Uninterrupted Power Supply to The Society in Variable Resources with High Efficiency

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***Abstract*— In this paper, a control strategy for power flow management of a grid-connected to hybrid PV-wind-battery based system with a high efficiency. PV-wind energy conversion is the fastest-growing source of new electric generation in the society. Due to increase in population, there is a demand in electricity. To overcome this problem we are urge to adopt some variable renewable energy resources for power generation. In addition to this we are having battery back-up to avoid interruption. Here we are increasing the efficiency and reducing ripples and harmonics .The overall control is done by using DSC controller. One single inverter is used to convert AC from wind and solar power. This improves the efficiency and reliability of the system. Simulation results obtained using MATLAB/Simulink show the performance of the proposed control strategy for power flow management under various modes of operation. The effectiveness of the topology and efficiency of the proposed control strategy are validated through detailed experimental studies, to demonstrate the capability of the system operation in different modes.**

Keywords— ***Hybrid system, solar photovoltaic, wind energy, buck-boost converter, battery charge control, DSC controller.***

I. INTRODUCTION

swift attenuation of fossil fuel reserves, ever increasing energy demand and concerns over climate change motivate power generation from renewable energy sources. Solar photovoltaic (PV) and wind have emerged as popular energy sources due to their eco-friendly nature and cost effectiveness. However, these sources are intermittent in nature. Hence, it is a provocation to supply stable and continuous energy using these sources. This can be addressed by efficiently integrating with energy storage elements.

The attention compatible behaviour of solar insolation and wind velocity pattern coupled with the above mentioned advantages, has led to the research on their integration resulting in the hybrid PV-wind systems. For achieving the amalgamation of multiple renewable sources, the traditional approach involves using dedicated single-input converters one for each source, which are connected to a common dc-bus. However, these converters are not effectively utilized, due to the intermittent nature of the renewable sources. In addition, there are multiple power conversion stages which reduce the efficiency of the system.

Significant amount of literature exists on the integration of solar and wind energy as a hybrid energy generation system with focus mainly on its sizing and optimization. In the sizing of generators in a hybrid system is investigated. In this system, the sources and storage are interfaced at the dc link, through their dedicated converters. Other contributions are made on their modeling aspects and control techniques for a stand-alone hybrid energy system. Dynamic performance of a stand-alone hybrid PV-wind system with battery storage is analyzed. In a passivity/sliding mode control is presented which controls the operation of wind energy system to complement the solar energy generating system.

Not many attempts are made to optimize the circuit configuration of these systems that could reduce the cost and increase the efficiency and reliability. In integrated converters for PV and wind energy systems are presented. An integrated four-port topology based on hybrid PV-wind system is proposed in [18]. However, despite simple topology the control scheme used is complex. In to feed the dc loads, a low capacity multi-port converter for a hybrid system is presented.

Hybrid PV-wind based generation of electricity and its interface with the power grid are the important research areas. the proposed a multi-input hybrid PV-wind power generation system which has a buck/buck boost fused multi-input dc-dc converter and a full-bridge dc ac inverter. This system is mainly focused on improving the dc-link voltage regulation. In the six-arm converter topology proposed, 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. This paper focuses on system engineering, such as energy production, system reliability, unit sizing, and cost analysis. In a hybrid PV-wind system along with a battery is presented, in which both sources are connected to a common dc-bus through individual power converters. In addition, the dc-bus is connected to the utility grid through an inverter. when small power or error occurs from inverter, to rectify .it we use DSC between inverter and grid.

The use of multi-input converter (MIC) for hybrid power systems is attracting increasing attention because of reduced component count, enhanced power density, compactness and centralized control. Due to these advantages, many topologies are proposed and they can be classified into three groups, non-isolated, fully-isolated and partially-isolated multi-port topologies.

II. EXSISTING SYSTEM

The converter consists of a transformer coupled boost dual-half-bridge bidirectional converter fused with bidirectional buck-boost converter and a single-phase full-bridge inverter. The converter has reduced number of power conversion stages with less component count and high efficiency compared to the existing grid-connected schemes. The boost dual-half-bridge converter has two dc-links on both sides of the high frequency transformer. A bidirectional buck-boost dc-dc converter is integrated with the primary side dc-link and single-phase full bridge bidirectional converter is connected to the dc-link of the secondary side. Bidirectional buck boost converter is used to harness power from PV along with battery charging/discharging control. 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. With six 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.
- Improved utilization factor of the power converter, since the use of dedicated converters for ensuring MPP operation of both the sources is eliminated.
- Galvanic isolation between input sources and the load.
- 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.

Enhancement in the battery charging efficiency as a single converter is present in the battery charging path.

From the PV source .The topology is simple and needs only six power switches.

To eliminate leakage ground current circulating through pv arrays and ground, several transformer less inverter topologies were proposed. The proposed converter has reduced number of power conversion stages with less component count and high efficiency compared to the existing grid-connected schemes. The topology is simple and needs only six power switches.

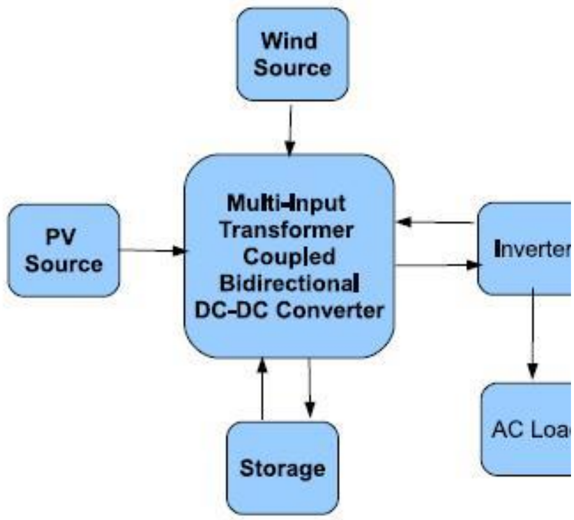

Fig. 1. Grid-connected hybrid PV-wind-battery bas applications.

a battery is presented, in which both sources are connected to a common dc-bus through individual power converters. In addition, the dc-bus is connected to the utility grid through an inverter. 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.in the conventional pv inverter technology ,it has five level inverter have been used. Because of five level inverter it have more number of switches.it has high switching loss and also low effiency.in the application of inverter ,the inverter with five level inversion topology can produce output not as the high step up output voltage and with high number of switches .conventional inverter with more number of switches .The 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.

Draw backs

- Even though they can achieve high efficiency, they require more components than the conventional full-bridge topology.
- To regulate the dc-bus voltage for the grid-connected inverter, the controls, such as robust.
- Heavy step-load change at the dc-bus Side will cause high dc-bus voltage variation and fluctuation, and the system might run abnormally or drop into under or over voltage protection.
- To achieving fast dc-bus voltage dynamics, the systems with load connected to the dc bus have not been studied yet.
- Therefore, to operate the dc-distribution system efficiently while reducing the size of dc-bus capacitors, a droop regulation mechanism according to the inverter current levels is proposed in this study.
- High power losses
- Low efficiency
- High input current ripple

III. PROPOSD SYSTEM

The proposed converter consists of a transformer coupled boost dual-half-bridge bidirectional converter fused with bidirectional buck-boost converter and a single-phase full-bridge inverter. The proposed converter has reduced number of power conversion stages with less component count and high efficiency compared to the existing grid-connected schemes. The topology is simple and needs only four power switches. The schematic diagram of the converter is depicted. The boost dual-half-bridge converter has two dc-links on both sides of the high frequency transformer. Controlling the voltage of one of the dc-links, ensures controlling the voltage of the other. This makes the control strategy simple. Moreover, additional converters can be integrated with any one of the two dc-links. A bidirectional buck-boost dc-dc converter is integrated with the primary side dc-link and single-phase full- bridge bidirectional converter is connected to the dc-link of the secondary side.

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 along with battery charging/discharging control. The unique feature of this converter is that MPP (Maximum Power Point) tracking, battery charge control and voltage boosting are accomplished through a single converter. Transformer coupled boost half-bridge converter is used for harnessing power from wind and a single-phase full-bridge bidirectional converter is used for feeding ac loads and interaction with grid. The proposed converter has reduced number of power conversion stages with less component count and high efficiency compared to the existing grid-connected converters.

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 bank discharges through the transformer primary and switch T3. In secondary side capacitor bank charges through transformer secondary and anti-parallel diode of switch Thyrister . When switch T 3 is turned OFF and T 4 is turned ON, initially the inductor current flows through anti-parallel diode of switch T 4 and through the capacitor bank. The path of current is shown in Fig.3. During this interval, the current flowing through diode decreases and that flowing through transformer primary increases. When current flowing through the inductor becomes equal to that flowing throughtransformer primary, the diode turns OFF. Since, T 4 is gatedON during this time, the capacitor C2 now discharges throughswitch T 4 and transformer primary. During the ON time ofT 4, anti-parallel diode of switch T 6 conducts to charge thecapacitor C4. The path of current flow is shown in Fig. 5.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 capacitorvoltages are considered constant in steady state and they settleat $VC3 = nVC1$, $VC4 = nVC2$.

Hence the output voltage isgiven by Vdc $= VC3 + VC4 = nVw/(1 - Dw)$(1)

Therefore, the output voltage of the secondary side dc-link isa function of the duty cycle of the primary side converter andturns ratio of transformer.

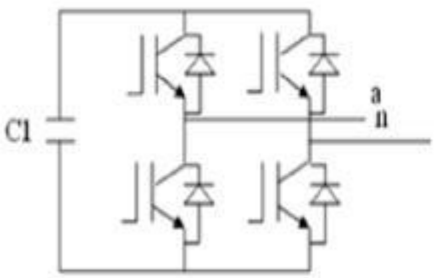

Fig 2. Full bridge inverter

Operating condition

i. Proposed converter configuration.
ii. Operation when switch T3 is turned ON.
iii. Operation when switch T4 ON, charging the capacitor bank.
iv. Operation when switch T4 ON, capacitor bank discharging.

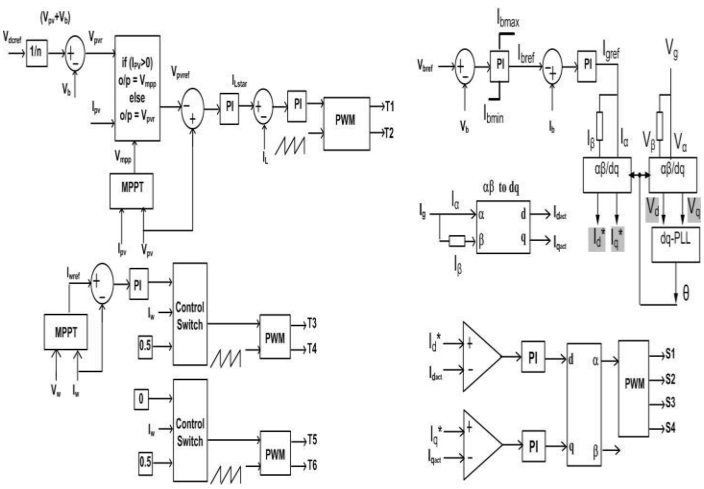

Fig. 3. Proposed control scheme for power flow management of a grid-connected hybrid PV-wind-battery based system.

Here, the stored energy in the inductor increases when T 2 isturned on and decreases when T 1 is turned on. It can be provedthat $Vb=(D/1-D)Vpv$.

The output voltage of the transformercoupled boost half-bridge converter is given by,

$Vdc = n(VC1 + VC2) = n(Vb + Vpv) = nVw/(1 - Dw)$(2)

This voltage is n times of primary side dc-link voltage. Theprimary side dc-link voltage can be controlled by half-bridgeboost converter or by bidirectional buck-boost converter. Therelationship between the average value of inductor, PV andbattery current over a switching cycle is given by $IL = Ib + Ipv$.It is evident that, Ib and Ipv can be controlled by controllingIL. Therefore, the MPP operation is assured by controlling IL,while maintaining proper battery charge level. IL is used asinner loop control parameter for faster dynamic response whilefor outer loop, capacitor voltage across PV source is used forensuring MPP voltage. An incremental conductance method isused for MPPT.

A. Limitations and Design issues

The output voltage Vdc of transformer coupled boost dualhalf-bridge converter, depends on MPP voltage of PV array VP V mpp, the battery voltage Vb and the transformer turnsratio n. Since the environmental conditions influence PV arrayvoltage and the battery voltage depends on its charge level,the output dc-link voltage Vdc is also influenced by the same.

However, the PV array voltage exhibits narrow variation involtage range with wide variation in environmental conditions.On the other hand, the battery voltage is generally stiff and itremains within a limited range over its entire charge-dischargecycle. Further, the SOC limits the operating range of thebatteries used in a stand-alone scheme to avoid overchargeor discharge. Therefore, with proper selection of n, PV arrayand battery voltage the output dc-link voltage Vdc can be kept within an allowable range, though not controllable. However,when there is no PV power, by controlling the PV capacitorvoltage the output dc-link voltage Vdc can be controlled.

IV. 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), requiresa control scheme for power flow management to balance thepower flow among these sources.

The control philosophy for power flow management of themulti-source system is developed based on the power balanceprinciple. In the stand-alone case, PV and wind source generatetheir corresponding MPP power and load takes the requiredpower. In this case, the power balance is achieved by chargingthe battery until it reaches its maximum charging current limit Ibmax. Upon reaching this limit, to ensure power balance, oneof the sources or both have to deviate from their MPP powerbased on the load demand. In the grid-connected system boththe sources always operate at their MPP. In the absence ofboth the sources, the power is drawn from the grid to chargethe battery as and when required. The equation for the powerbalance of the system is given by:

$$V_{pv}I_{pv}+V_wI_w=V_bI_b+V_gI_g \quad (3)$$

The peak value of the output voltage for a single-phase full-bridge inverter is,

$\hat{V}=m_aV_{dc}$ (4) and the dc-link voltage is,

$$V_{dc} = n(V_{pv} + V_b) \quad (5)$$

Hence, by substituting for Vdc in (4), gives,

$$V_g =(1/\sqrt{2})(m_a n(V_{pv} + V_b)) \quad (6)$$

In the boost half-bridge converter,

$V_w = (1 - D_w)(V_{pv} + V_b)$ (7) Now substituting Vw and Vg in (3),

$$V_{pv}I_{pv}+(V_{pv}+V_b)(1-D_w)I_w=V_bI_b+(1/\sqrt{2})m_a n(V_{pv}+V_b)I_g \quad (8)$$

After simplification,

$$I_b=I_{pv}((1-D_{pv})/D_{pv})+I_w((1-D_w)/D_{pv})-I_g((m_a n)/(\sqrt{2}D_{pv})) \quad (9)$$

From the above equation it is evident that, if there is a changein power extracted from either PV or wind source, the batterycurrent can be regulated by controlling the grid current Ig.Hence, the control of a single-phase full-bridge bidirectionalconverter depends on availability of grid, power from PV andwind sources and battery charge status. To ensure the supply of uninterruptedpower to critical loads, priority is given to charge the batteries.After reaching the maximum battery charging current limitIbmax, the surplus power from renewable sources is fed tothe grid. In the absence of these sources, battery is chargedfrom the grid.

V. SIMULATION RESULTS AND DISCUSSION

Detailed simulation studies are carried out on MATLAB/Simulink platform and the results obtained for various operating conditions are presented in this section. Values of parameters used in the model for simulation are listed in Table I.The steady state response of the system during the MPPT mode of operation is shown in Fig. 4. The values for source-1 (PV source) is set at 35.4 V (Vmpp) and 14.8 A (Imppp), and for source-2 (wind source) is set at 37.5 V (Vmpp) and 8 A (Imppp). It can be seen that Vpv and Ipv of source-1, and Vw and Iw of source-2 attain set values required for MPP operation. The battery is charged with the constant magnitude of current and remaining power is fed to the grid. The system response for step changes in the source-1 insolation level while operating in MPPT mode is shown in Fig. 5. Until 2 s, 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 2 s, 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 s, insolation of source-1 is brought to the same level as before 2 s. 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. The same results are obtained for step changes in source-2 wind speed level. These results

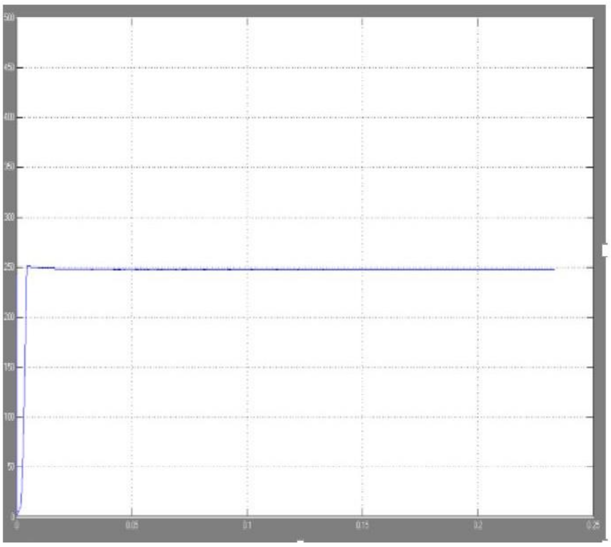

Fig. 4. Steady state operation for solar panel voltage

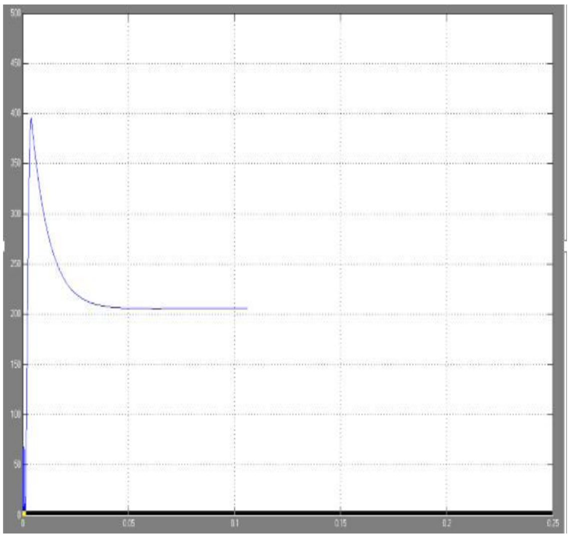

Fig 5.Steady state operation for solar panel current

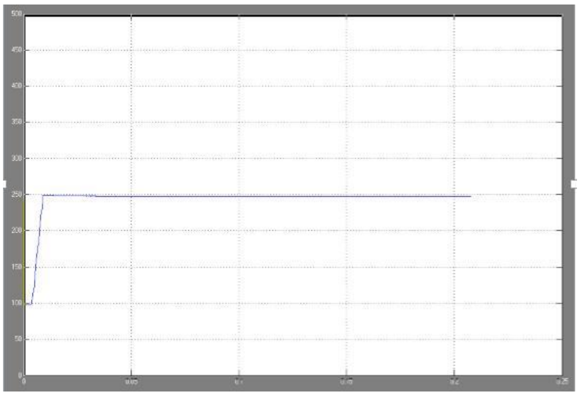

Fig 6 Steady state operation of wind energy voltage

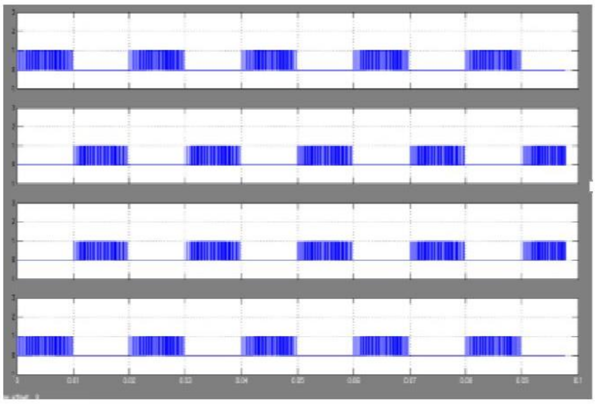

Fig. 7. Response of the system for changes in insolation level of applied gate pulse of inverter

The response of the system in the absence of source isshown in Fig. 7. Till time 2 s, 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 2 s, 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 4 s, 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. The same results are obtained in the absence of source-2. These results are shown in Fig. 8. Fig. 9 shows the results in the absence of both PV t]

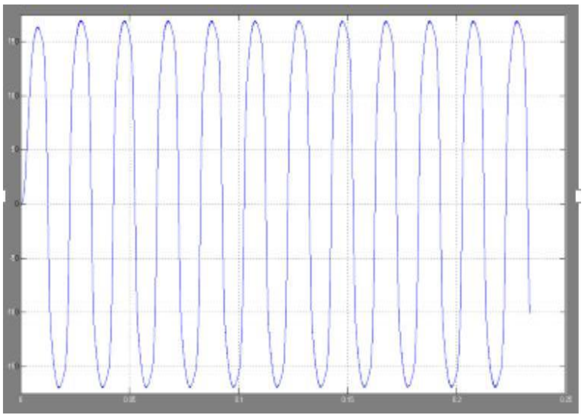

Fig. 8. Response of the system for changes in insolation level of source (PV source) during operation

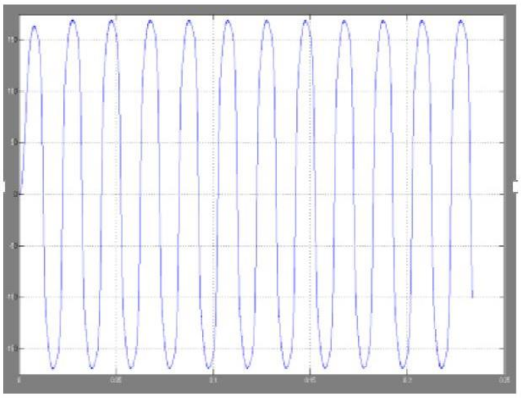

Fig. 9. Response of the system for changes in wind speed level (wind source) during operation
and wind power, battery is charged from the grid.

VI. EXPERIMENTAL VALIDATION

The control strategy is implemented by employing DSC(Digital Signal Controller) with ANN(Artificial Neural Network) feedback controller.

A. Design of multi-input transformer coupled dc-dc converter

The MPP voltage of the PV is considered as 36 V (Vmpp).The nominal voltage level of the battery is chosen as 36 V (Vb). The voltage across the dc-bus at the primary side of the transformer is (V c1 + V c2) which is equal to (Vpv+Vb). It implies that this dc-bus voltage depends on the magnitude of Vpv and Vb. An overall variation of ± 10 V on (Vpv+Vb) is considered for design purpose and thus overall variation in this dc-bus is in the range of 62-82 V.

The dc-bus voltage at the transformer secondary side, Vdc is

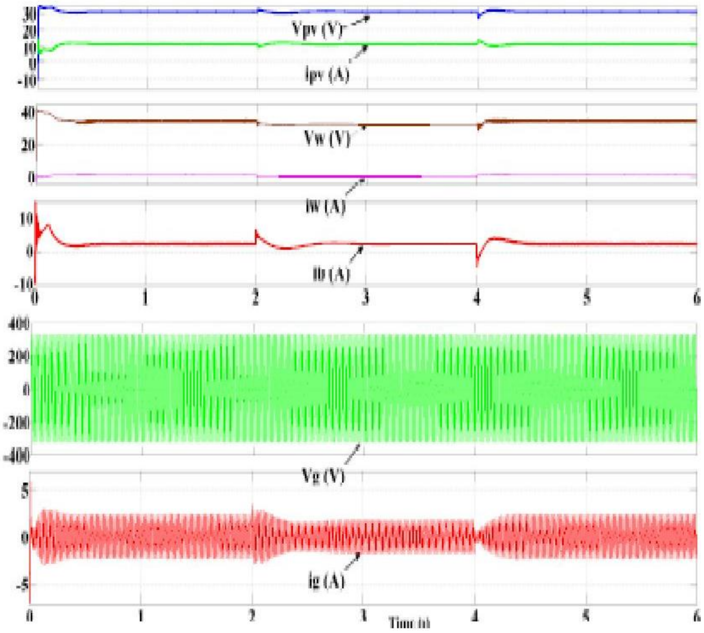

Fig. 10. Response of the system in the wind source (wind source) while continues to operating mode

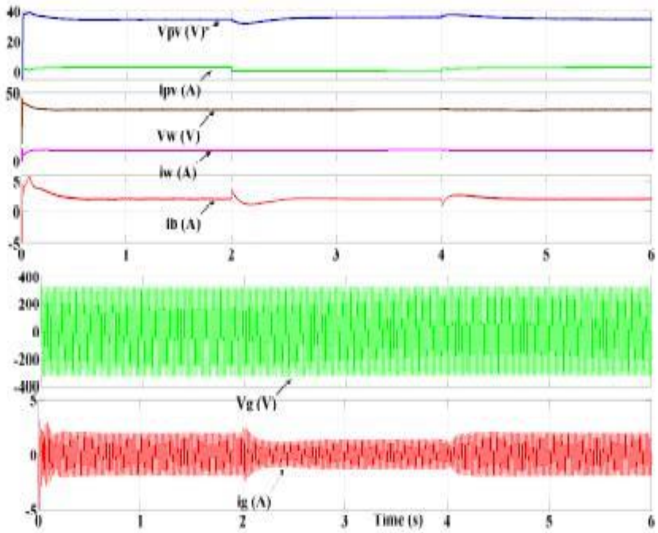

Fig 11.Response of the system in the solar source (solar PV pannel)
while continues to operating mode

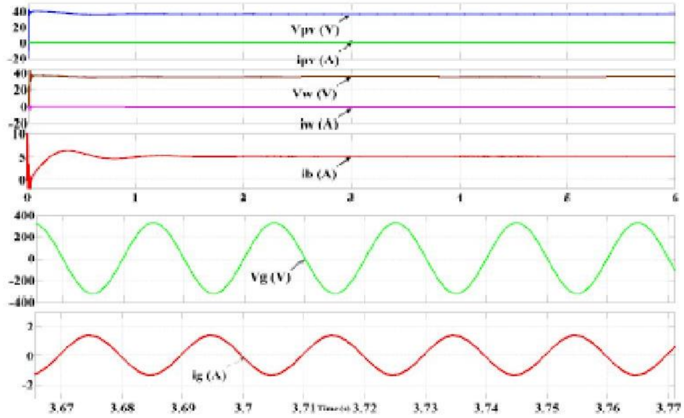

Fig. 12. Response of the system in the absence of both the sources and
charging the battery from grid.

required to be maintained at 350 V. Since, the dc-link voltage at secondary side is _n times the dc-link voltage at primary side,_n turns out to be

5.65 (=350/62). Now, considering voltage drops at transformer primary and secondary sides, the turnsratio is chosen to be 6. During ON/OFF operation of switches T3 and T4 (Fig.2), each of the capacitors, C1 and C2, appear across the transformer primary winding. Considering the range of variation of voltage of the wind source as 36-44 V, the capacitors C1 and C2 will experience a voltage in the range of 18-46 V (calculation is given below). Therefore, by keeping a small safety factor, the transformer primary voltage is chosenas 50 V. Thus, the secondary voltage rating is chosen as, 6 × 50 V = 300 V. The transformer chosen has a capacity of 1
kVA.

The relationship between Vw and Vbus is,

$$V_{bus} = V_w(1-D),$$

where D is duty ratio of switch T3.

$$D = 1 - (V_w / V_{bus}) = 0.46. \qquad (10)$$

In steady state,

$$D V_{c1} - (1 - D) V_{c2} = 0,$$

(11) and $V_{c1} + V_{c2} = V_{bus}$.

The steady state response of the system during the continuous operation mode is shown in Fig. 11. The values for solar source (PV source) and wind energy (wind source), are set at 40 V (Vmpp) and 5 A (Imppp) respectively and both the sources attain the set value required for MPP operation. The battery is charged at a constant magnitude of current and remaining power is fed to the grid. The system response for step changes in the source-1 insolation level while the continuous operating mode is shown in Fig. 12. Until time t1, both the sources are operating at MPPT, battery is charged at a constant current and the remaining power is fed to the grid. At time t1, source-1 insolation level is increased. As a result the solar source power increases. Both

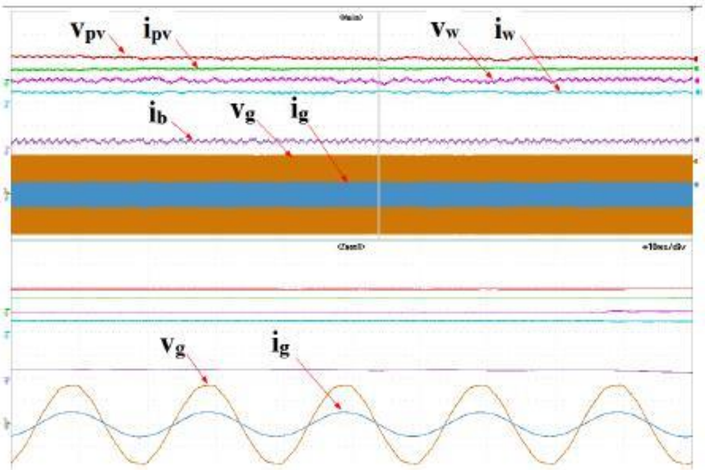

Fig. 13. Steady state operation in operating mode . Zoomed version of vg &ig during steady state operation.

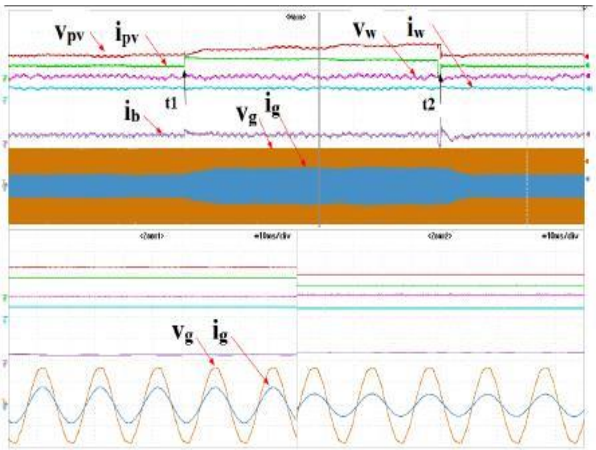

Fig. 14. Response of the system for changes in insolation level of source (PV source) during operating mod. Zoomed version of vg &ig during step change in insolation.

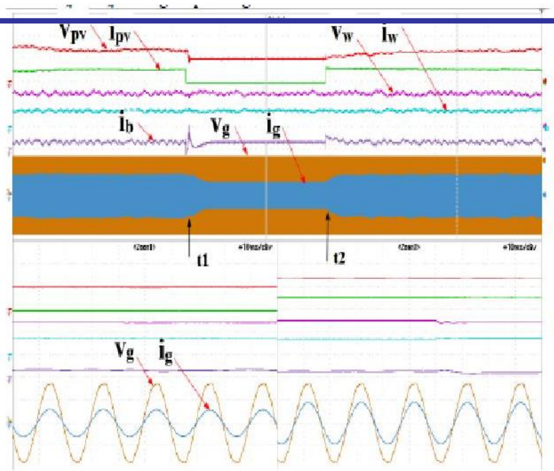

Fig. 15. Response of the system in the solar source (PV source)while while the continues operating mode

Fig. 16. Response of the system for changes in wind speed level ofsource(wind source) during operation mode . Zoomed version of vg &ig during step change in insolation.

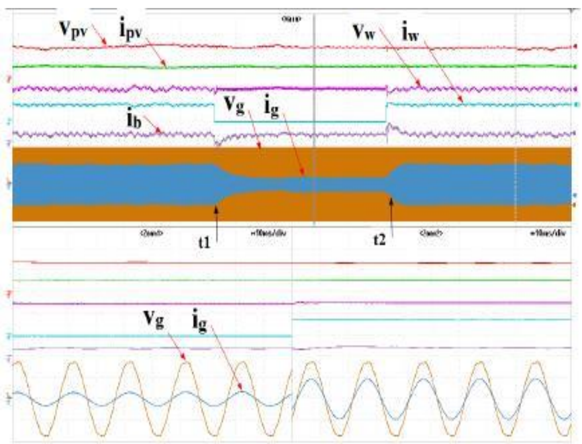

Fig. 17. Response of the system in the wind energy (wind source)while the continues to operating condition

the sources continue to operated. Though the solar source power has increased, the battery is still charged at the same magnitude of current. The additional power is fed to the grid. At time t2, solar source is brought to the same insolation level as before t1. The power generated by the solar source decreases, and there is no change in charging current of the battery. The power injected to the grid decreases. The same results are obtained for step changes in (wind energy) source wind speed level.

The response of the system without source solar is shown in Fig. 11. Till time t1, both the sources are present in the system, operating at their corresponding MPP and charging the battery at constant magnitude of current. The remaining power is fed to the grid. At time t1, source-1 is disconnected from the system. However, the battery continues to get charged at the same rate,and the power injected into the grid reduces. At time t2, wind source is brought back into the system. This additional power is injected into the grid. The same results are obtained in the continuous operation of wind source. These results are shown in Fig. 10.

Fig.18. Response of the system during changes of the operatingmode from grid-connected without injection to grid-connected with injection (vpv=10V/div; ipv=1A/div; vw=10V/div; iw=1A/div; vg=200V/div; ig=2A/div; ib=2A/div). Zoomed version of vg &ig during mode transition.

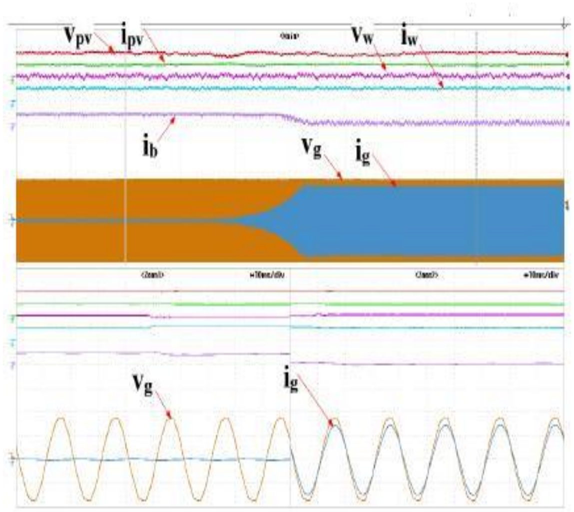

Fig. 18 shows that when the battery reaches its float voltage Vbref ,

Iit goes to constant voltage mode. The surplus power from the renewable sources is fed to the grid. It is clear that before the battery reaches its float voltage the current injected into grid is zero, and it increases thereafter.

VII. CONCLUSION

A grid-connected hybrid PV-wind-battery based power evacuationscheme 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 feedingac loads is presented. Detailed simulation studies are carried out to ascertain the viability of the scheme. The experimental results obtained are in close agreement with simulations and are supportive in demonstrating the capability of the system to operate either in grid feeding or stand-alone mode. 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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