Impact Factor (SJIF): 5.301

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 5, Issue 4, April-2018

OPTIMIZATION OF PV-WIND-BATTERY BASED MULTI-INPUT TRANSFORMER COUPLED HYBRID CONVERTER FOR HOUSEHOLD APPLICATIONS

Mrs. N. Anipriya, Assistant Professor, M. N. Abarna, Student Member, IEEE, R. Rangitha, Therasa. B

Abstract-In this paper the increment of voltage and reducing the stages of the hybrid system is presented. The hybrid PV-wind-battery based system for household applications, which can work either in stand-alone or grid connected mode. This system is suitable for household applications, where cost is low, simple and compact system capable of autonomous operation is desirable. The proposed system has a transformer coupled full bridge converter fused with a bi-directional buck boost converter and voltage doubler and a single phase full bridge inverter. The proposed converter has reduced number of power conversion stages with less number of components and high efficiency compared to existing system. The bi-directional buck boost converter fused with full bridge inverter helps in harnessing the power from solar and wind is connected on primary side of multi input transformer whereas voltage doubler and single phase full bridge inverter connected on secondary side. A full bridge inverter and voltage doubler circuit helps in increasing the voltage and reducing the size of the transformer. Thus, it improves the efficiency and reliability of the system. Simulation results obtained using MATLAB/Simulink show the performance of the proposed system under various modes of operation.

Keywords-Hybrid system, photovoltaic, wind energy, multi-input transformer coupled boost full-bridge converter, bidirectional buck-boost converter, maximum power point tracking, voltage doubler, battery charge control.

I.INTRODUCTION

With increase in global warming and the depletion of fossil fuel reserves, people are looking at sustainable energy solutions in order to preserve the earth for the future generations. Other than hydro power, wind and photovoltaic energy are the most potential to meet our energy demands. Alone, wind energy can supply large amounts of power but its presence is unpredictable as it can be here one moment and gone in another. Similarly, solar energy is present the whole day but the solar irradiation levels vary due to sun intensity and unpredictable shadows cast by clouds, birds, trees, etc. The common inherent drawback of wind and photovoltaic systems are their intermittent natures which make them unreliable. However, on combining these two intermittent sources and by incorporating maximum power point tracking (MPPT) algorithms, the system's power transfer efficiency and reliability can be significantly improved.

When a source is unavailable or insufficient in order to meet the load demands, the other energy source has the ability to compensate for the difference. Many hybrid wind/PV power systems with MPPT control have been proposed and discussed. Most of the systems use a separate DC/DC boost converter connected in parallel in the rectifier stage as shown in Figure: to perform the MPPT control for each of the renewable energy power sources. A simpler multi input structure has been suggested by combining the sources from the DC-end while still achieving MPPT for each source. The structure proposed by is a fusion of the buck and boost converter. The older systems require passive input filters to remove the high frequency current harmonics injected into wind turbine generators. The lifespan of the generator decreases due to the harmonic content in the generator current which also increases the power loss due to heating.

Significant amount of literature exists on the integration solar and wind energy as hybrid energy generation system focus on sizing and optimization. The sources and storage are interfaced at the DC link in the existing system through their bi directional buck boost and half-bridge converters to the multi input transformer. Other DC link consists of controlled rectifier connected to load. Other contributions are made on their modelling accepts and control operation of wind energy system to compliment the solar energy generating system.

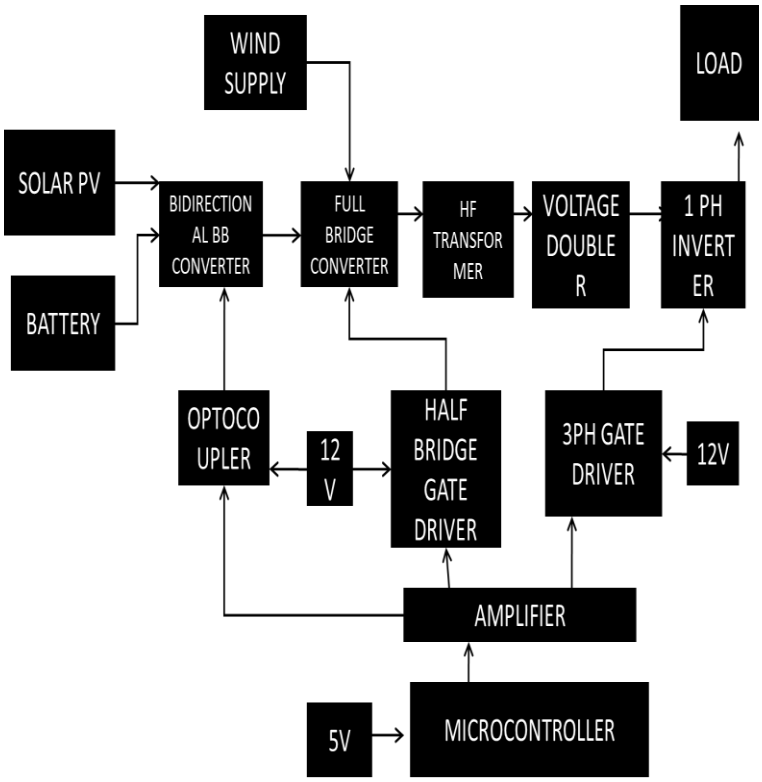
Not many attempts are made to optimize the circuit configuration of this systems that could reduce the cost and increase the efficiency and reliability. The existing system so far can accommodate only one renewable energy source and one storage energy element. Whereas, the proposed system is capable of interfacing two renewable sources and an energy storage element. Hence this system is more reliable as two different types of renewable resources like PV and wind sources are used either individually or simultaneously without increase in the component count compared to the existing system. The main objectives of this system are as follows:

- To develop and simulate grid connected converter.
- To develop Energy storage with bidirectional capability in hybrid energy system.
- To inject power into the grid and charge the battery from the grid.
- To reduce the power conversion stages.

This system can work either in stand- alone or grid connected mode. The core of the proposed system is the multi-input transformer coupled full bridge and bidirectional buck-boost converters that interconnects various power sources and the storage element and a voltage doubler circuit is used which increases the output voltage. Further, a control scheme for effective power flow management to provide uninterrupted power supply to the loads, while injecting excess power into the grid is proposed.

- MPP tracking of both the sources, battery charging control and bidirectional power flow are accomplished with controllable switches.
- The voltage boosting capability is accomplished by connecting PV and battery in series which is further enhanced by a high frequency step-up transformer and a voltage doubler circuit.
- The proposed controller can operate in different modes of a grid-connected scheme ensuring proper operating mode selection and smooth transition between different possible operating modes.

BLOCK DIAGRAM:



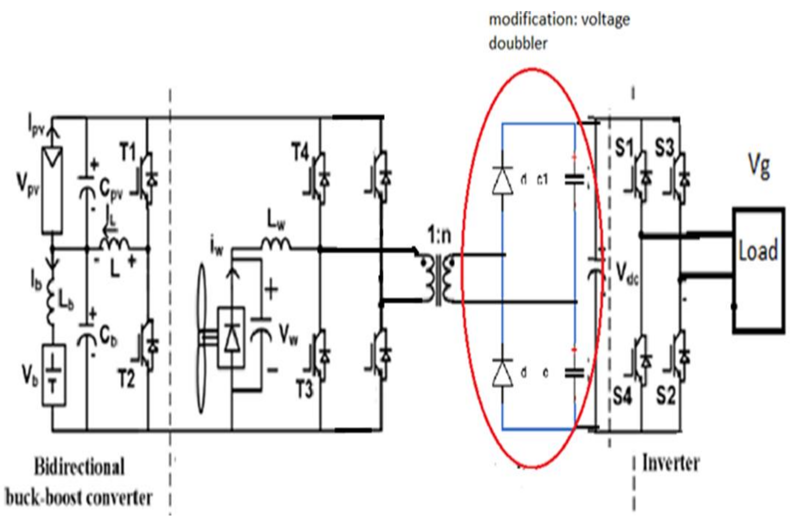
II. PROPOSED CONVERTER CONFIGURATION

The proposed converter consists of a transformer coupled boost half-bridge bidirectional converter and voltage doubler fused with bidirectional buck-boost converter and a three-phase full-bridge inverter. The proposed system has reduced number of power conversion stages with less component count and high efficiency compared to the existing schemes. The system is simple and needs only four power switches. The boost half-bridge converter and voltage doubler has two dc-links on both sides of the high frequency transformer. Controlling the voltage of one of the dc-links needs controlling the voltage of the other. Moreover, additional converters can also be integrated with any one of the two dc-links. A bidirectional buck-boost converter is integrated with the primary side dc-link and single-phase full-bridge bidirectional converter is connected to the secondary side dc-link. The input of the half-bridge converter is formed by connecting the PV array in series with the battery, thereby incorporating an inherent boosting stage for the scheme. The boosting capability is further enhanced by a high frequency step-up transformer. The transformer also ensures galvanic isolation to the load from the sources and the battery. Bidirectional buck-boost converter is used to harness power from PV source along with battery charging/discharging control. The unique feature of this converter is that MPP tracking, battery charge control and boosting of voltage are accomplished through a single converter. Transformer coupled boost half-bridge converter is used for harnessing power from wind source, voltage doubler is used for doubling the voltage and a single-phase full-bridge bidirectional converter is used for feeding ac loads and also interaction with grid.

The power flow from wind source is controlled through a unidirectional boost half-bridge converter. For obtaining MPP effectively, smooth variation in source current is required which can be obtained using an inductor. In the proposed topology, an inductor is placed in series with the wind source which ensures continuous current and thus this inductor current can be used for maintaining MPP current. When switch T 3 is ON, the current flowing through the source inductor increases. The capacitor C1 discharges through the transformer primary and switch T 3. In secondary side capacitor C3 charges through transformer secondary and anti-parallel diode D5. When switch T 3 is turned OFF and T 4 is turned ON, initially the inductor current flows through antiparallel diode of switch T 4 and through the capacitor bank. During this interval, the current flowing through diode decreases and that flows through transformer primary increases. When current flowing through the inductor becomes equal to that flowing through transformer primary, the diode turns OFF. Since, T 4 is gated ON during this time, the capacitor C2 now discharges through switch T 4 and transformer primary. During the ON time of T 4, anti-parallel diode D6 conducts to charge the capacitor C4. During the ON time of T 3, the primary voltage $VP = -VC1$. The secondary voltage $VS = nVp = -nVC1 = -VC3$, or $VC3 = nVC1$ and voltage across primary inductor Lw is Vw. When T 3 is turned OFF and T 4 turned ON, the primary voltage $VP = VC2$. Secondary voltage $VS = nVP = nVC2 = VC4$ and voltage across primary inductor Lw is $Vw -(VC1 + VC2)$. It can be proved that $(VC1 + VC2) = Vw\,(1-Dw)$. The capacitor voltages are considered constant in steady state and they settle at $VC3 = nVC1$, $VC4 = nVC2$.

Therefore, the output voltage of the secondary side dc-link is a function of the duty cycle of the primary side converter and turns ratio of transformer. In the proposed configuration as shown in fig, a bidirectional buck-boost converter is used for MPP tracking of PV array and battery charging/discharging control.

Further, this bidirectional buck-boost converter charges/discharges the capacitor bank C1-C2 of transformer coupled full-bridge boost converter based on the load demand. The full-bridge boost converter extracts energy from the wind source to the capacitor bank C1-C2. During battery charging mode, when switch T 1 is ON, the energy is stored in the inductor L. When switch T 1 is turned OFF and T 2 is turned ON, energy stored in L is transferred to the battery. If the battery discharging current is more than the PV current, inductor current becomes negative. Here, the stored energy in the inductor increases when T 2 is turned on and decreases when T 1 is turned on. It can be proved that $Vb = D1-DVpv$. This voltage is n times of the primary side dc-link voltage. The primary side dc-link voltage can be controlled by half-bridge boost converter or by bidirectional buck-boost converter. The relationship between the average value of inductor, PV and battery current over a switching cycle is given by $IL = Ib + Ipv$. It is evident that, Ib and Ipv can be controlled by controlling IL. Therefore, the MPP operation is assured by controlling IL, while maintaining proper battery charge level. IL is used as inner loop control parameter for faster dynamic response while for outer loop, capacitor voltage across PV source is used for ensuring MPP voltage.

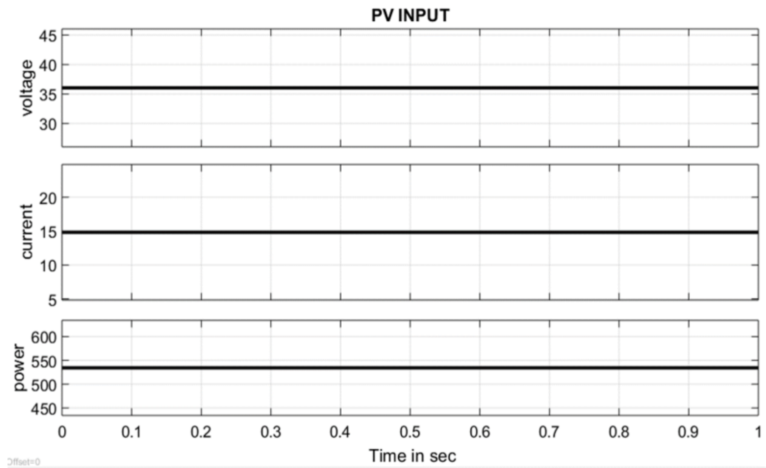


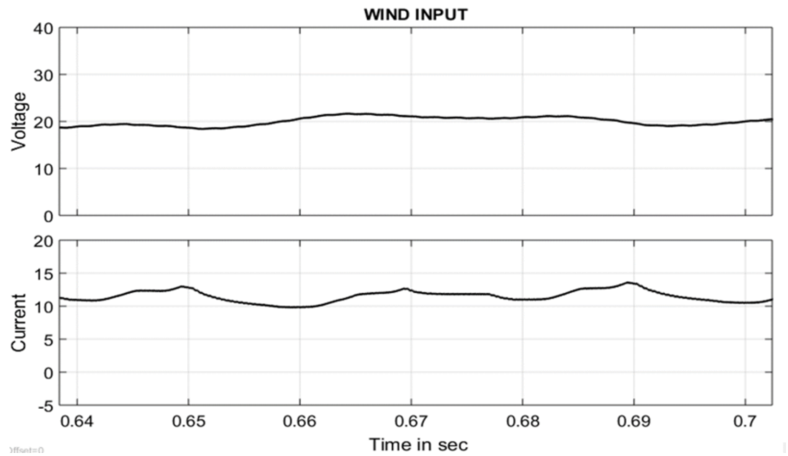
III. SIMULATION RESULTS AND DISCUSSION

Detailed simulation studies are carried out on MAT-LAB/Simulink platform and the results obtained for various operating conditions are presented in the section.

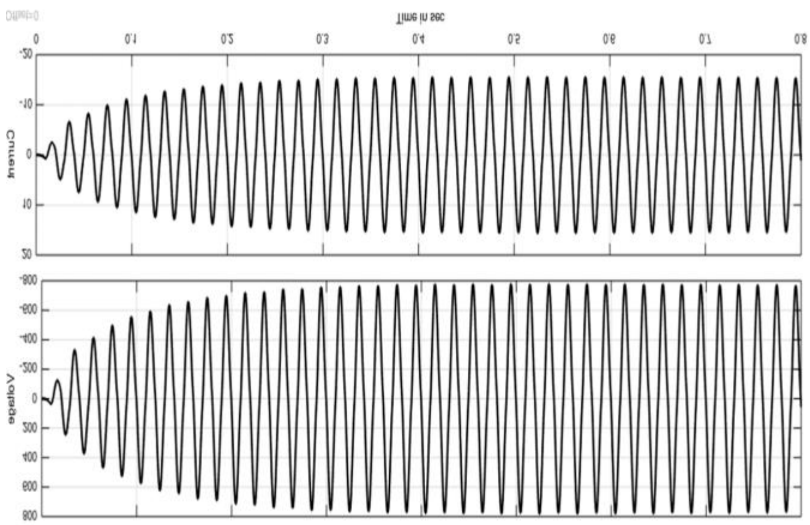
Mode:1

Both the PV and Wind sources are active



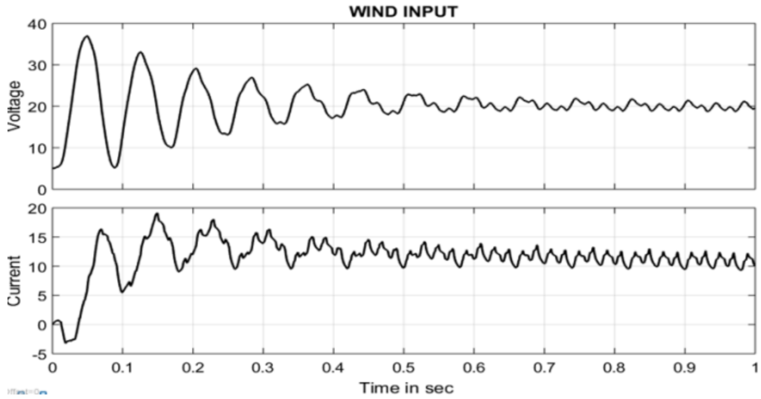


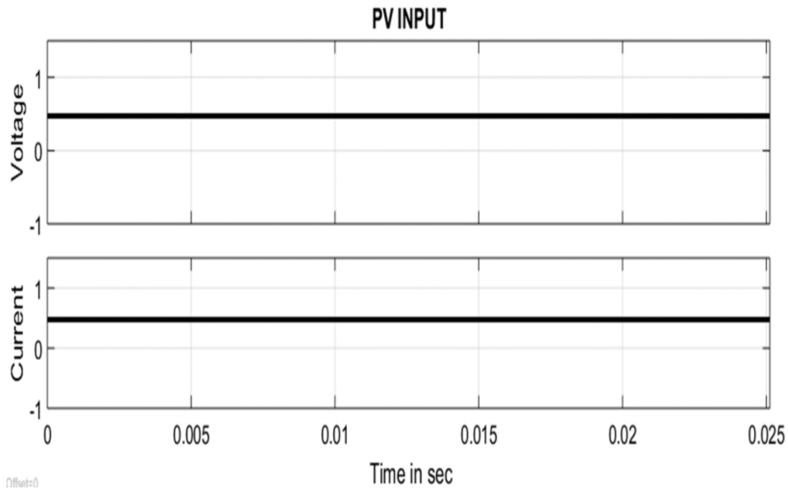
Output:



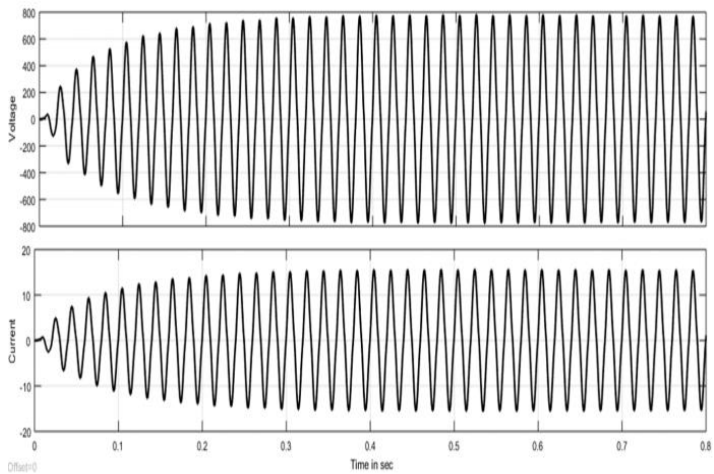
Mode:2

Only wind source is active



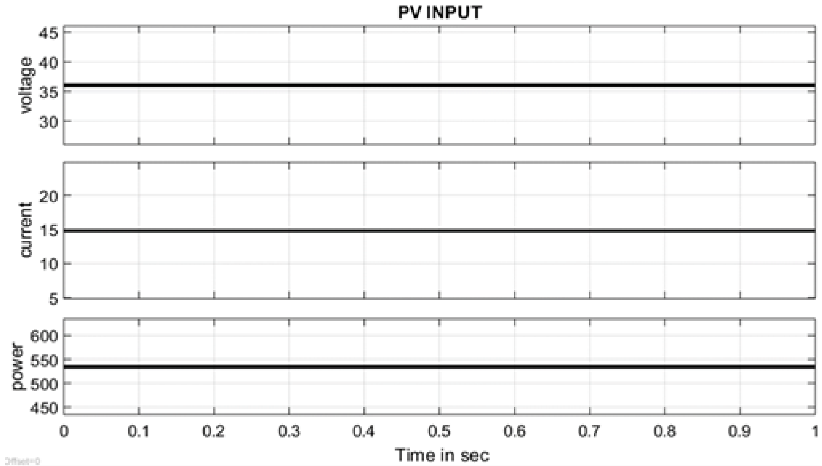


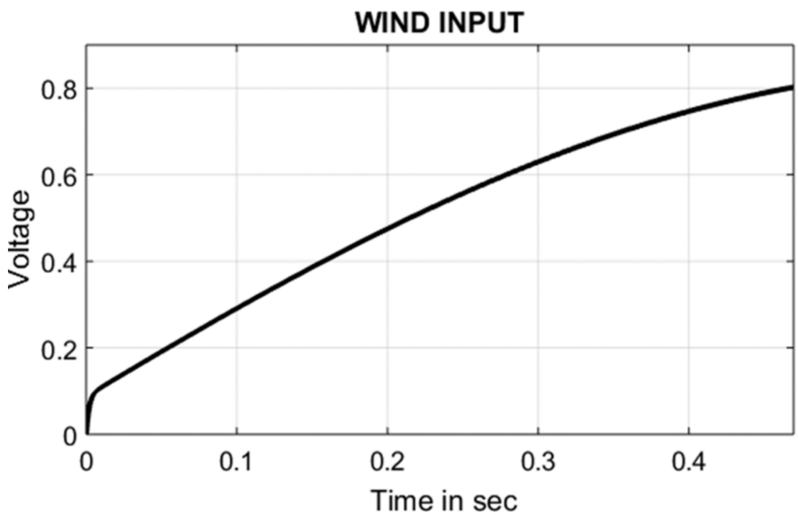
Output:



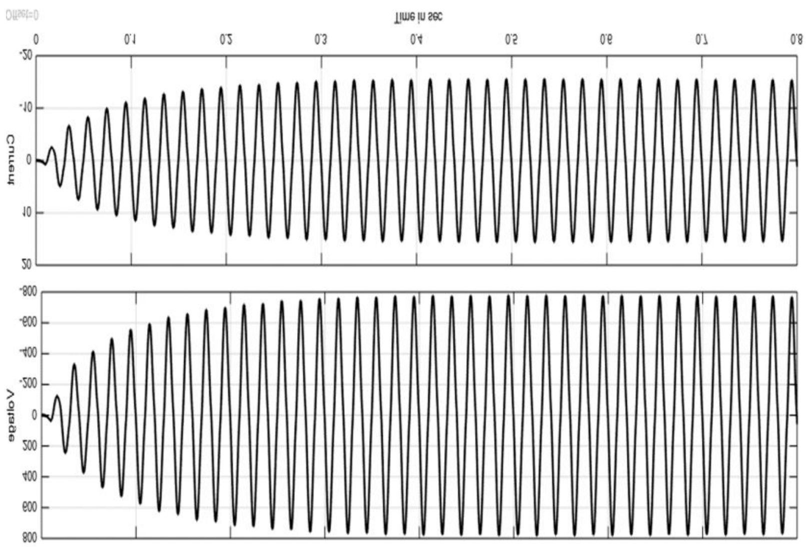
Mode:3

Only PV source is active



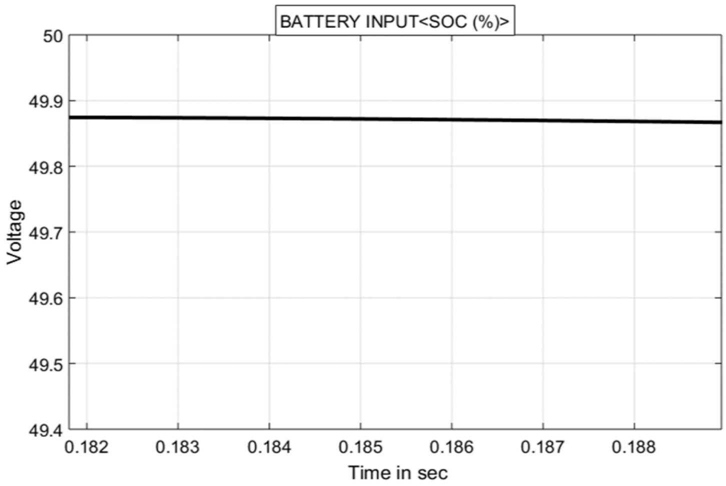


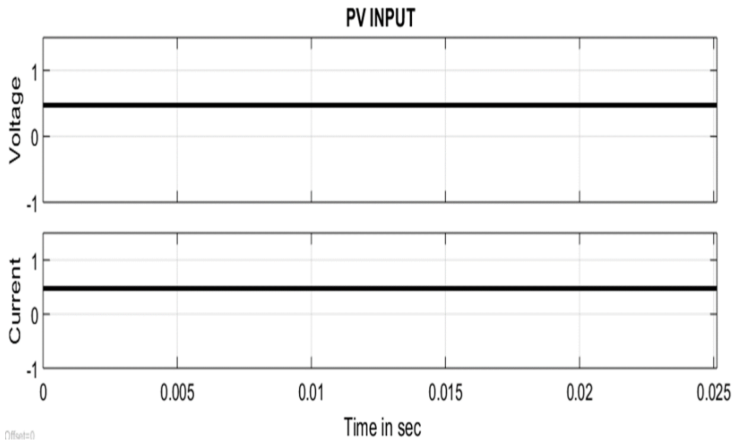
Output:

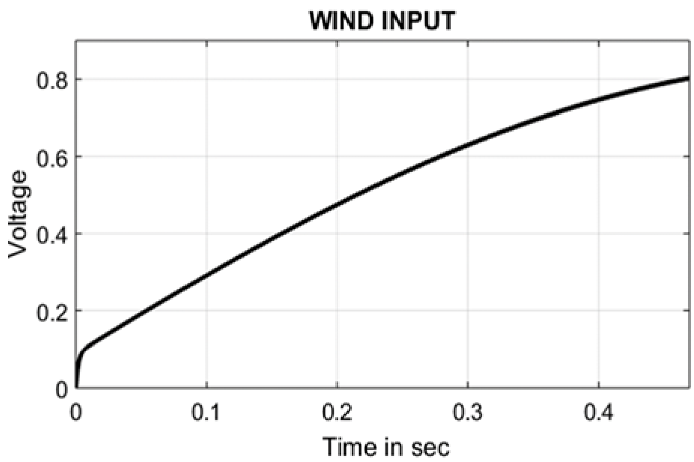


Mode:4

Battery charging





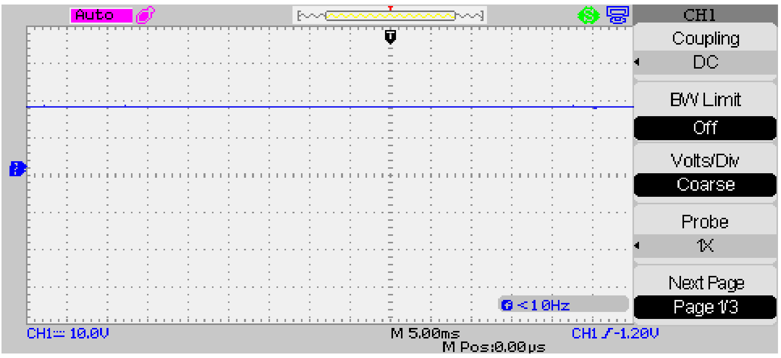


VI. EXPERIMENTAL VALIDATION

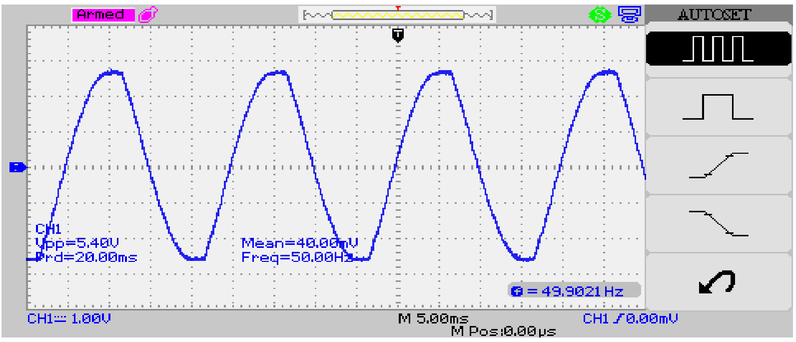
MODE: 1

PV-Wind sources are active

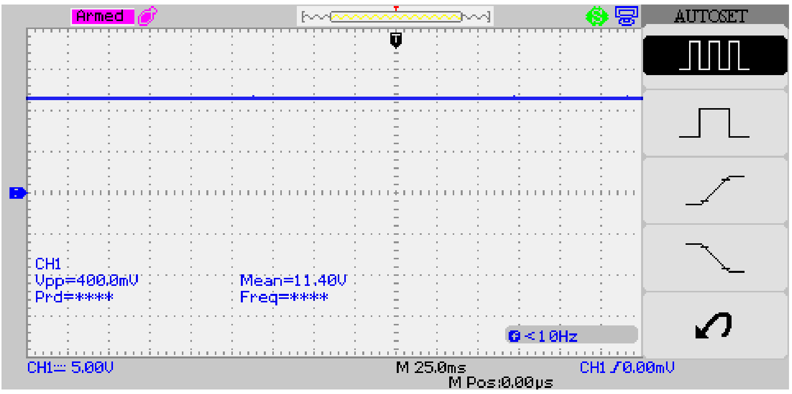
PV Source:

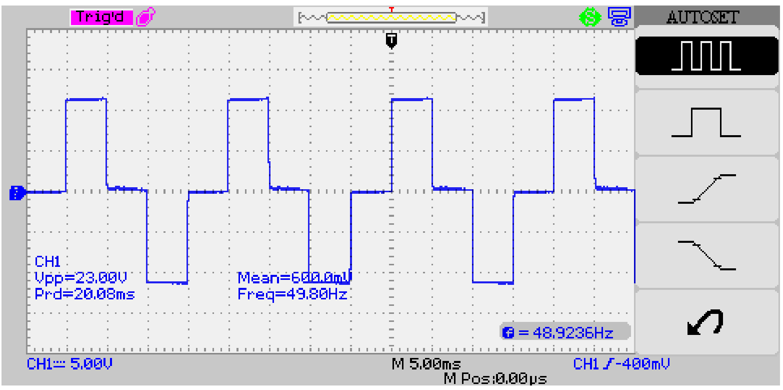


Wind Source:



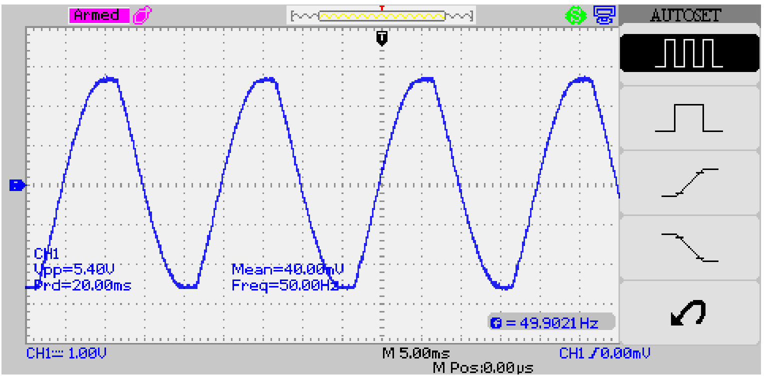
Output:



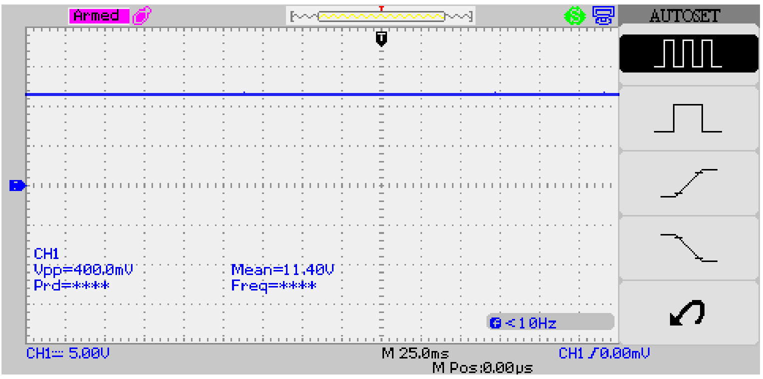


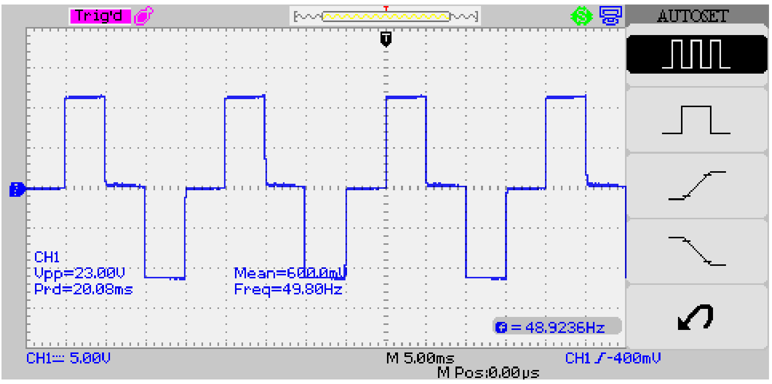
MODE:2

Wind source is active



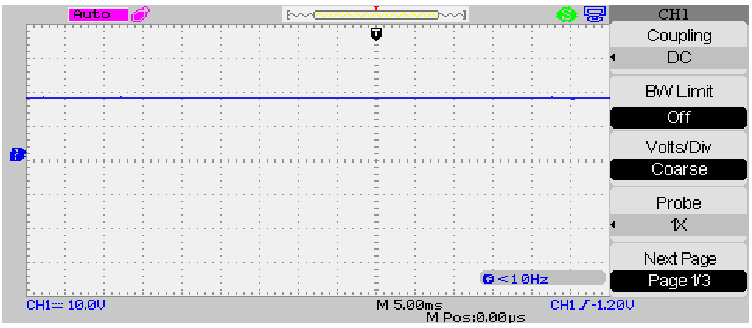
Output:



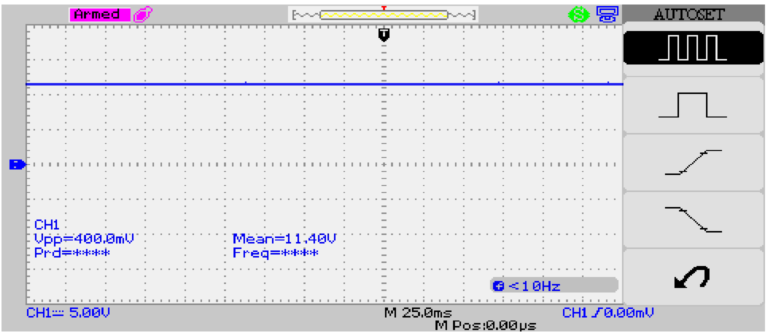


MODE:3

PV source is active



Output:



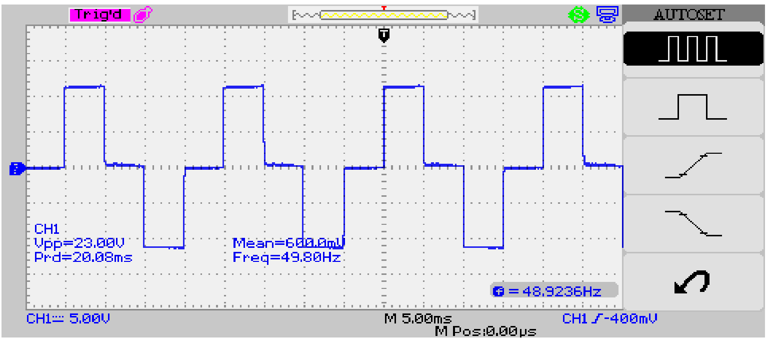
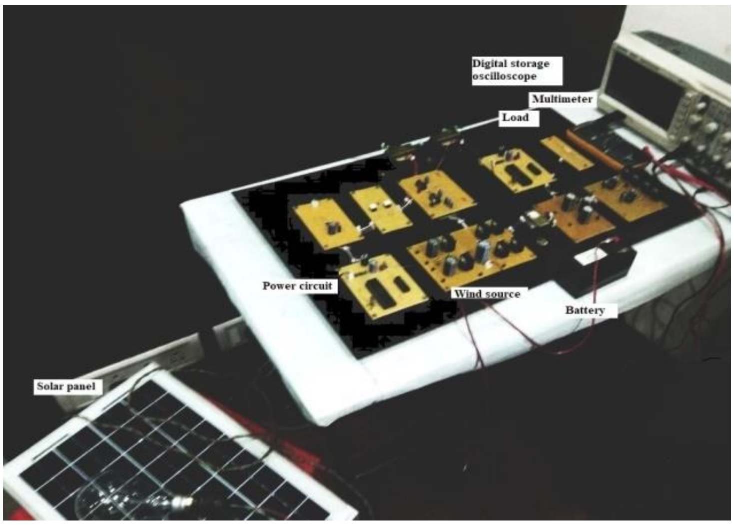


Fig: Experimental setup of proposed system



V. CONCLUSION

The proposed hybrid system for household applications provides an elegant integration of PV and wind source to extract maximum energy from both the sources. A flexible control strategy which achieves better utilization of PV, wind power, battery capacities without effecting life of the battery and power flow management in a hybrid PV-wind-battery based grid connected system feeding ac loads is presented. Detailed simulation studies have been carried out.

REFERENCES

[1] F. Valenciaga and P. F. Puleston,"Supervisor control for a stand-alone hybrid generation system using wind and photovoltaic energy," IEEE Trans. Energy Convers., vol. 20, no. 2, pp. 398-405, Jun. 2005.

[2] C. Liu, K. T. Chau and X. Zhang,"An efficient wind-photovoltaic hybrid generation system using doubly excited permanent-magnet brushless machine, "IEEE Trans. Ind. Electron., vol. 57, no. 3, pp. 831-839, Mar.2010.

[3] W. Qi, J. Liu, X. Chen, and P. D. Christofides, "Supervisory predictive control of standalone wind/solar energy generation systems," IEEE Trans. Control Sys. Tech., vol. 19, no. 1, pp. 199-207, Jan. 2011.

[4] F. Giraud and Z. M. Salameh, "Steady-state performance of a grid-connected rooftop hybrid wind-photovoltaic power system with battery storage," IEEE Trans. Energy Convers., vol. 16, no. 1, pp. 1-7, Mar.2001.

[5] S. K. Kim, J. H. Jeon, C. H. Cho, J. B. Ahn, and S. H. Kwon, "Dynamic modeling and control of a grid-connected hybrid generation system with versatile power transfer," IEEE Trans. Ind. Electron., vol. 55, no. 4, pp.1677-1688, Apr. 2008.

[6] M. Dali, J. Belhadj and X. Roboam, "Hybrid solar-wind system with battery storage operating in grid-connected and standalone mode: control and energy management-experimental investigation," Energy, vol.35, no. 6, pp. 2587-2595, June 2010.

[7] W. Kellogg, M. Nehrir, G. Venkataramanan, and V. Gerez, "Generation unit sizing and cost analysis for stand-alone wind, photovoltaic and hybrid wind/PV systems," IEEE Trans. Ind. Electron., vol. 13, no. 1, pp. 70-75, Mar. 1998.

[8] L. Xu, X. Ruan, C. Mao, B. Zhang, and Y. Luo, "An improved optimal sizing method for wind-solar-battery hybrid power system," IEEE Trans. Sustainable Energy., vol. 4, no. 3, pp. 774785, Jul. 2013.

[9] B. S. Borowy and Z. M. Salameh,"Dynamic response of a stand-alone wind energy conversion system with battery energy storage to a wind gust, "IEEE Trans. Energy Convers., vol. 12, no. 1, pp. 73-78, Mar. 1997.

[10] S. Bae and A. Kwasinski,"Dynamic modeling and operation strategy for a microgrid with wind and photovoltaic resources," IEEE Trans. Smart Grid, vol. 3, no. 4, pp. 1867-1876, Dec. 2012.

[11] C. W. Chen, C. Y. Liao, K. H. Chen and Y. M. Chen,"Modeling and controller design of a semi isolated multi input converter for a hybrid PV/wind power charger system," IEEE Trans. Power Electron., vol. 30, no. 9, pp. 4843-4853, Sept. 2015.

[12] M. H. Nehrir, B. J. LaMeres, G. Venkataramanan, V. Gerez, and L.A. Alvarado, "An approach to evaluate the general performance of stand-alone wind/photovoltaic generating systems,"IEEE Trans. Energy Convers., vol. 15, no. 4, pp. 433-439, Dec. 2000.

[13] W. M. Lin, C. M. Hong, and C. H. Chen," Neural network-based MPPT control of a stand-alone hybrid power generation system," IEEE Trans. Power Electron., vol. 26, no. 12, pp. 3571-3581, Dec. 2011.

[14] F. Valenciaga, P. F. Puleston, and P. E. Battaiotto,"Power control of a solar/wind generation system without wind measurement: a passivity sliding mode approach," IEEE Trans. Energy Convers., vol. 18, no.4, pp. 501-507, Dec. 2003.

[15] T. Hirose and H. Matsuo, "Standalone hybrid wind-solar power generation system applying dump power control without dump load," IEEE Trans. Ind. Electron., vol. 59, no. 2, pp. 988-997, Feb. 2012.

[16] S. A. Daniel and N. A. Gounden, "A novel hybrid isolated generating system based on PV fed inverter-assisted wind-driven induction generators," IEEE Trans. Energy Convers., vol. 19, no. 2, pp. 416-422, Jun.2004.

[17] R. Wandhare and V. Agarwal, "Novel integration of a PV-wind energy system with enhanced effciency," IEEE Trans. Power Electron., vol. 30, no. 7, pp. 3638-3649, Jul. 2015.

[18] Z. Qian, O. A. Rahman, and I. Batarseh, "An integrated four-Port DC/DC converter for renewable energy applications," IEEE Trans. Power Electron., vol. 25, no. 7, pp. 1877-1887, July. 2010.

[19] F. Nejabatkhah, S. Danyali, S. Hosseini, M. Sabahi, and S. Niapour, "Modeling and control of a new three-input DC-DC boost converter for hybrid PV/FC/battery power system, " IEEE Trans. Power Electron., vol. 27, no. 5, pp. 2309-2324, Feb. 2014.

[20] Y. M. Chen, C. Cheng, and H. Wu, "Grid-connected hybrid PV / wind power generation system with improved DC bus voltage regulation strategy," in Proc. of Applied Power Electronics Conference and Exposition, (APEC), Texas, pp.1088-1094, Mar. 2006.