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A Novel Hybrid PV/Wind/Battery based Generation System for Grid Integration



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Abstract:

A hybrid wind/PV system for supplying an isolated small community electrical with energy simulated and presented in this paper. a digitally control strategy for power flow management of a grid-connected hybrid photovoltaic (PV)-windbattery-based system with an efficient multi-input bidirectional dc-dc converter is presented. A converter is used to harness power from wind, while a bidirectional buck-boost converter is used to harness power from PV along with battery charging/discharging control. The proposed converter architecture has reduced number of power conversion stages with less component count and reduced losses compared with existing grid-connected hybrid systems. This improves the efficiency and the reliability of the system. The proposed controllers are coordinated dynamic error driven PI regulators to control the interface converters.

I. INTRODUCTION:

In remote isolated areas and arid communities such as small islands, diesel generator sets and micro gas turbines are usually the main source of power supply. Fossil fuel for electricity generation has several drawbacks: it is costly due to transportation to the remote areas and it causes global warming pollution and greenhouse gases. The need to provide an economical, viable and environmental safe alternative renewable green energy source is very important. As green renewable energy resources such as wind Photovoltaic (PV) and have gained great acceptance as a substitute for conventional costly and scare fossil fuel energy resources. Stand-alone renewable green energy is already in operation at many places despite solar and wind variations and stochastic nature. Isolated green energy hybrid operation may not be effective or viable in terms of the cost; efficiency and supply reliability unless an effective and robust stabilization of AC-DC interface scheme and maximum energy tracking control strategies are fully implemented. An effective approach is to ensure renewable energy diversity and effective utilization by combining these different renewable energy sources to form a coordinated and hybrid integrated energy system. Hybrid green energy system is a valid alternative solution for small scale micro-grid electrification for remote rural and isolated village/island where the utility extension is both grid costly and geographically difficult. Hybrid renewable green energy system incorporates a combination of several diverse renewable energy sources such as photovoltaic, wind energy and possibly wave and fuel cell sources. A system using such diverse combination has the full advantage of supply diversity, capacity and system stability that may offer the strengths of each type that complement others. The main objective of hybrid green energy scheme is to provide supply security for remote communities.

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Hybrid integrated green energy systems are also pollution free, and can provide electricity at comparatively viable and economic advantages to grid or diesel generator set utilized in micro village/island electricity. Hybrid PV-wind-based generation of electricity and its interface with the power grid are the important research areas. A multiinput hybrid PV-wind power generation system which has a buck/buck-boost-fused multi-input dcdc converter and a full-bridge dc-ac inverter. This paper focuses on system engineering, such as energy production, system reliability, unit sizing, and cost analysis. 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. The use of multiinput converter 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 pro-posed, and they can be classified into three groups, namely, non-isolated, fully isolated, and partially isolated multiporttopologies.

II. PROPOSED CONVERTER CONFIGURATION

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.

1) To explore a multi-objective control scheme for optimal charging of the battery using multiple sources.

2) Supplying uninterruptible power to loads.

3) Ensuring the evacuation of surplus power from the renewable sources to the grid, and charging the battery from the grid as and when required.



Fig 1: Grid-connected hybrid PV–wind-batterybased system

The grid-connected hybrid PV-wind-battery-based system for household applications is shown in Fig. 1, which can work either in stand-alone or in gridconnected modes. This system is suitable for household applications, where a low cost, simple and compact topology capable of autonomous operation is desirable. The core of the proposed system is the multi-input transformer-coupled bidirectional dc-dc converter that interconnects various power sources and the storage element. Furthermore, 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. Thus, the proposed configuration and control scheme provide an elegant integration of PV and wind energy source. It has the following advantages.

1) The maximum power point (MPP) tracking of both the sources, battery charging control, and bidirectional power flow is accomplished with controllable switches.

2) The voltage boosting capability is accomplished by connecting PV and battery in series.

3) The improved utilization factor of the power converter, since the use of dedicated converters for ensuring MPP operation of both the sources is eliminated.



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4) 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.

5) Enhancement in the battery charging efficiency as a single converter is present in the battery-charging path from the PV source.

The proposed converter consists of a bidirectional converter fused with a bidirectional buck-boost converter and a three-phase bridge inverter. The proposed converter has reduced number of power conversion stages with less component count and high efficiency compared with the existing grid-connected schemes. The boost converter has two dc-links on both the 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 a 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 transformer also ensures galvanic isolation to the load from the sources and the battery. A 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 tracking, battery charge control, and voltage boosting are accomplished through a single converter. A 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 the grid.

The proposed converter has reduced number of power conversion stages with less component count and high efficiency compared with the existing grid-connected converters. The power flow from wind source is controlled through aunidirectional 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.

III. 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 standalone 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

VpvIpv + VwIw = VbIb + Vg Ig

The peak value of the output voltage for a threephasebridge inverter is

 $v = m_a V dc$ and the dc-link voltage is V dc = n(V pv + Vb)

In the boost half-bridge converter

Vw = (1 - Dw)(Vpv + Vb)



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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–windbattery-based system.

IV. SIMULATION RESULTS:

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



Fig3: simulation circuit of proposed system



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



Fig 5: Battery power



Fig 6: Active generated by WECS



Fig 7: DC power by PV array



Fig 8: Three-inverter input and output currents



Fig 9: Output voltage of inverter

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V. CONCLUSION:

A novel hybrid PV-wind renewable power generation system with appropriate power management algorithm has been designed and modeled in this paper for standalone island uses in the absence of electric power grid. The power available from green energy sources is highly dependent on weather conditions such as solar irradiations and wind speed. In this paper, a PV system integrated with a wind turbine and battery bank using a novel topology to overcome this deficiency. This standalone hybrid topology shows excellent performance under varying load power requirement, solar irradiation and wind speeds where solar irradiation and wind speed data are based on real world records. The converter can provide a high step-up capability for power conversion systems including the PV array, the battery storage, and the isolated load consumption. Three operating modes are analyzed and have shown the effective operation of the proposed topology for PV applications. From simulation and experimental tests, it can be seen that the output voltage and PV voltage can be controlled independently by the phase angle shift and PWM, respectively.

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