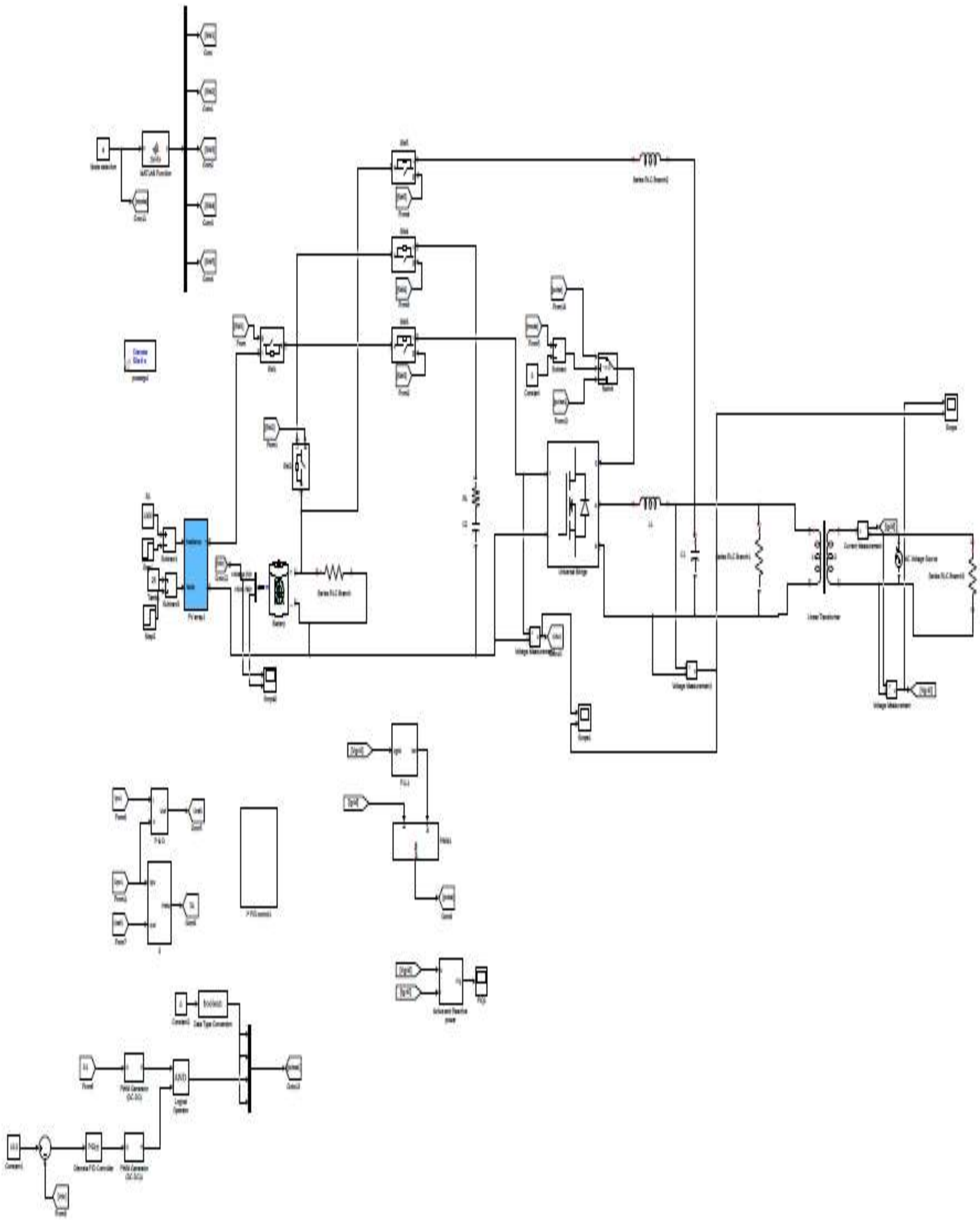

Fig. 15. MATLAB Simulation Model.

TABLE III
HARMONIC CONTRIBUTIONS BY DIFFERENT APPLIANCES

Appliances	THDV (%)	THDI (%)
Air conditioner	3.72	18
Bread toaster	2.3	2.7
CFL bulbs	3.6	99.9
Computer	2.7	99.6
Induction cook top	1.8	3.8
Fan	1.8	1.5
Incandescent bulb	1.7	2.2
Iron box	2.3	2.8
Laptop charger	2.3	39.1
Microwave oven	3.3	22
Mixer	2.9	13
Refrigerator	3	5.2
UPS	2.9	18
Battery charger	2.5	54
Cooler	2.4	1.7
Florescent lamp	2	99.8
Rice cooker	2.2	2.4
Tele vision	3	99.9
LED bulb	2.2	33.8

The harmonic contributions of different appliances are calculated experimentally and given in Table III. From the table, current total harmonic distortions (THDI) are higher for mainly lighting loads like CFL, tube light and charging loads like computer, battery chargers, etc., from this the loads, which injects more harmonics is replaced with its dc counterparts and connected to dc supply side. Thus, it mitigates harmonics injection by bypassing these loads to dc supply side

3.5 Simulation Result:

- **Mode-1: PV-Grid**

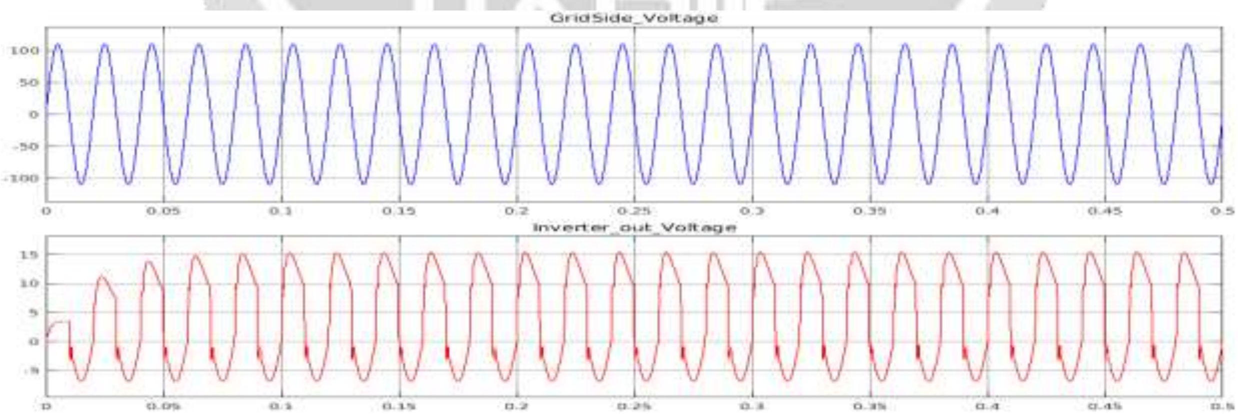

Fig. 16. Grid side voltage and inverter out voltage in PV Grid Mode.

Fig. 16 shows the peak voltage is maximum and so, two waveforms are given in upper and lower to show the synchronization with the grid without any significant deviations. PLL is actually a servo mechanism which will reduce the difference between phase and frequency of incoming signal to a reference signal.

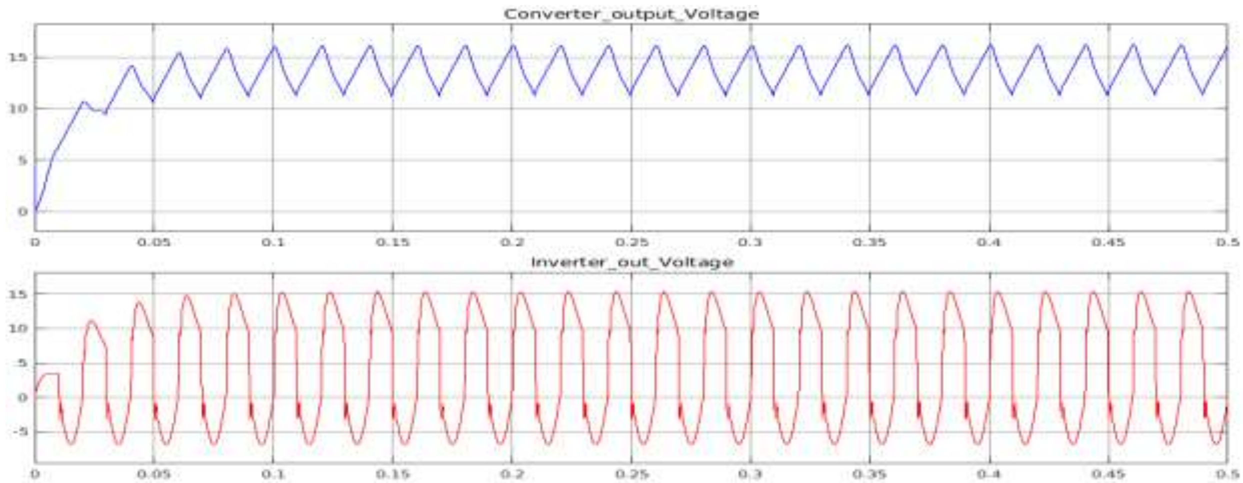

Fig. 17. Converter and Inverter output voltage PV Grid mode.

Fig. 17 shows converter output voltage of PV and Inverter output voltage Synchronization with constant output. Active power transfer to the grid is possible if there is a difference between the phase of the inverter and the grid supply system. PLL will capture the phase of the grid supply and required phase shift is generated using an inverter controller for power transfer.

- **Mode -2: PV-Battery-Grid**

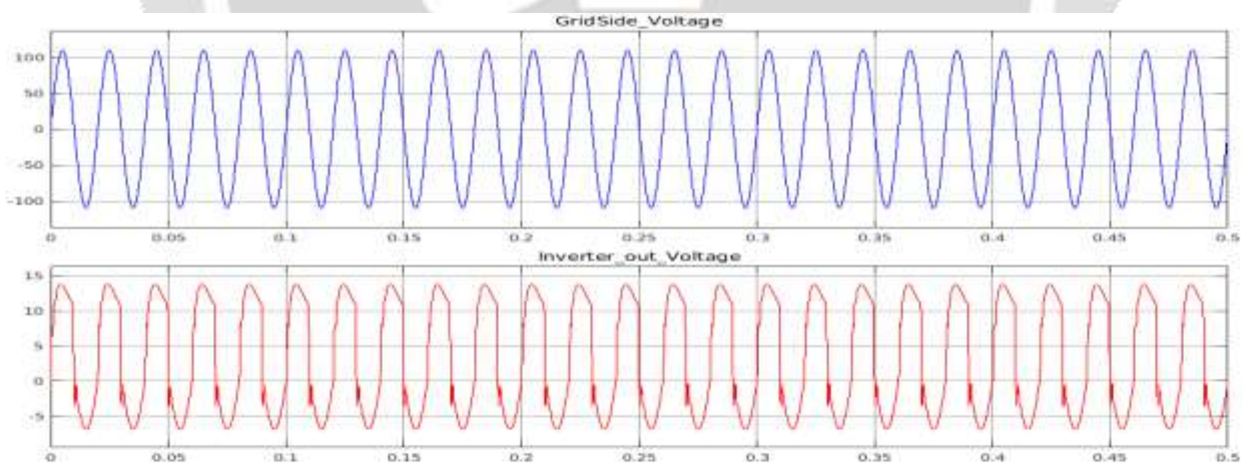

Fig. 18. Grid side and Inverter output voltage PV-battery- Grid mode.

Fig. 18 Show the synchronization with the grid without any significant deviations. But Synchronization battery output voltage and PV voltage at same time not possible. So, PV output voltage must be stop when Battery provides the output voltage.

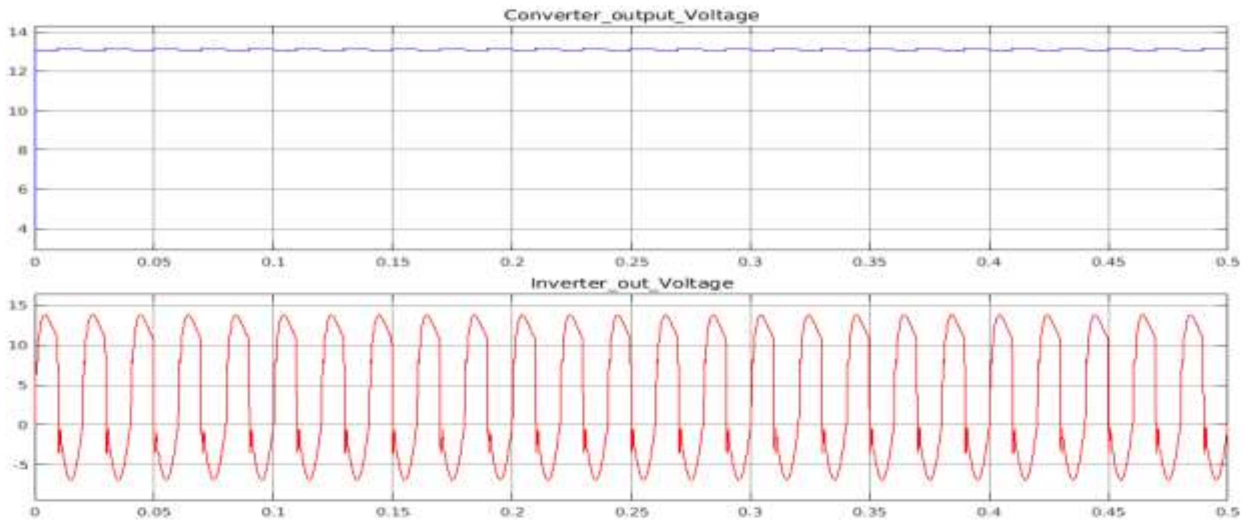

Fig. 19. Converter and Inverter output voltage PV-battery- Grid mode.

Fig. 19 shows the converter output voltage and inverter output voltage

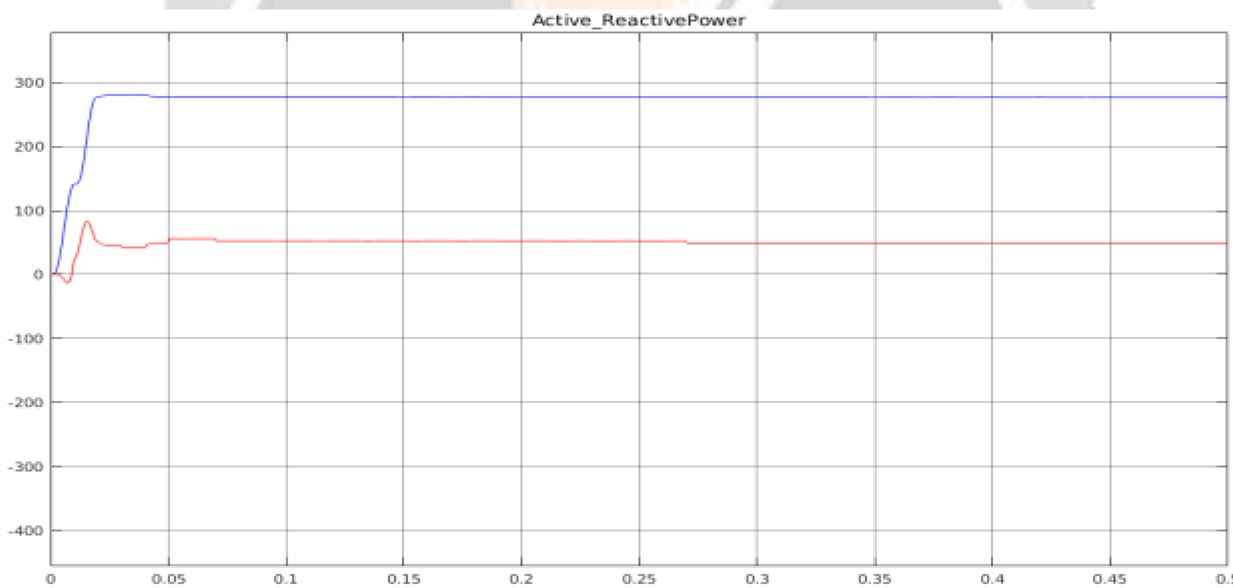

Fig. 20. Active Reactive power in PV-battery- Grid mode.

- **Mode -3: PV-Battery**

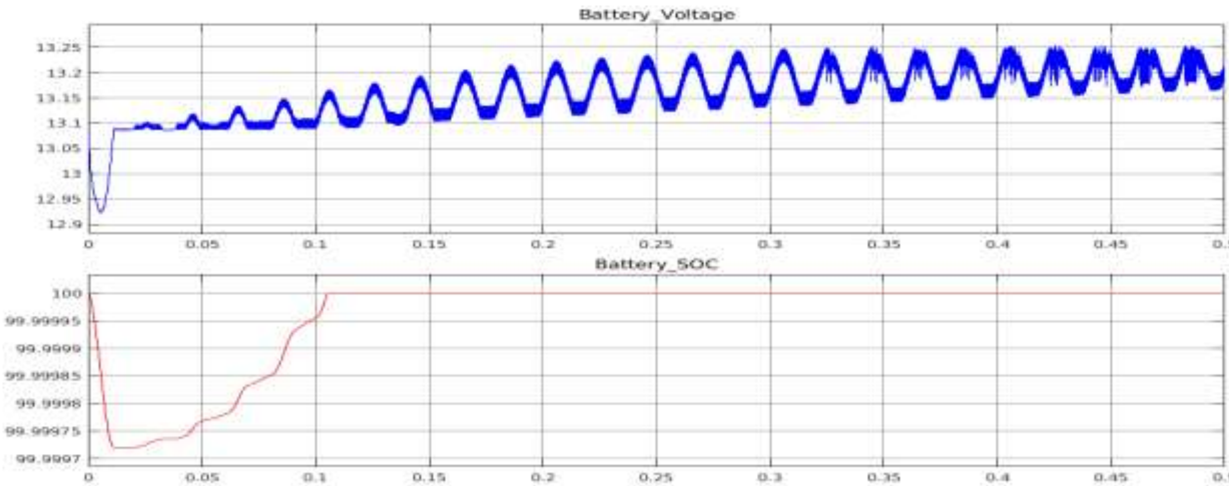

Fig. 21. Battery voltage and battery SOC in PV-battery- Grid mode.

Fig. 21 This control scheme is used for the controlling of dc-dc bidirectional converter. SOC: State of charge. The rms voltage is 220 V and current is 1.5-A peak. The dc/dc operation of the RSC is done by keeping the battery voltage to 15 V as its nominal charging voltage. Battery charged through the proposed topology. Here, constant voltage charging method is followed. Li-ion battery which is an inbuilt block of MATLAB/Simulink is used as battery storage. The output voltage during the charging is given in Fig. 21. Thus, all operations of the converter are tested in simulation and results are analyzed. The control algorithm works perfectly in the simulation in MATLAB.

- **Mode -4: Battery-Grid**

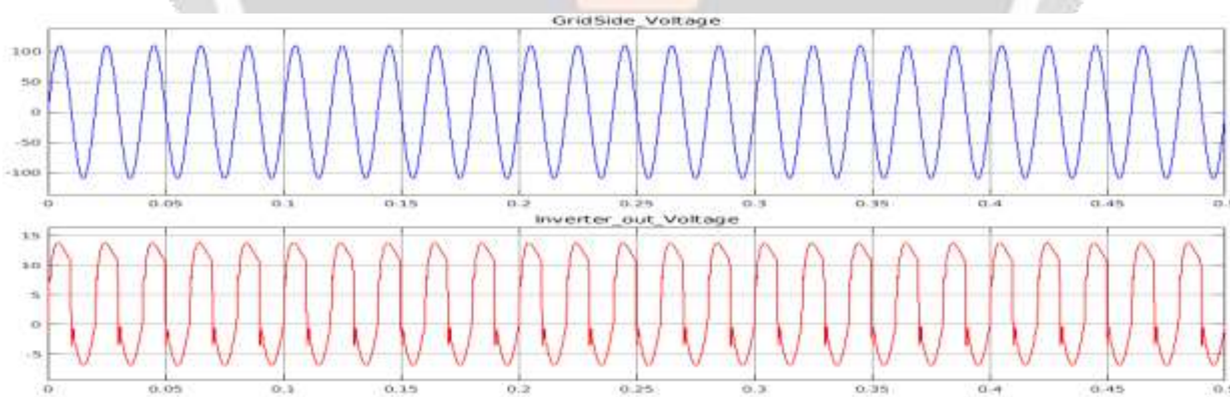

Fig. 22. Grid side voltage and inverter out voltage in PV-battery- Grid mode.

Fig. 22. Shows the voltage of the inverter lies along the voltage of the grid. Fig. 23. shows the synchronization of converter and inverter output voltage. Fig. 24. Shows the active power transfer with the grid. The active and reactive power waveform shown below.

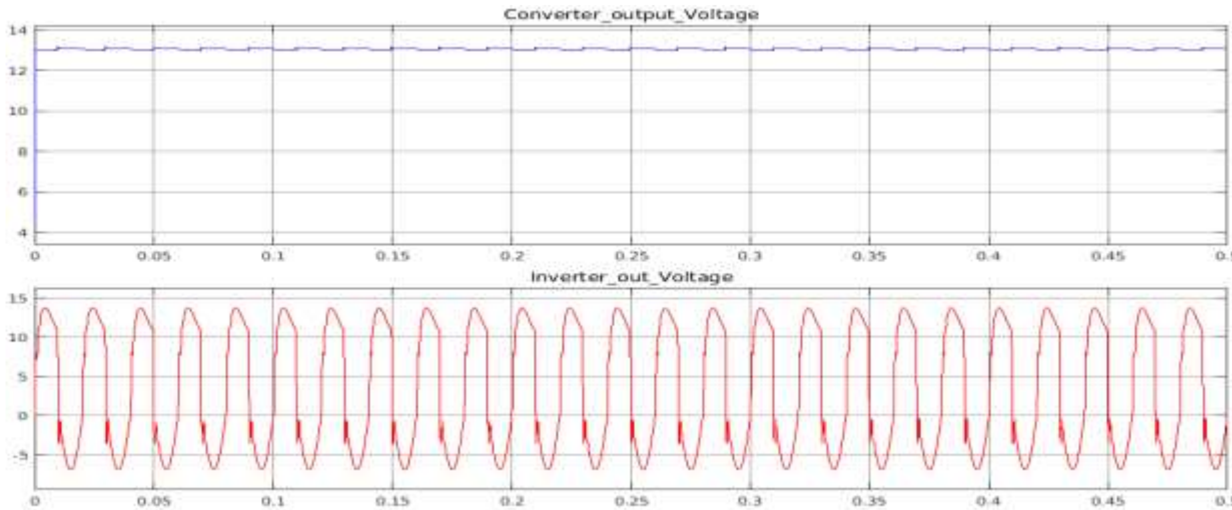

Fig. 23. Converter and inverter output voltage in PV-battery- Grid mode.

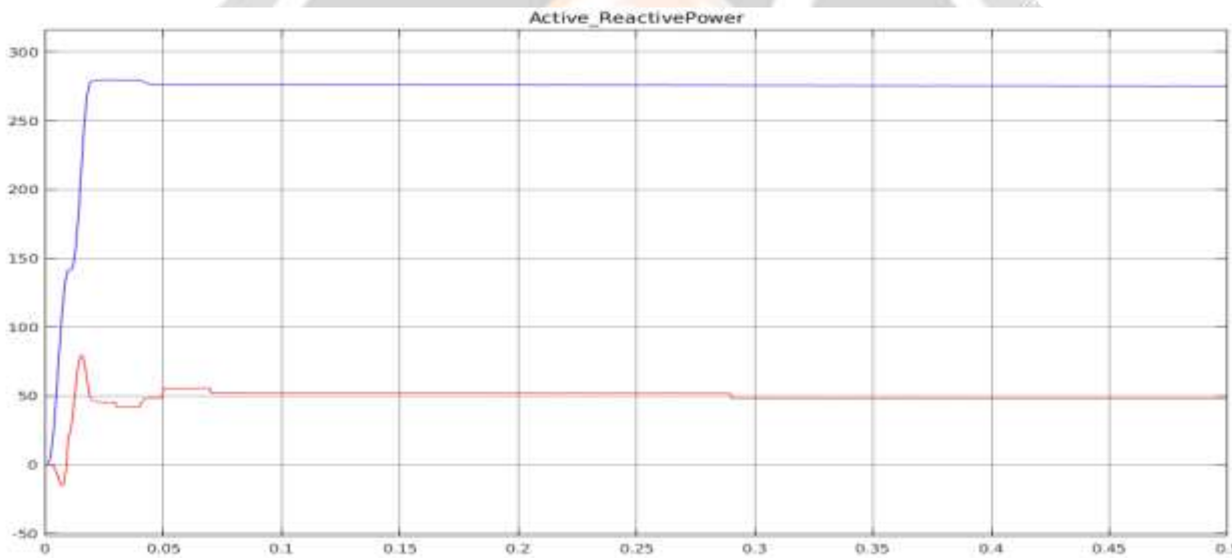

Fig. 24. Active and reactive power in PV-battery- Grid mode.

- **Voltage and Current.**

waveform “V” is grid voltage and “I” represents as the inverter current injected to grid for active power transfer. The current and voltage are in the phase which will inject the active power to the grid. The rms voltage is 220 V and current is 1.5-A peak. The dc/dc operation of the RSC is done by keeping the battery voltage to 15 V as its nominal charging voltage.

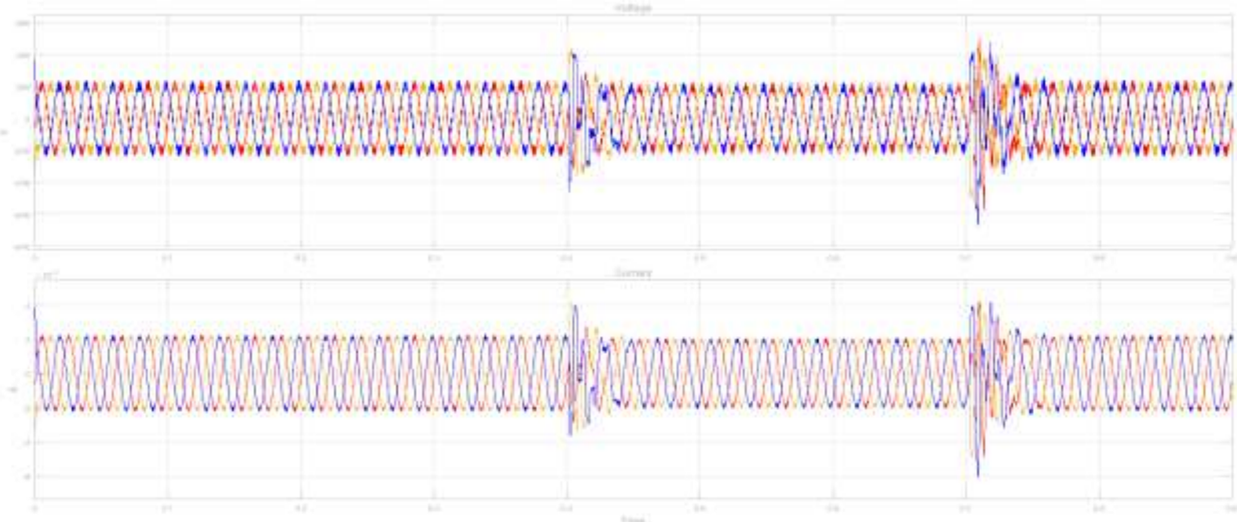

Fig. 25. Voltage and current waveform.

4. CONCLUSION

4.1 Advantages

- it minimizes the number of conversion stages
- improving efficiency and reducing cost, weight, and volume
- Helps to reduce the power loss avoiding unnecessary double stages of power conversion
- Improves the harmonic profile by isolating dc loads to dc supply side and rest to ac side.

4.2 Conclusion

This paper suggested a more suitable converter topology for a solar powered hybrid ac/dc home. The main idea of this topology is to utilize single conversion of ac power to dc and vice versa, which improves the efficiency, reduces volume, and enhances the reliability. The hardware implementation validates that the suggested converter topologies would be helpful to reduce significant number of harmonics in the residential feeders of the future smart grid. Though, here only solar PV is considered as source of power, this topology could be equally applicable to wind, fuel cells, etc.

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