Single-Phase Reconfigurable Converter Topology

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ABSTRACT:
This Project 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. It Improves The Harmonic Profile By Isolating Dc Loads To Dc Supply Side And Rest To Ac Side. Simulation Is Done In Matlab/Simulink Environment. This 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.

Keywords: Hybrid Ac/Dc Solar Powered Home, Inverter, Solar, Dc/Dc, Dc/Ac, Matlab/Simulink, Smart Grid , Micro Grid, Single-Phase Single-Stage Inverter, Solar Photovoltaic (Pv).

I. INTRODUCTION:

THE current century has witnessed an unprecedented evolution and growth of renewable energy worldwide [1]. 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 photo voltaics (PVs) experienced the swiftest growth rate in added power capacity among all the renewables. 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. 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 project 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.

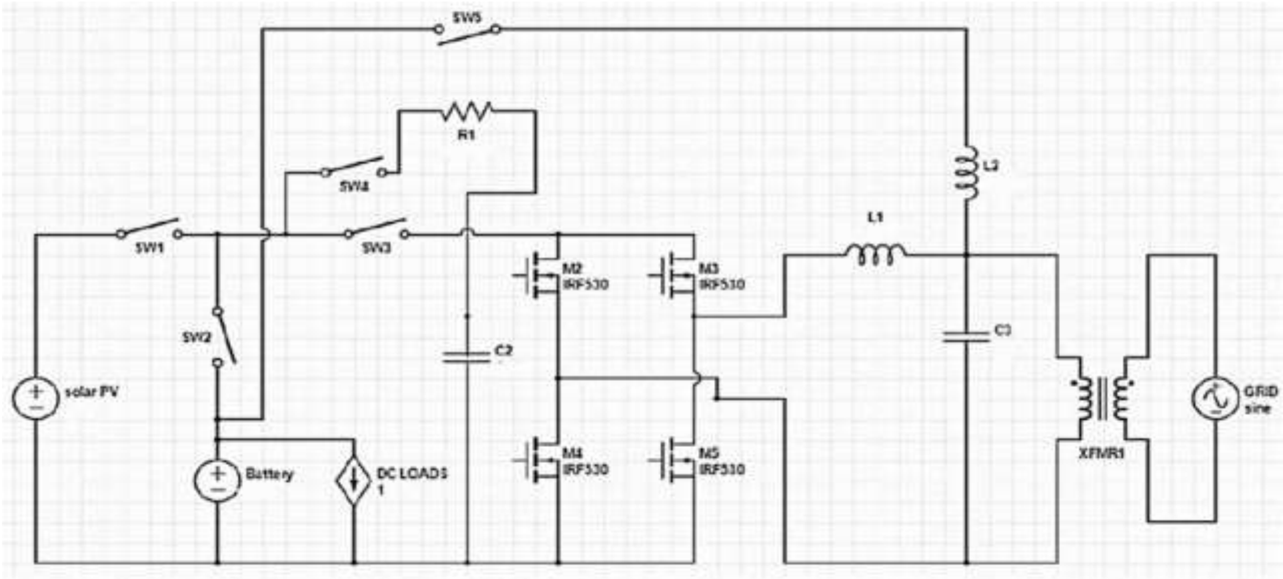
II LITERATURE REVIEW

S. Munir and L. Y. Wei, "Residential distribution system harmonic compensation using PV interfacing inverter," proposed the increased non-linear loads in today's typical home are a growing concern for utility companies. This situation might be worsened by the harmonic resonance introduced by the installation of capacitor banks in the distribution network. To mitigate the harmonic distortions, passive or active filters are typically used. However, with the increasing implementation of distributed generation (DG) in residential areas, using DG systems to improve the power quality is becoming a promising idea, particularly because many DG systems, such as photovoltaic (PV), wind and fuel cells, have DG- grid interfacing converters. In this project, the potential for using photovoltaic (PV) interfacing inverters to compensate the residential system harmonics is explored. A system model including the residential load and DG is first developed. An in-depth analysis and comparison of different compensation schemes based on the virtual harmonic damping impedance concept are then carried out. The effects of the capacitor banks in the system are also studied. The effectiveness of the harmonic compensation strategies under different conditions is verified through analysis and simulations.

Von Appen,T. Stetz, M. Braun, and A.Schmiegel, "Local voltage control strategies for PV storage systems in distribution grids," proposed local PV storage systems are emerging in Germany as PV feed-in tariffs have dropped below electricity prices for households. These PV storage systems provide the opportunity to increase the local consumption of locally generated PV energy. The so called self-consumption does not imply an explicit benefit for highly PV penetrated distribution grids suffering PV related voltage rises. Hence, this project introduces several local voltage control strategies using PV storage systems. These strategies focus on adding a voltage control capability to self-consumption strategies through a combination of voltage dependent battery charging, automatic reactive power provision as well as PV power curtailment. Their potential to smooth the grid integration of PV while increasing self- consumption is assessed through grid simulations and an economic evaluation. In conclusion, PV storage systems which are capable of voltage control can improve PV grid integration and provide a benefit to storage system owners.

A. Arancibia, K. Strunz, and F. Mancilla- David, "A unified single- and three-phase control for grid connected electric vehicles," proposed in
order to reduce cost, size, weight, and volume of on board chargers in electric vehicles, it has been proposed to pursue integration for the dual usage of converters for both charging and propulsion. The solution here goes further in that it also supports the control of slow single-phase and fast three-phase charging through one and the same power electronic converter. A unified control methodology for the on- board chargers in electric vehicles is proposed. The control is distinguished in that it can perform four quadrant operation while connected in single-phase or three-phase mode. The operation and network synchronization are automatically adjusted based on given terminal voltage and current measurements without the need for supplementary status signals. An analysis illustrates how the various measurements are processed for obtaining single- and three-phase flexibility while retaining compatibility with well-established methods of converter current mode control. The proposed control is validated via detailed simulation and demonstrated in a smart grid

PROPOSED RSC CIRCUIT:



Fig–1: Schematic of the proposed RSC circuit laboratory.

B. T. Patterson, "DC, come home: DC microgrids and the birth of the enernet,"
proposed most discussions about ac versus dc electricity include a retelling of the famous technical and commercial battle between Edison and Westinghouse/Tesla. It's a story about everything from electrocuting elephants at state fairs to the ambitious work of electrifying both urban and rural America. It's the tale of one of man's greatest engineering feats. It tells of a centralized power generation system based on the dominant use of incandescent light bulbs and ac constant-speed motors. In the end though, it is a retelling of history and unfortunately, it is a history that doesn't project.

TABLE I MODES OF OPERATION

MODES OF OPERATION	**ON switches**	**Off switches**
PV-GRID	SW1,SW3,SW4.	SW2,SW5.
PV-BATTERY- GRID	SW1,SW2,SW3,SW4.	SW5.
PV- BATTERY	SW1,SW3,SW5.	SW2,SW4.
BATTERY-GRID	SW2,SW3.	SW1,SW4,SW5.

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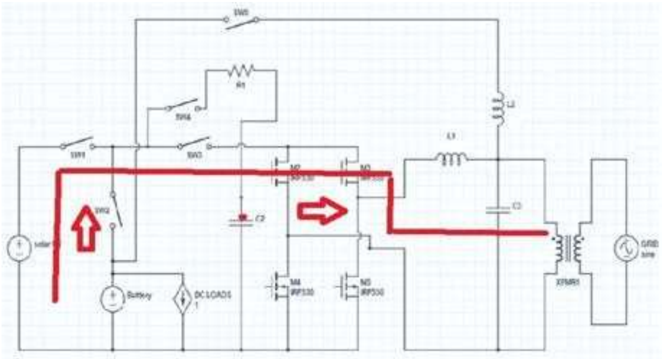
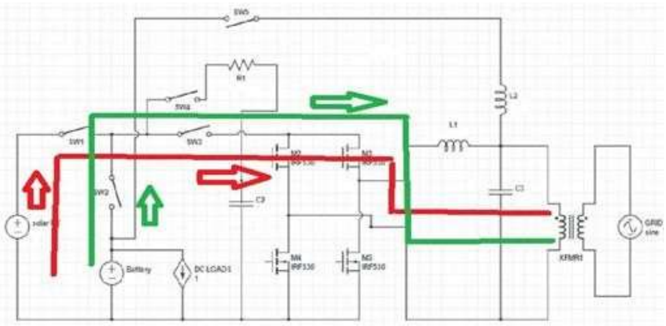
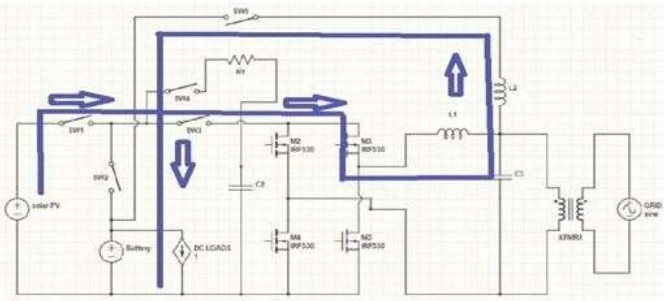


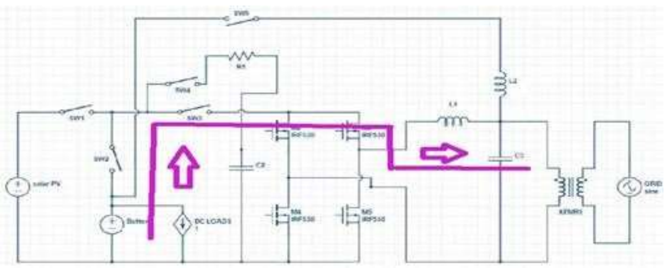
Fig–2: PV -GRID



Fig–3: PV- battery to grid



Fig–4: Pv to battery charging



Fig–5: Battery to grid

Mode-1

The mode of operation as shown in Fig. 2 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.

Mode-2

In Fig. 3, 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.

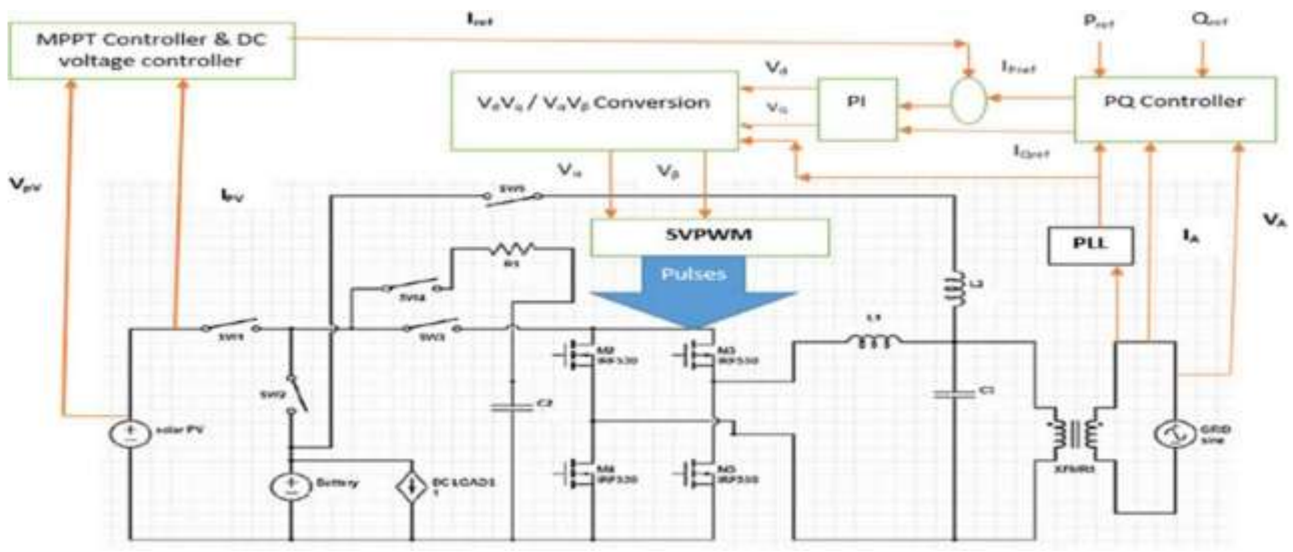
Since battery voltage is stiff, MPPT controller cannot be used for this configuration.

Mode-3

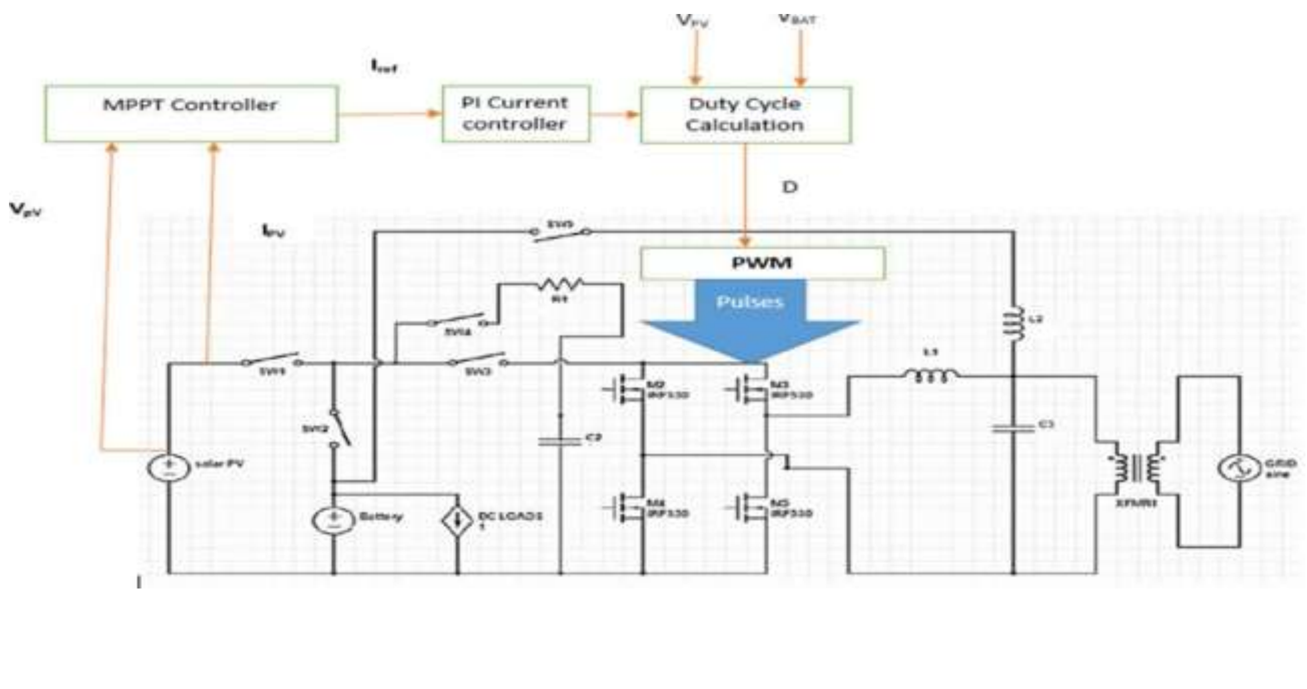
Fig. 4 shows dc/dc operation of the proposed topology, where battery is charged by a chopper action of the converter. The extra inductor is optional to reduce ripple in the charging current further. When there is an excess energy available, the battery is charged for the night time usage.

Mode-4

From Fig. 5, 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.



Fig–6: DC/AC inverter operation.



Fig–7: DC/DC chopper operation.

The control diagram for different modes of operations of the RSC is given in Figs. 6 and 7. In Fig. 6, 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 refer ence 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. 7. 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 MAT LAB/Simulink. The parameters used for the simulation are given in Table II. The radiation is kept at maximum at 1000W/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. The active and re active power output for a load of 320 Wand80VArissimulated and shown in Fig. 8. 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. PLL

TABLE II SIMULATIONPARAMETERS

Components	**Parameters**
Battery	12V,9Ah
Filter capacitor(C1)	47µF
Filter inductor(L1)	2.3mH
Switching frequency	4000Hz
DC link capacitor(C2)2nos.	2200µF,16V
Resistance(R1)	1kΩ

Solar panel		**etails**
No of cells per module		32
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

RESULTS

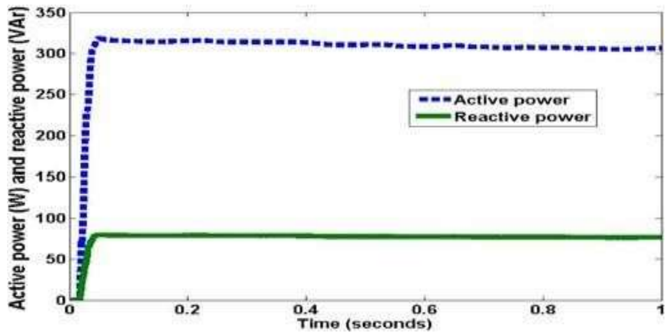


Fig. 8. Active and reactive power generation.

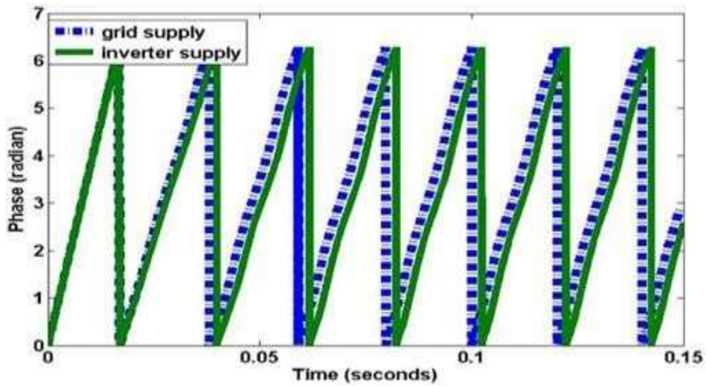


Fig. 9. Phases in radians.

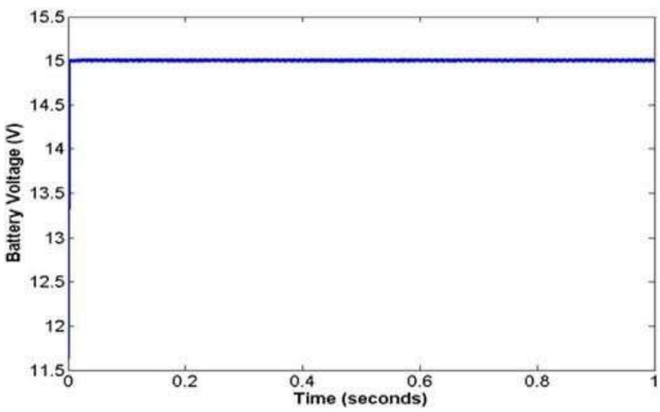


Fig. 10. Battery voltage.

is actually a servo mechanism which will reduce the difference between phase and frequency of incoming signal to a referencesignal. Active power transfer to the grid is possible if there is adifference between the phase of the inverter and the grid supply system. PLL will capture the phase of the grid supply and re- quired phase shift is generated using an inverter controller for power transfer. The phasor diagram of inverter and grid supplyduring the power transfer is shown in Fig. 9. Battery charged through the proposed topology. Here, constant voltage charging method is followed. Li-ion battery whichis an inbuilt block of MATLAB/Simulink is used as battery storage. The output voltage during the charging is given in Fig. 10. Thus, all operations of the converter are tested in simulation and results are analyzed. The control algorithm works perfectly in the simulation in MATLAB

CONCLUSION

This project 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 there commended converter topologies would be helpful to decrease significant amount 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 uniformly applicable to wind, fuel cells, etc.

FUTURE SCOPE

Intelligent devices like microprocessors, PLC (programmable logic controller) may be added to the system to keep the operating point (maximum power point) for get maximum efficiency. Solar photovoltaic is a technology that offers a solution for a different problems associated with fossil fuels. It is clean decentralized, indigenous and don’t need continuous import of a resource. On the above of that, India has among the highest solar illumination in the world which makes Solar Photovoltaic all the more attractive and demand for India.

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