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Implementation of Bidirectional DC-DC converter for Power Management in Hybrid Energy Sources

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Abstract:
The proposed system aims to satisfy the load demand, manage the power flow from different sources, inject surplus power into the grid and charge the battery from grid as and when required. 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. The control philosophy for power flow management of the multisource system is developed based on the power balance principle. Bidirectional buck-boost converter is used to harness power from PV along with battery charging/discharging control. Simulation results obtained using MATLAB/Simulink show the performance of the proposed control strategy for power flow management under various modes of operation.

I. INTRODUCTION:

In this project, a control strategy for power flow management of a grid-connected hybrid PV-wind-battery based system with an efficient multi-input transformer coupled bidirectional dc-dc converter is presented. The proposed system aims to satisfy the load demand, manage the power flow from different sources, inject surplus power into the grid and charge the battery from grid as and when required [1-3]. A transformer coupled boost half-bridge converter is used to harness power from wind, while bidirectional buck-boost converter is used to harness power from PV along with battery charging/discharging control. A single-phase full-bridge bidirectional converter is used for feeding ac loads and interaction with grid.

The proposed converter architecture has reduced number of power conversion stages with less component count, and reduced losses compared to existing grid-connected hybrid systems. 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 efficacy of the proposed control strategy are validated through detailed experimental studies, to demonstrate the capability of the system operation in different modes. 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.

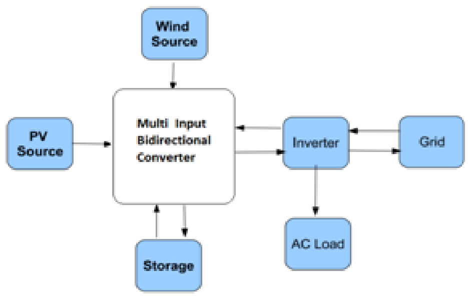

Fig. 1: Grid-connected hybrid PV-wind-battery based system

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

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topologies. All the power ports in non-isolated multi-port topologies share a common ground. To derive the multi-port dc-dc converters, a series or parallel configuration is employed in the input side. Some components can be shared by each input port. However, a time-sharing control scheme couples each input port, and the flexibility of the energy delivery is limited. The series or parallel configuration can be extended at the output to derive multi-port dc-dc converters. However, the power components cannot be shared. All the topologies in non-isolated multi-port are mostly combinations of basic topology units, such as the buck, the boost, the buck-boost or the bidirectional buck/boost topology unit. These timesharing based multi-port topologies promise low-cost and easy implementation. However, a common limitation is that power from multiple inputs cannot be transferred simultaneously to the load. Further, matching wide voltage ranges will be difficult in these circuits. This made the researchers to prefer isolated multi-port converters compared to non-isolated multi-port dc-dc converters.

II. CONTROL STRATEGY:

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 multisource system is developed based on the power balance principle. In the stand-alone case, PV and wind source generate their corresponding MPP 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 MPP. In the absence of both the sources, the power is drawn from the grid to charge the battery as and when required.

The equation for the power balance of the system is given by

$$V_{pv}I_{pv} + V_wI_w = V_bI_b + V_g I_g$$

The peak value of the output voltage for a three-phasebridge inverter is

$$v = m_aV_{dc}$$

and the dc-link voltage is

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

In the boost half-bridge converter

$$V_w = (1 - D_w)(V_{pv} + V_b)$$

Hence, the control of a single-phase full-bridge bidirectional converter depends on the availability of grid, power from PV and wind sources, and battery charge status. Its control strategy is shown in Fig. 3. To ensure the supply of uninterrupted power to critical loads, priority is given to charge the batteries. After reaching the maximum battery charging current limit Ib max, the surplus power from renewable sources is fed to the grid. In the absence of these sources, battery is charged from the grid.

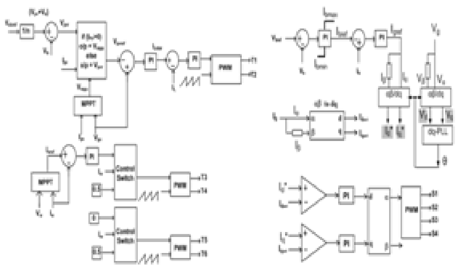

Fig 2: Proposed control scheme for power flow management of a grid-connected hybrid PV–wind-battery-based system.

III. SIMULATION RESULTS

Detailed simulation studies are carried out on the MATLAB/Simulink platform, and the results obtained for various operating conditions are presented in this section.

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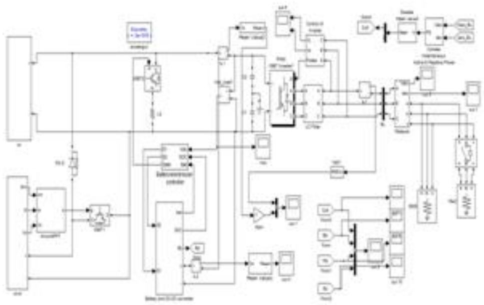

Fig 3: simulation circuit of proposed system

The simulation results of the proposed system are described below. The wind energy conversion system is designed based on permanent magnetic synchronous generator with variable wind speed with respect to time. The photovoltaic system is designed with dynamic analysis and also irradiance is various with time vary. Maximum power point tracking control strategy is employed to DC voltage of rectifier connected to PMSG of WECS to extract maximum power. Charge controller is used across the battery bidirectional converter to control the discharging and charging of battery based load variation and output power of WECS and PV array. LC filter is connected in between the output terminal of inverter and input and load terminals. Simulation graph of load power under dynamic performance of WECS and PV is shown in Fig 4. As per the wave from the varied the load is varied at 4 sec and it is getting settled at 4.5 sec.

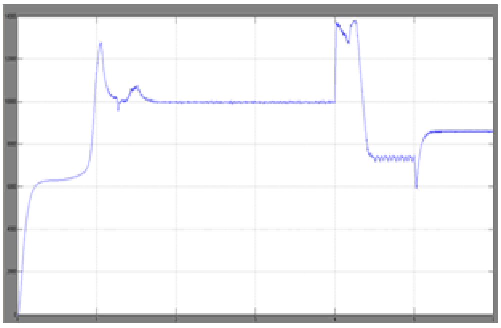

Fig 4: Load power under dynamic performance of wind and PV

The battery power simulation wave form is shown in fig 5. It can be clearly seen that the battery power is getting fluctuating from 1 s to 4 sec. and it is raised at 4 sec.

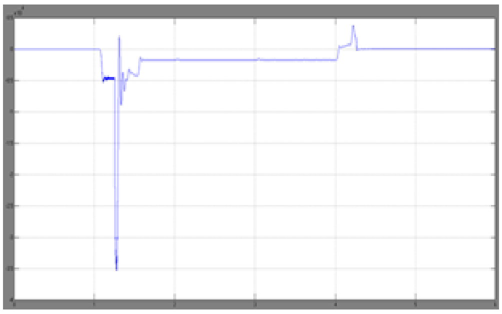

Fig 5: Battery power

The active power of generated by wind energy conversion system is shown in figure 6. Power rating is increased from 0.5 sec due to increase in wind speed and it is reached to peak at 1 sec because of maximum wind speed and it can be clearly understand that there is disturbance in the power rating between 4-5 sec, due to load variation.

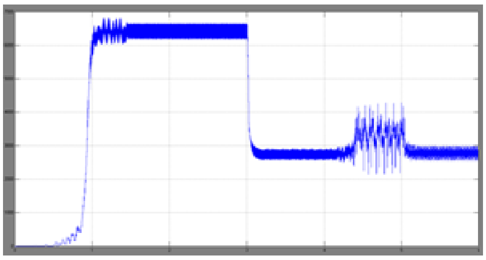

Fig 6: Active power generated by WECS

The variation in the Photovoltaic power in DC is observed in the following figure 7, and the variation in power value is depends on the WECS wind speed and load rating.

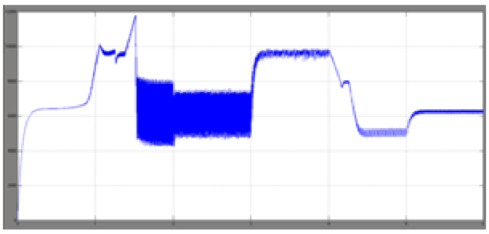

Fig 7: DC power by PV array

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The inverter input and output currents are shown in figure 8. The variation in the currents are depends on the power rating on either side of the inverter nothing but load power variation and sources operating conditions depends upon the input wind speeds and irradiance of the sunlight

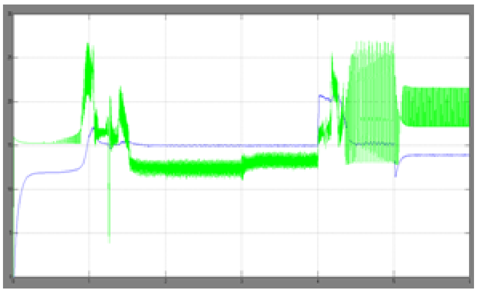

Fig 8: Three-phase inverter input and output currents

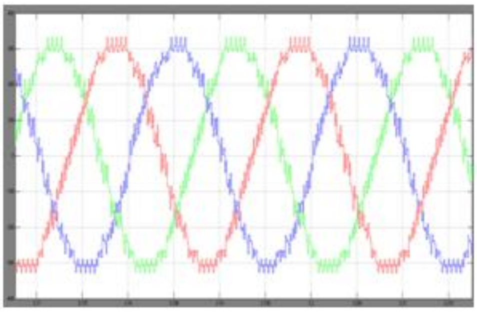

Fig 9: Output voltage of inverter

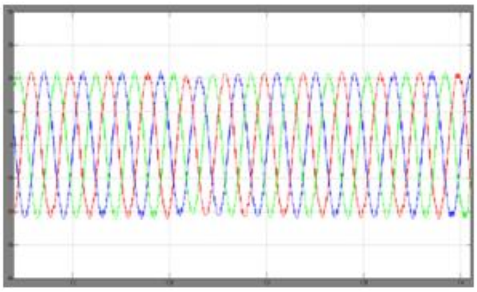

Fig 10: Output current of inverter

IV. CONCLUSION:

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.

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