FUZZY BASED MULTI RESPONSE OF A GRID CONNECTED WIND-PV-BATTERY FOR HOUSE HOLD APPLICATIONS

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***Abstract*:- The objective of this paper is to provide a control scheme of a power flow management of a grid connected hybrid PV-wind-battery. The hybrid PV-wind-battery system is connected to a multi-input transformer coupled bidirectional dc-dc converter and using a fuzzy controller. The power from the PV along with battery charging/discharging is controlled by a bidirectional buck-boost converter. The power from wind is controlled by a transformer coupled boost half-bridge converter. A single-phase full-bridge bidirectional converter is used for feeding ac loads and interaction with grid. The proposed converter design has lessened number of power transformation stages with less segmentally, and diminished misfortunes contrasted with existing grid-connected hybrid frameworks. In this proposed work analyzing the multi response of a grid connected hybrid PV-wind-battery in different cases. In the proposed system has two renewable power sources, load, grid and battery. Hence, a power flow management system is essential to balance the power flow among all these sources. The main objectives of this system are as follows:**

- **To explore a multi-objective control scheme for optimal charging of the battery using multiple sources.**
- **Supplying un-interruptible power to loads.**
- **Ensuring evacuation of surplus power from renewable sources to the grid, and charging the battery from grid as and when required.**

The performance of the control strategy for power flow management under various modes of operation was examining by using MATLAB® Simulink Software.

Keywords:- Hybrid PV-Wind-Battery, Bidirectional dc-dc converter, Fuzzy controller, Transformer coupled boost half-bridge converter, Bidirectional buck-boost converter.

I. INTRODUCTION

Fast consumption of fossil fuel reserves, regularly expanding energy demand and worries over environmental change persuade control age from renewable energy sources. Solar photovoltaic (PV) and wind have risen as well known energy sources due to their eco-accommodating nature and cost adequacy. Be that as it may, these sources are irregular in nature. Consequently, it is a test to supply steady and nonstop power utilizing these sources. This can be tended to by proficiently coordinating with energy stockpiling components. The intriguing corresponding conduct of solar insolation and wind speed design combined with the previously mentioned points of interest, has prompted the examination on their combination bringing about the hybrid PV-wind systems. This hybrid PV-wind system is connected along with a battery because of intermittent nature of wind and solar. In [1], S. A. Daniel and N. A. Gounden - they have been proposed, Dynamic performance of a stand-alone hybrid PV-wind system with battery storage is analyzed. In integrated converters for PV and wind energy systems are presented. PV-wind hybrid system, proposed by Daniel has a simple power topology but it is suitable for stand-alone applications. In [2], T. Hirose and H. Matsuo - they have been proposed, A unique standalone hybrid power generation system, fed by four power sources: wind power, solar power, storage battery, and diesel engine generator, and which is not connected to a commercial power system. It is anticipated that this hybrid power generation system, into which natural energy is incorporated, will contribute to global environmental protection on isolated islands and in rural locations without any dependence on commercial power systems.

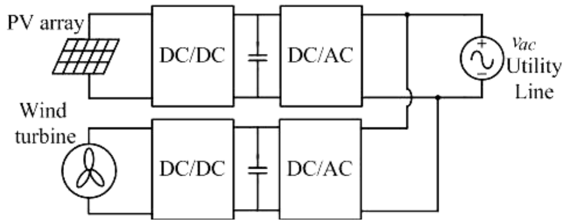
II. EXISTING SYSTEMS

In [9], Y. M. Chen, C. Cheng, - they have been proposed, a grid connected hybrid PV-wind power generation system with improved DC bus voltage regulation strategy. However, despite simple topology the control scheme used is complex. To feed the dc loads, a low capacity multi-port converter for a hybrid system is presented. This system is mainly focused on improving the dc-link voltage regulation. In the six-arm converter topology proposed by H. C. Chiang [3], the outputs of a PV array and wind generators are fed to a boost converter to match the dc-bus voltage. The steady-state performance of a grid connected hybrid PV and wind system with battery storage is analyzed.

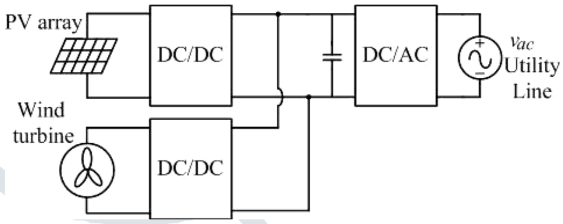
Distinctive circuit topologies for the grid-associated hybrid PV/Wind control system are appeared in Fig. 1. Since the yield voltage of the PV array is not quite the same as the one of the wind turbine and the maximum power point tracking (MPPT) include is demanded, a dc/dc converter and a dc/ac conditioning inverter are required for the PV/Wind control system. Fig. 1(a) demonstrates an ac conditioner shunted grid-associated hybrid PV/Wind control system utilizing two individual dc/dc/ac conditioning converters.

Every last one of them is competent to convey the greatest power created by the PV array or the wind turbine. Be that as it may, due to the reciprocal property of the solar energy and the wind energy, the circuit topology appeared in Fig 1(a) can be diminished as the one appeared in Fig. 1(b) where the two dc/dc converters are shunted at the dc transport. The power rating of the dc/ac conditioning inverter for the dc-shunted grid-associated control system is not as much as the aggregate power appraisals of the two individual dc/ac conditioning inverters.

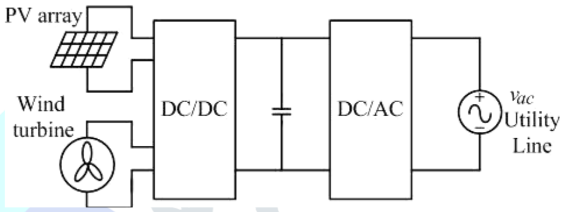
It can lessen the size and the cost of the power system. All things considered, the circuit topology appeared in Fig. 1(b) can be additionally improved as the one appeared in Fig. 1(c), where a multi-input dc/dc converter is utilized to supplant the two individual dc/dc converters.



(a) The ac-shunted grid-connected hybrid PV/Wind power system.



b) The dc-shunted grid-connected hybrid PV/Wind power system.



(c) The multi-input grid-connected hybrid PV/Wind power system.

Fig.1. Different circuit topologies for the grid-connected hybrid PV/Wind power system.

A tri-modular half-connect topology is proposed by Al-A trash et al [7] &[11]. This topology is basically an adjusted variant of the half-connect topology with a free-wheeling circuit branch comprising of a diode and a switch over the essential winding of the transformer. The charging inductance of the transformer is utilized to store vitality, and to interface the sources/stockpiling component.

All the best in class on converter topologies displayed so far can suit just a single inexhaustible source and one vitality stockpiling component. Though, the proposed topology is fit for interfacing two inexhaustible sources and a vitality stockpiling component. However, it is more solid as two distinct sorts of sustainable sources like PV and wind are utilized either separately or all the while without increment in the component count contrasted with the existing cutting edge topologies.

III.PROPOSED SYSTEM

The proposed system is a grid connected PV-wind-battery hybrid system coupled with a multi-input transformer coupled bidirectional dc-dc converter using a fuzzy controller.

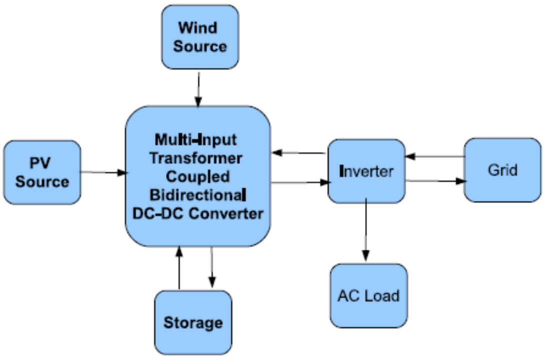


Fig. 2. Grid-connected hybrid PV-wind-battery based system for household applications.

The proposed system contains two power sources, load, grid and battery. However, a power flow management system is basic to adjust the power flow among every one of these sources. The fundamental targets of this system are as per the following:

(i). To investigate a multi-target control plot for optimal charging of the battery utilizing numerous sources.
(ii). Supplying un-interruptible power to loads.
(iii). Ensuring clearing of surplus power from inexhaustible sources to the grid, and charging the battery from grid as and when required.

The Grid-connected hybrid PV-wind-battery based system for family unit applications is appeared in Fig. 1, which can work either in remain solitary or grid connected mode. This system is reasonable for family applications, where an ease, straightforward and conservative topology fit for self-governing task is attractive. The centre of the proposed system is the multi-input transformer coupled bidirectional dc-dc converter that interconnects different power sources and the capacity component. Further, a control conspires for compelling power flow management to give continuous power supply to the loads, while infusing abundance power into the grid is proposed. Consequently, the proposed setup and control plot give a rich integration of PV and wind vitality source. It has the accompanying favourable circumstances:

• MPP following of both the sources, battery charging control and bidirectional power flow are proficient with six controllable switches.

• The voltage boosting ability is proficient by associating PV and battery in arrangement which is additionally improved by a high recurrence venture up transformer.

• Improved use factor of the power converter, since the utilization of devoted converters for guaranteeing MPP task of both the sources is killed.

• Galvanic isolation between input sources and the load.

• The proposed controller can work in various methods of a grid-connected plan guaranteeing legitimate working mode determination and smooth change between various possible working modes.

• Enhancement in the battery charging proficiency as a solitary converter is available in the battery charging way from the PV source.

(A). PROPOSED CONVERTER CONFIGURATION

The proposed converter comprises of a transformer coupled boost double half-bridge bidirectional converter melded with bidirectional buck-boost converter and a solitary stage full-bridge inverter. The proposed converter has lessened number of power transformation stages with less component count and high proficiency contrasted with the existing grid-connected plans. The topology is basic and needs just six power switches. The schematic outline of the converter is delineated in Fig. 3. The boost double half-bridge converter has two dc-connects on the two sides of the high recurrence transformer. Controlling the voltage of one of the dc-links, guarantees controlling the voltage of the other. This makes the control strategy straightforward. Also, extra converters can be coordinated with any of the two dc-links.

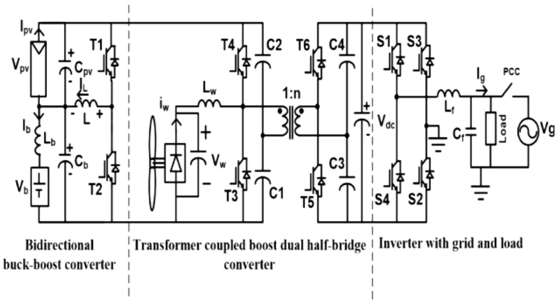


Fig.3. Proposed converter configuration.

A bidirectional buck-boost dc-dc converter is incorporated with the essential side dc-connection and single-stage full-bridge bidirectional converter is connected to the dc-connection of the auxiliary side. The contribution of the half-bridge converter is shaped by associating the PV cluster in arrangement with the battery, in this manner joining an inalienable boosting stage for the plan. The boosting ability is additionally upgraded by a high recurrence venture up transformer. The transformer additionally guarantees galvanic isolation to the load from the sources and the battery. Bidirectional buck-boost converter is utilized to tackle power from PV alongside battery charging/discharging control. The remarkable component of this converter is that MPP following, battery charge control and voltage boosting are refined through a solitary converter. Transformer coupled boost half-bridge converter is utilized for outfitting power from wind and a solitary stage full-bridge bidirectional converter is utilized for encouraging ac conditioning burdens and communication with grid.

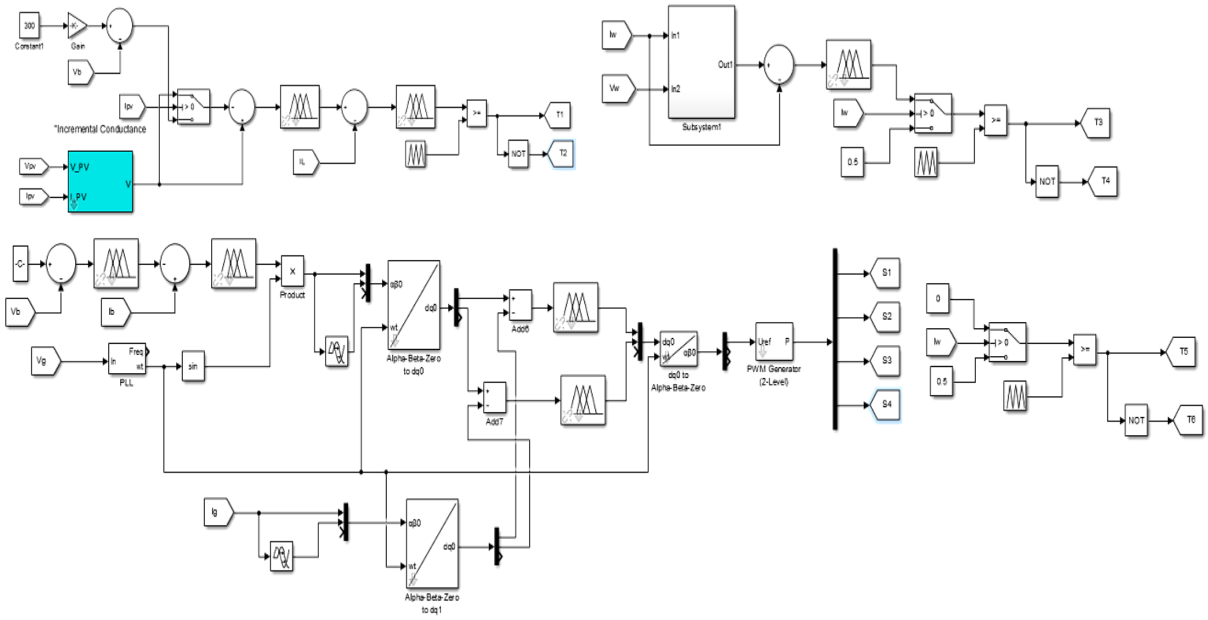


Fig. 4. Proposed control scheme for power flow management of a fuzzy controller based grid-connected hybrid PV-wind-battery system.

The proposed converter has lessened number of power transformation stages with less part check and high productivity contrasted with the existing grid-connected converters. The power flow from wind source is controlled through a unidirectional boost half-bridge converter. For getting MPP viably, smooth variety in source current is required which can be acquired utilizing an inductor. In the proposed topology, an inductor is set in arrangement with the wind source which guarantees continuous current and along these lines this inductor current can be utilized for keeping up MPP current.

(B). PROPOSED CONTROL SCHEME FOR POWER FLOW MANAGEMENT

A grid-connected hybrid PV-wind-battery based system consisting of four power sources (grid, PV, wind source and battery) and three power sinks (grid, battery and load), requires a control scheme for power flow management to balance the power flow among these sources. The control philosophy for power flow management of the multi-source system is developed based on the power balance principle. In the stand-alone case, PV and wind source generate their corresponding MPPT power and load takes the required power. In this case, the power balance is achieved by charging the battery until it reaches its maximum charging current limit I_{bmax}. Upon reaching this limit, to ensure power balance, one of the sources or both have to deviate from their MPP power based on the load demand. In the grid-connected system both the sources always operate at their MPPT. In the absence of both the sources, the power is drawn from the grid to charge the battery as and when required.

IV. SIMULATION RESULTS AND DISCUSSIONS

Simulation of the proposed control scheme were performed by using MATLAB/Simulink under various operating conditions are discussed in this section.

Case (1): Steady state operation in MPPT mode.

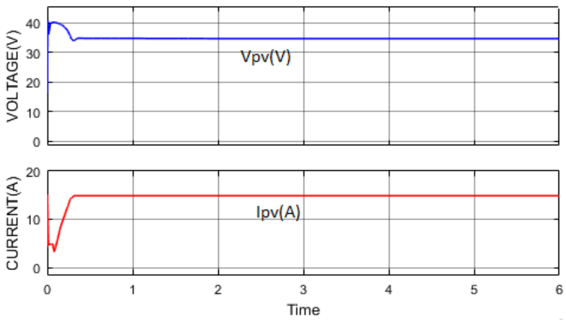


Fig. 5(a). Steady state operation of the source-1 (PV source) in MPPT mode.

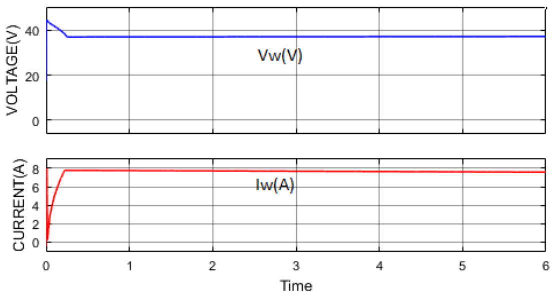


Fig. 5(b). Steady state operation of the source-2 (wind source) in MPPT mode.

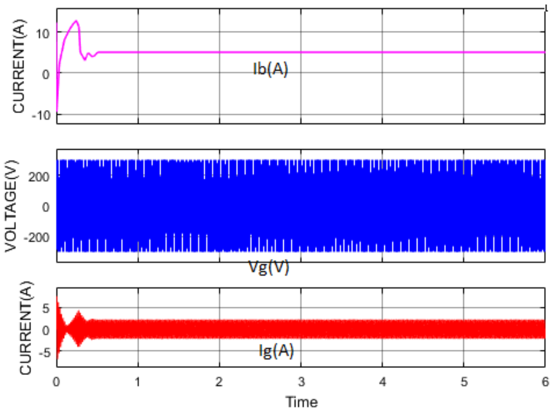


Fig. 5(c). Battery current, Grid voltage & Grid current in steady state operation.

The steady state response of the system during the MPPT mode of operation is shown in Fig. 5(a), Fig. 5(b) & Fig. 5(c). In the steady state response, the source1 (PV source) and source-2 (wind source) are obtained their MPPT values. The battery is charged with the constant magnitude of current and remaining power is fed to the grid.

Case (2): Response of the system for changes in insolation level of source-1 (PV source) during operation in MPPT mode.

The system response for step changes in the source-1 insolation level while operating in MPPT mode is shown in Fig. 6(a), Fig. 6(b) & Fig. 6(c). Until 2sec, both the sources are operating at MPPT and charging the battery with constant current and the remaining power is fed to the grid. At instant 2sec, the source-1 insolation level is increased. As a result the source-1 power increases and both the sources continue to operate at MPPT. Though the source-1 power has increased, the battery is still charged with the same magnitude of current and power balance is achieved by increasing the power supplied to the grid. At instant 4 sec, insolation of source-1 is brought to the same level as before 2sec. The power supplied by source-1 decreases. Battery continues to get charged at the same magnitude of current, and power injected into the grid decreases.

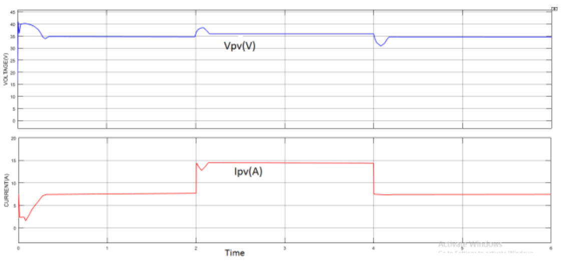


Fig. 6(a). Source-1 (PV source) voltage & current while changes in insolation level of source-1 (PV source) during operation in MPPT mode.

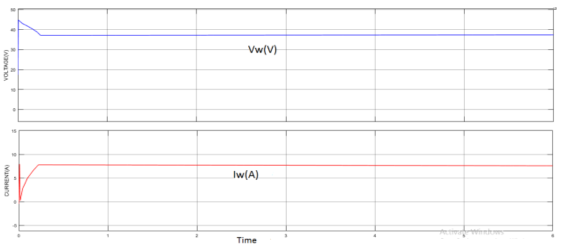


Fig. 6(b). Source-2 (Wind source) voltage & current while changes in insolation level of source-1 (PV source) during operation in MPPT mode.

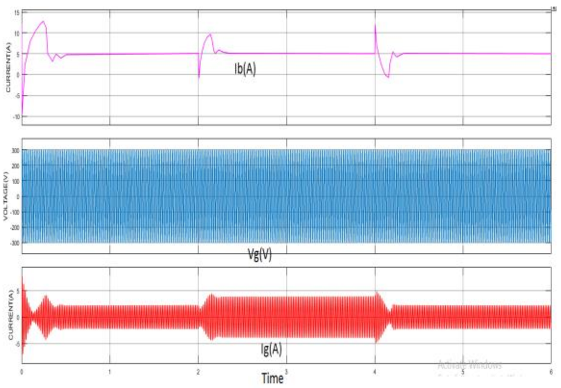


Fig. 6(c). Battery current, Grid voltage & current while changes in insolation level of source-1 (PV source) during operation in MPPT mode.

Case (3): Response of the system for changes in wind speed level of source-2 (wind source) during operation in MPPT mode.

The system response for step changes in the source-2 wind speed level while operating in MPPT mode is shown in Fig 7(a), Fig. 7(b) & Fig. 7(c). Until 2 sec, both the sources are operating at MPPT and charging the battery with constant current and the remaining power is fed to the grid. At instant 2sec, the source-2 wind speed level is increased. As a result the source-2 power increases and both the sources continue to operate at MPPT. Though the source-2 power has increased, the battery is still charged with the same magnitude of current and power balance is achieved by increasing the power supplied to the grid. At instant 4sec, wind speed of source-2 is brought to the same level as before 2sec. As a result the power supplied by source-2 decreases. Battery continues to get charged at the same magnitude of current, and power injected into the grid decreases.

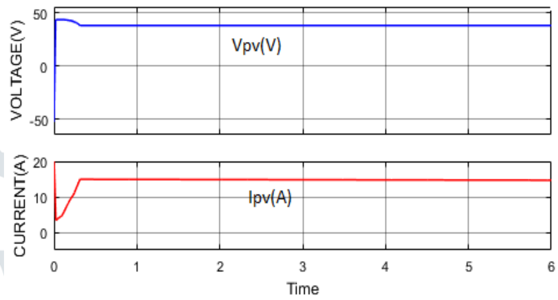


Fig. 7(a). Source-1 (PV source) voltage & current while changes in wind speed level of source-2 (Wind source) during operation in MPPT mode.

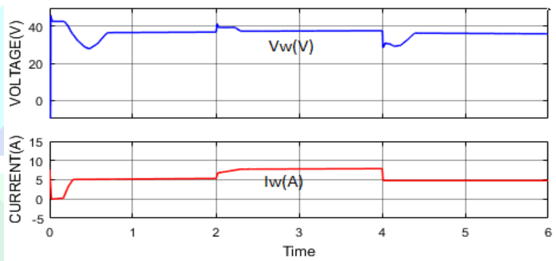


Fig. 7(b). Source-2 (Wind source) voltage & current while changes in wind speed level of source-2 (Wind source) during operation in MPPT mode.

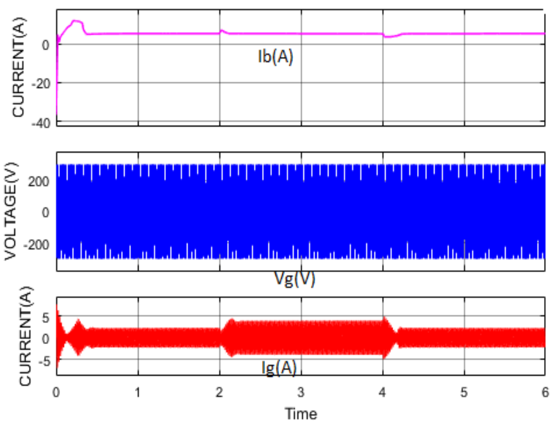


Fig. 7(c). Battery current and grid voltage & current while changes in wind speed level of source-2 (Wind source) during operation in MPPT mode.

Case (4): Response of the system in the absence of source-1 (PV source) while source-2 continues to operate at MPPT.

The response of the system in the absence of source-1 is shown in Fig 8(a), Fig. 8(b) & Fig. 8(c). Till time 2sec, both the sources are generating the power by operating at their corresponding MPPT and charging the battery at constant magnitude of current, and the remaining power is being fed to the grid. At 2sec, source-1 is disconnected from the system. The charging current of the battery remains constant, while the injected power to the grid reduces. At instant 4sec, source-1 is brought back into the system. There is no change in the charging rate of the battery. The additional power is fed to grid.

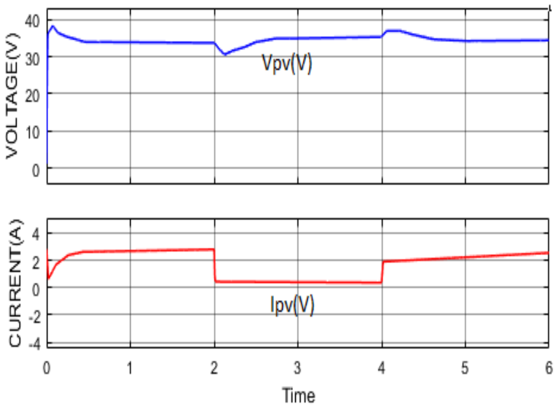


Fig. 8(a). Source-1 (PV source) voltage & current while the absence of source-1.

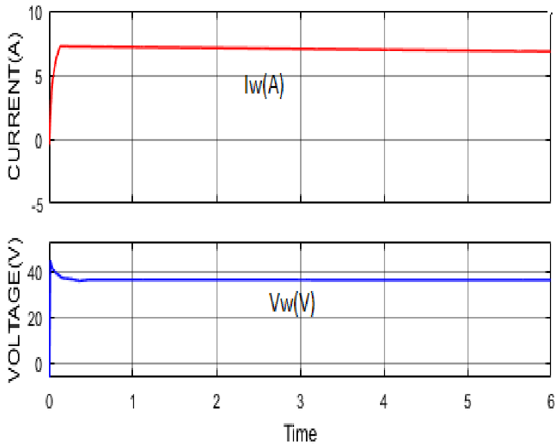


Fig. 8(b). Source-2 (Wind source) current & voltage while the absence of source-1.

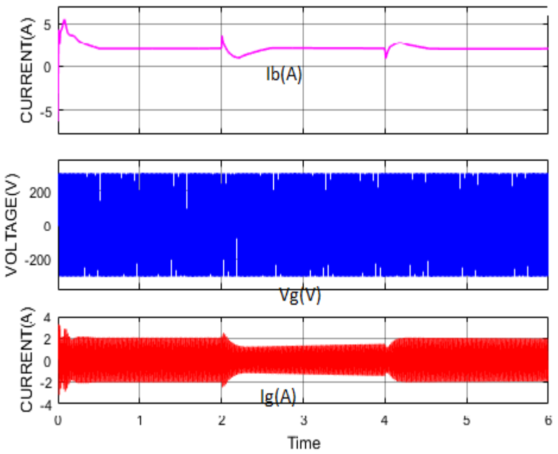


Fig. 8(c). Battery current and grid voltage & current while the absence of source-1.

Case (5): Response of the system in the absence of source-2 (wind source) while source-1 continues to operate at MPPT.

The response of the system in the absence of source-2 is shown in Fig 9(a), Fig. 9(b) & Fig. 9(c). Till time 2sec, both the sources are generating the power by operating at their corresponding MPPT and charging the battery at constant magnitude of current, and the remaining power is being fed to the grid. At 2sec, source-2 is disconnected from the system. The charging current of the battery remains constant, while the injected power to the grid reduces. At instant 4sec, source-2 is brought back into the system. There is no change in the charging rate of the battery. The additional power is fed to grid.

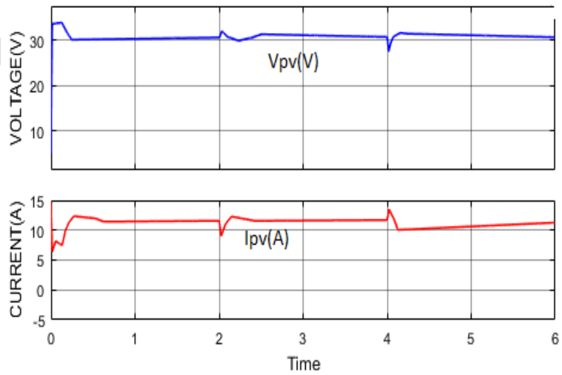


Fig. 9(a). Source-1 (PV source) voltage & current while the absence of source-2.

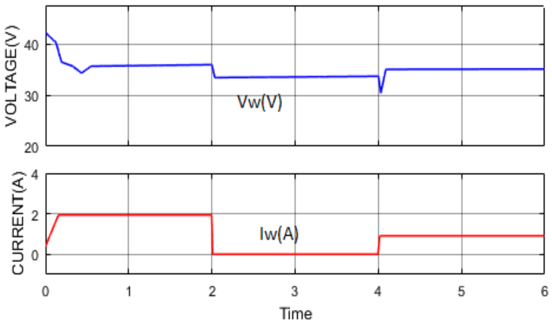


Fig. 9(b). Source-2 (Wind source) voltage & current while the absence of source-2.

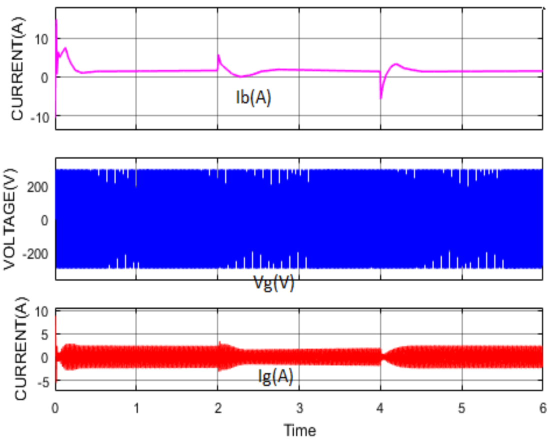


Fig. 9(c). Battery current and grid voltage & current while the absence of source-2.

Case (6): Response of the system in the absence of both the sources and charging the battery from grid.

The response of the system in the absence of both sources is shown in Fig 10(a), Fig. 10(b) & Fig. 10(c). The absence of both PV and wind power, battery is charged from the grid.

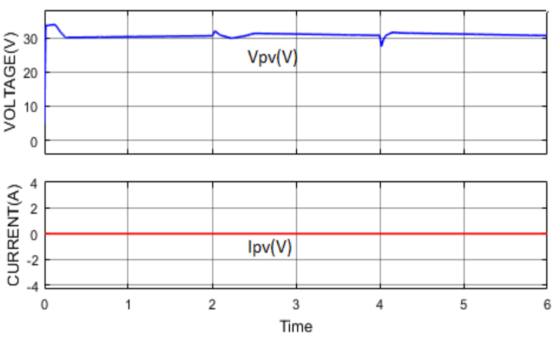


Fig. 10(a). Source-1 (PV source) voltage & current while the absence of both sources.

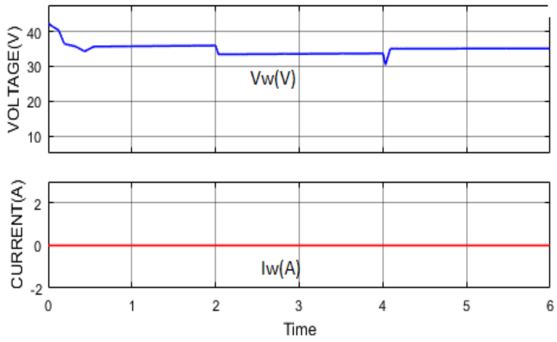


Fig. 10 (b). Source-2 (Wind source) voltage & current while the absence of both sources.

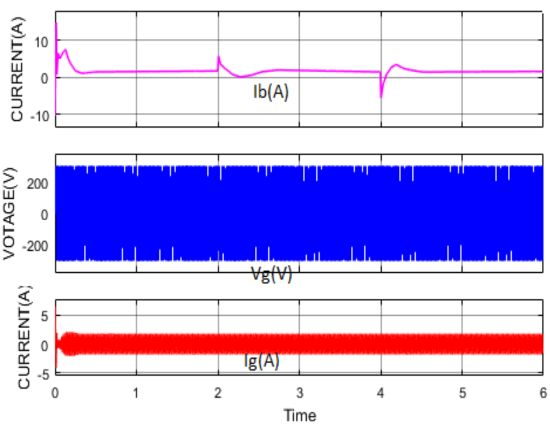


Fig. 10(c). Battery current and grid voltage & current while the absence of both sources.

V. CONCLUSION

A grid-connected hybrid PV-wind-battery based power evacuation scheme for household application is proposed. The proposed hybrid system provides an elegant integration of PV and wind source to extract maximum energy from the two sources. It is realized by a novel multi-input transformer coupled bidirectional dc-dc converter followed by a conventional full-bridge inverter. A versatile control strategy which achieves better utilization of PV, wind power, battery capacities without effecting life of battery and power flow management in a grid-connected hybrid PV-wind-battery based system feeding ac loads is presented. Detailed simulation studies are carried out to ascertain the viability of the scheme. The proposed configuration is capable of supplying un-interruptible power to ac loads, and ensures evacuation of surplus PV and wind power into the grid.

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