A Hybrid Diesel-Wind PV based Microgrid

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Abstract

An experimental implementation of a standalone microgrid topology based on a single voltage source converter (VSC) and brushless generators. The microgrid system is energised with different renewable energy sources namely wind and solar PV array. However, a diesel generator (DG) set and a battery energy storage system (BESS) are also used to maintain the reliability of the system. The proposed topology has the advantage of reduced switching devices and simple control. The implemented topology has DG set as an AC source. The wind generator and the solar PV array are DC sources which are connected to the DC link of the VSC. The BESS is also used at the DC link to facilitate the instantaneous power balance under dynamic conditions. Two controllers for generator, PV and Wind are explained in which one is simulated using Matlab Simulink and Output is obtained.
Keyword- Power Flow Control, Control Strategy, Equalized Output of All Sources

I. INTRODUCTION

There are many locations in the world where the small localities are developed far away from the well-developed societies. It is technically and economically difficult to setup a transmission system to make electricity available there due to the cost incurred, the problems related to grounding of the transmission tower at hilly areas and ROW (Right of Way) problems due to forests in between. However, on the other hand, these areas have abundance of natural resources like solar energy, wind, hydro etc. Due to uncertain nature of all these renewable energy sources, a small self-sustaining supply system cannot be established which can supply the loads continuously. To make the system self-sustaining, some reliable sources are required. Therefore, generally a diesel generator is used at these sites. To account for randomness of the natural resources, a full rating diesel generator is a costly option. Some energy storage device can be employed there, which reduces the diesel generator rating and considerable fuel consumption.

As described earlier, since the system is setup at a remote area, the brushless generators are used to avoid the maintenance as much as possible. The proposed topology in this paper includes solar PV array and wind energy as natural resources. There are many topologies, control algorithms and operation strategies for the micro grid system with many energy sources. Like DFIGs (Doubly Fed Induction Generators) are used for wind and diesel based system, where the controller is optimizing the fuel consumption and regulating the voltage and frequency of the system with maximum available power extraction from wind.

Different operating strategies to include wind power in a diesel based system to save fuel and to reduce the overall cost of the system is proposed in. A time frame based control algorithm is proposed for a wind-diesel system with an energy storage. In this paper, authors have proposed an ESS (Energy Storage System) to account for wind randomness and fuel cost. A standalone hybrid wind-solar system with engine generator and a battery is proposed in, where the operational aspects and topology are described. The proposed topology has six VSCs to integrate the complete system have proposed a solar and diesel–wind hybrid generation system with BESS, in which synchronous generator is used for a diesel generator which requires AVR (Automatic Voltage Regulator) and speed governor for voltage and frequency regulation. The proposed different configurations of a hybrid system using solar PV array, wind and diesel systems.

With the given load profile of an area for whole day, size and scheduling of the generator are performed to maximize the generator efficiency. Similarly, to reduce the battery size and to increase efficiency of the system, an ultra-capacitor is used with the battery to exchange power during dynamics and the battery is used to supply under sustained load generator power.

A. Hybrid Diesel-Wind PV Based Energy Generation System with Brushless Generators

Fig.1. shows the block diagram of the proposed Hybrid Diesel-Wind PV based Energy Generation system with generators. The system contains a disel generator which is connected to the battery through a bidirectional converter. There are other sources of supply to the grid namely, Wind whose output is rectified and boosted and is connected to the battery and PV whose output s boosted using a boost converter and is stored in the battery. Supply to the load is given by all these sources and the extra power generated is stored in battery. Diesel generator is used to increase the reliability of the system by supplying power to the load whenever the load demand is greater than the power generated from renewable sources.

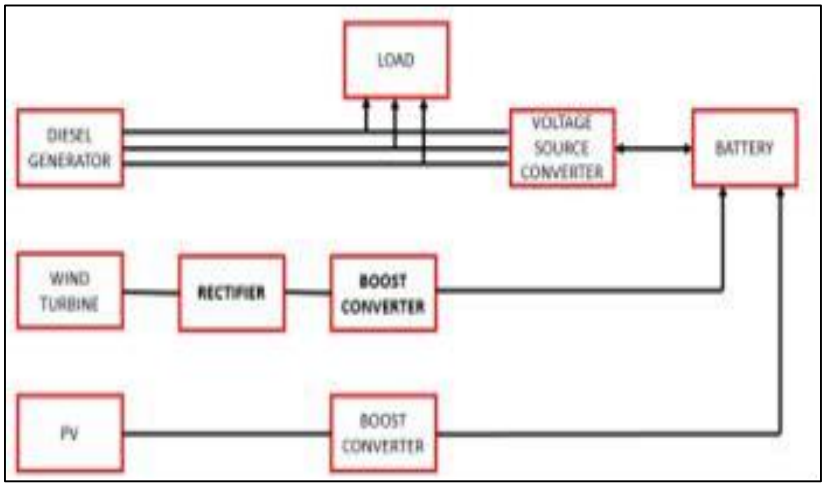

Fig. 1: Basic Block Diagram

B. Circuit Diagram and Description

The proposed system is a diesel-wind-solar PV based standalone micro grid with the battery energy storage to feed the local loads. The complete system topology is shown in Fig.2. A synchronous reluctance generator (SynRG) is used as a diesel generator and a permanent magnet brushless DC generator (PMBLDC) as a wind generator. These generators are selected purposefully due to the following reasons. Both these generators are brushless generators that reduces the maintenance cost relative to the brushed ones. For a diesel generator, SyRG is used rather than a conventional synchronous generator, so the need of a speed governor and AVR is eliminated yet the voltage and frequency of the system are regulated using VSC. The PMBLDC generator is driven by a wind turbine. The WECS (Wind Energy Conversion System) is connected at the DC link of the VSC through a diode rectifier and a boost converter. PMBLDCG is best suited for an uncontrolled rectification due to trapezoidal back emf. If the winding currents are also made quasi-square wave, then a low ripple torque is produced and the machine operates smoothly. This feature is not there with PMSG as the EMF generated is sinusoidal, so the quasi square wave currents produce a fluctuating torque. Moreover, the energy density of the PMBLDC machine is high which makes it small in size, hence good option for pole mounting application. The proposed topology also includes solar PV system which is also connected to the DC link of the VSC for power transfer to the AC side where loads are present. As discussed earlier, to maintain the power balance and reliability of the supply, the battery energy storage device is required. Hence, a battery bank is also installed at the DC link of the VSC.

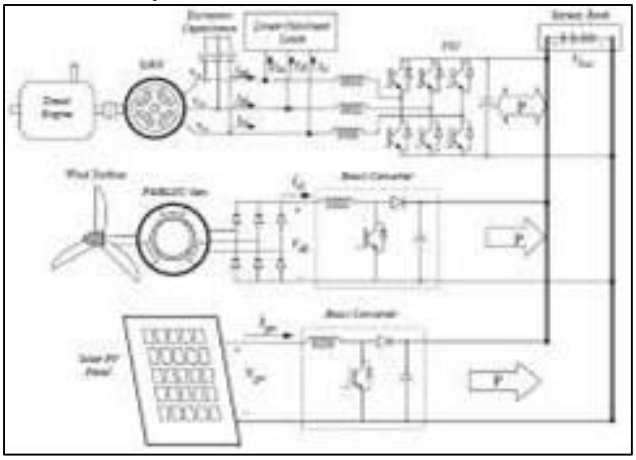

Fig. 2: Circuit Diagram

C. Control Strategy for Proposed Standalone Micro Grid System

The proposed system topology has many sources, so an operational strategy is developed to optimize the fuel efficiency and to maximize the extraction of free energy available. The diesel generator is the only AC source in the system, so the system and the load end frequency is related to the operation of the diesel generator only. A constant frequency of the system means the constant speed of the generator (as the generator is synchronous reluctance generator). It is stated in that with fixed speed operation of the diesel engine, the fuel consumption doesn't vary much from its value at full load, thus making the diesel engine fuel efficiency poor at lighter loads. The diesel engines operate at reasonable good efficiency between 80%-100% loading. Here the control strategy is developed for the diesel generator to operate it always within a specified loading range as shown in Fig. . The diesel generator with rating as full load rating is not required as there are renewable energy resources and the battery energy storage device is available. The wind energy conversion system (WECS) consists of a PMBLDC generator, three phase diode bridge

rectifier (DBR) and a boost converter. An inductor is used after the DBR to make the DC current almost constant which reflects as quasi-square waveform of current on the AC side which is beneficial for the operation of PMBLDCG as discussed earlier. The operation of the WECS is simplified by eliminating the need of any mechanical sensor for MPPT. An MPPT algorithm is used which requires only sensing of vdc and idc. This MPPT algorithm is same as perturb and observe which is used for maximum power extraction in solar PV system.

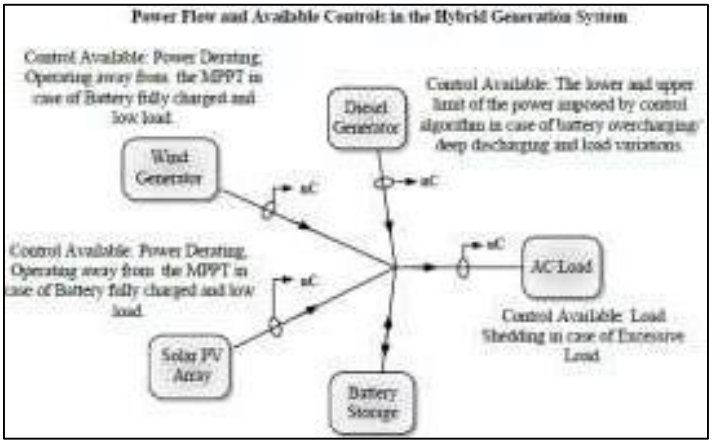

Fig. 3: Control System

Power balance mainly concerns the appropriate conduction of the real-time power flow, avoiding system oscillation or even collapse. The power dispatching strategy splits Pnet into different parts and if they are all well conducted, the real time power will certainly be balanced. Regarding Phigh, it is assigned to the ultra-capacitor for suppression and this is just in compliance with its high power rate and fast responsibility. Therefore, the high frequency power balance can be achieved through regulating the ultra-capacitor converter. As to the Plow and Pb, they can be well conducted through regulating the battery converter. The varying rate of P1ow is constrained within the capability scope of the diesel generator unit through designing a proper band width of the LPF. And also, the battery and its converter are able to compensates low-varying power flow precisely.

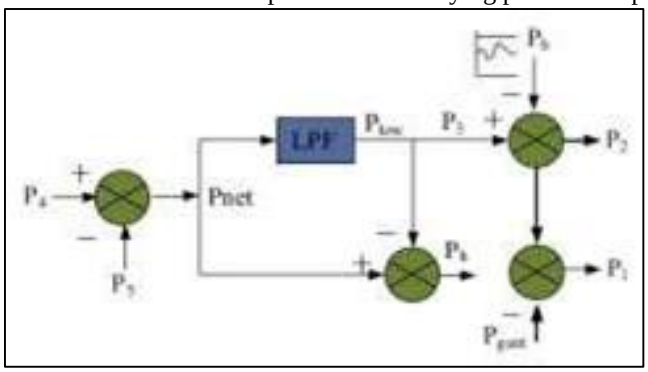

Fig. 4: Control System

II. RESULTS

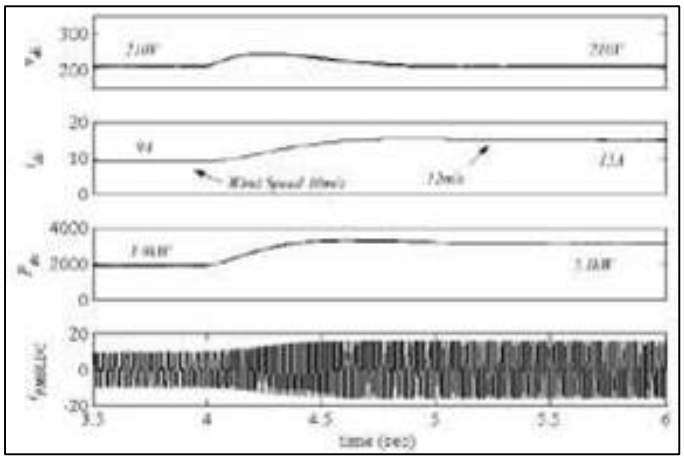

Fig. 5: Wind Variations

III. CONCLUSION

Micro-grid topology with a single VSC and brushless generators has been implemented under various operating conditions. Power balance in the whole system under various disturbances ranging from large load variation to renewable energy supply uncertainty. Some idea of battery charge discharge control and fault analysis is also discussed. Control of generator, PV and wind is done using the second controller mentioned in the report is done using MATLAB.

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