MICRO GRIDS: HYBRID ENERGY GENERATION WITH BRUSHLESS GENERATORS

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Abstract— **Power extension of grid to isolated regions is associated with technical and economical issues. It has encouraged exploration and exploitation of decentralized power generation using renewable energy sources (RES). This project presents an implementation of a standalone micro grid topology based on a single voltage source converter (VSC) and brushless generators. The micro grid system is energized 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. Along with the system integration, the VSC also has the capability to mitigate the power quality problems such as harmonic currents, load balancing and voltage regulation. A wide variety of matlab/simulink simulation results are presented to demonstrate all the features of the proposed system.**

***Index Terms*— Brushless generator, composite observer, power quality, standalone micro grid, voltage regulation, voltage source converter (VSC).**

I. INTRODUCTION

The PMBLDC generator is driven by a wind turbine. The WECS 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. Reliability evaluation of a wind-diesel-battery based system is reported, where wind energy conversion system reliability is obtained taking into consideration the wind fluctuations and component failure. Moreover, the reliability analysis of the complete system is also performed by taking diesel, wind and battery [1-5]. The control of a PMSG (Permanent Magnet Synchronous Generator) based WECS (Wind Energy Conversion System) connected to an inverter with battery acting as grid is presented. The power generated by WECS is used to control the SOC of battery. In most of the systems, described in the literature, variable speed wind energy conversion system operates to extract the maximum power from the wind.

Wind energy is free energy at the operation stage, so it is beneficial to extract the maximum power and to increase the efficiency and the utilization of WECS. It needs initial capital cost, but the fuel is free. Different methods for MPPT in WECS are proposed like algorithm similar to hill climbing, the mechanical sensor less MPPT algorithm with the current controlled inverter and the mechanical sensor less MPPT algorithm with a boost converter. Moreover, a control algorithm is required to control the VSC connected for its operation as voltage and frequency controller, mitigating power quality problems and integrating the dc sources with ac sources. Many basic control algorithms are reported in the literature [6-12].

An advanced control algorithm based on composite observer is reported. Composite observers are used to extract harmonic components from any signal and then the extracted fundamental is further used in this control algorithm. This project deals with an implementation of a reduced converter topology of a diesel-wind-solar PV-based standalone micro grid system with the BESS. These generators are synchronous reluctance generator (SyRG) and permanent magnet brushless dc generator (PMBLDCG). Both these generators are brushless in construction. The wind and solar PV systems are always operated at their maximum power point using boost converters and the DG is operated within a specified power range to optimize the efficiency of the DG. A VSC is used to integrate the DC sources with the AC sources with the bidirectional power flow capability and the power quality improvement capability [13-15]. A mechanical sensor less MPPT algorithm is used for WECS and an incremental conductance based MPPT algorithm is used for solar PV system.

II. HYBRID SYSTEM

Inter-connection of two or more sources of Renewable generations like wind power, photo voltaic power, electric cell and micro turbine generator to generate power to local load and or connecting to grid/micro grid forms Hybrid Energy Systems. Because of characteristics of solar energy and wind energy, the electric power generation of the PV array and also the wind turbine are corresponding the reliability of combined power generation which is much higher when compared to the power generated by an individual supply. A sizable battery bank is needed for load so that most power is drawn from Wind and photo voltaic array [16-22]. Recently, DC grids are resurging because of the development and deployment of renewable DC power sources and the advantage for DC loads in commercial, industrial and residential applications. To integrate with the various distributed generators DC micro grid has been proposed. However, AC sources need to be converted into DC before connected to a DC grid and DC/AC inverters are needed for conventional AC loads. When power can be absolutely provided by the renewable power sources. HV long distance transmission is no longer necessary. AC Micro grids are proposed to facilitate the association of renewable power sources to AC systems. However, photovoltaic (PV) panel's DC output power must be converted into AC using DC/DC boosters and DC/AC inverters connect to an AC grid. In an AC grid, embedded AC/DC and DC/DC converters are needed for various home and office facilities to provide different dc voltages.

A hybrid AC/DC micro grid is proposed in this paper to reduce multiple processes of reverse conversions in an individual AC or DC grid and to facilitate the association of various renewable AC and DC sources and loads to the power grid. The coordination control schemes among various modes are proposed to harness most power from renewable power sources to attenuate power transfer between AC and DC networks, and to maintain the stable operation of both AC and DC grids under variable supply and demand conditions once the hybrid grid operates in both grid-tied and islanding modes. The advanced power electronics and control technologies employed can create a future grid much smarter. Due to the fact that solar and wind power is intermittent and unpredictable in nature, higher penetration of their types in existing grid could cause and build high technical challenges, especially to weak grids or stand-alone systems without correct and enough storage capability [23-27]. By integrating the two renewable resources into an optimum combination, the impact of the variable nature of solar and wind resources will be partially resolved and the overall system becomes more reliable and economical to run.

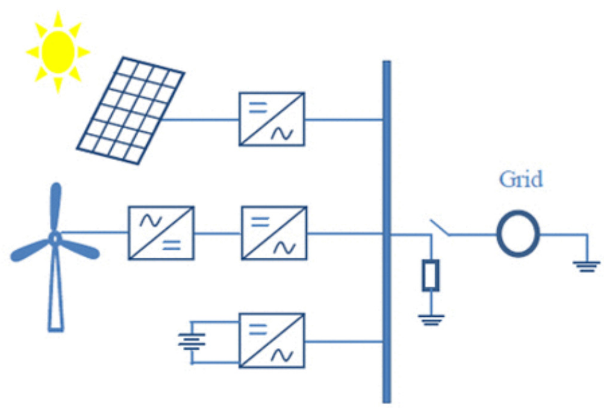

Fig:1. Hybrid system with AC Micro grid

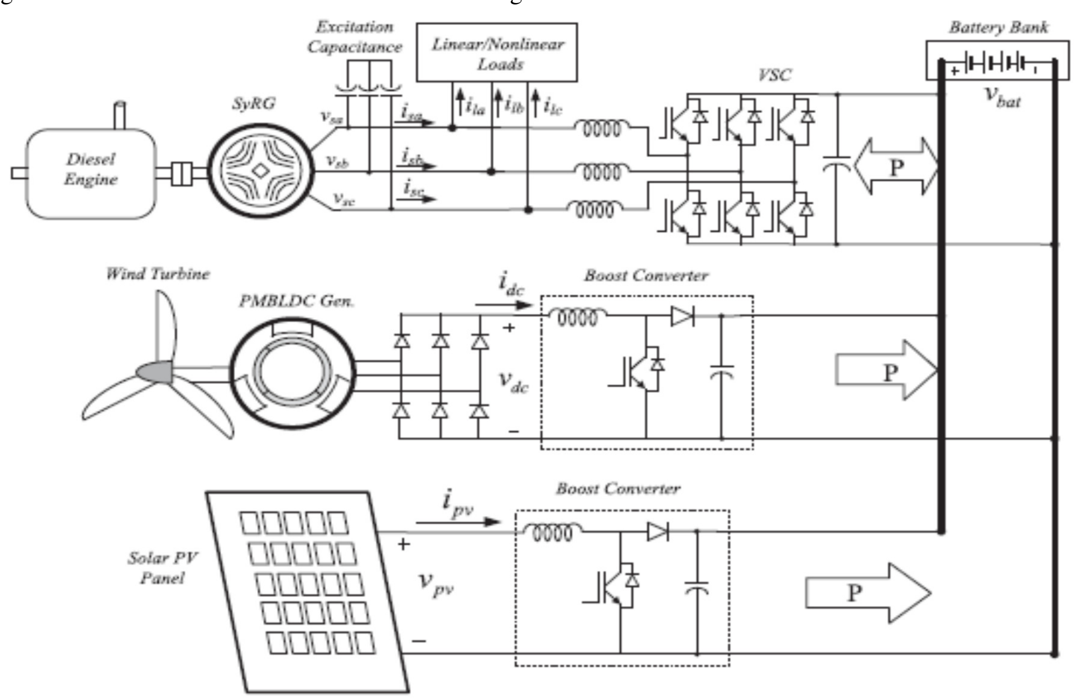

Fig: 2. Proposed single VSC and the brushless generation-based standalone micro grid system.

Voltage and frequency fluctuation, and harmonics are major power quality issues for both grid-connected and stand-alone systems with bigger impact in case of weak grid. This can be resolved to a large extent by having proper design, advanced fast response control facilities, and optimization of the hybrid systems. Micro grid is a new concept in power generation. The Micro grid concept was a cluster of loads and micro sources operating as a single controllable system that provides both power and heat. Some models could describe the components of a Micro grid.

III. SYSTEM MODELING

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 SyRG is used as a DG and a PMBLDCG as a wind generator. These generators are selected purposefully due to the following reasons. Both these generators are brushless generators that reduce the maintenance cost relative to the brushed ones. For a DG, 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. As shown in Fig. 2, the WECS 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.

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 DG is the only ac source in the system, so the system and the load end frequency is related to the operation of the DG only. A constant frequency of the system means the constant speed of the generator (as the generator is SyRG) [5-18]. It is stated that with fixed speed operation of the diesel engine, the fuel consumption does not 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 DG to operate it always within a specified loading range as shown in Fig. 3. The DG with rating as full load rating is not required as there are renewable energy resources and the battery energy storage device is available.

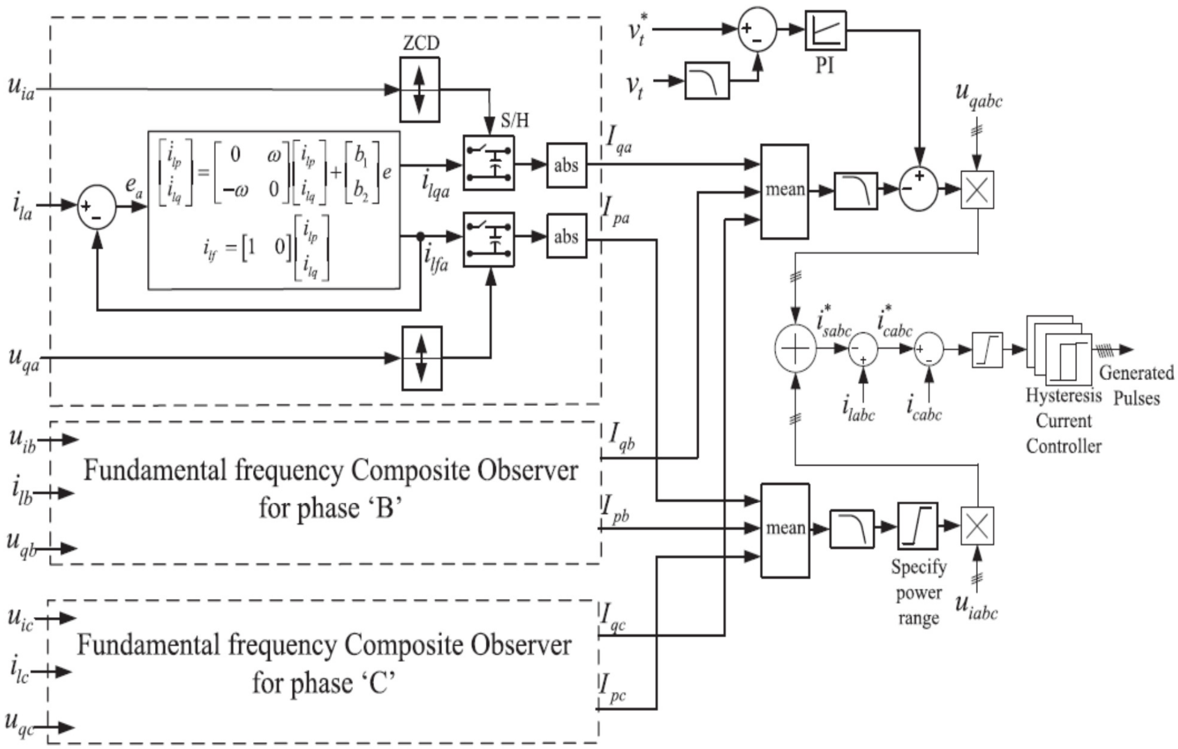

Fig: 3. Control strategy for VSC

The 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 *v*dc and *i*dc. This MPPT algorithm is the same as perturb and observe, which is used for maximum power extraction in solar PV system.

IV. SIMULATION RESULTS

The complete system is simulated using MATLAB/SIMULINK and from simulation results the MPPT of WECS is verified. The DG is operated under specified power range. The wind and solar systems are operated always at MPP.

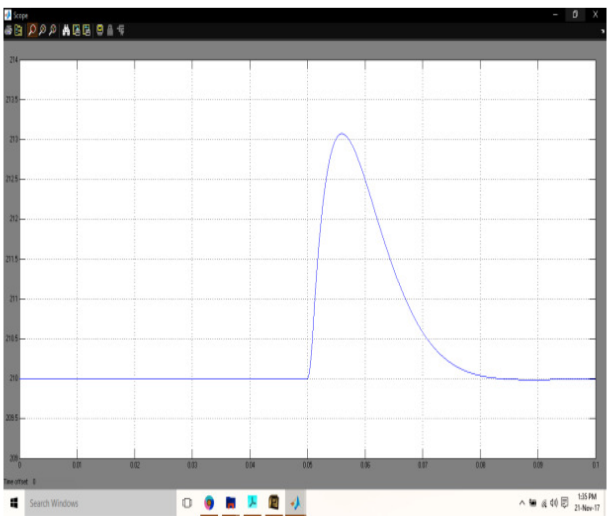

Fig: 4(a) Vdc

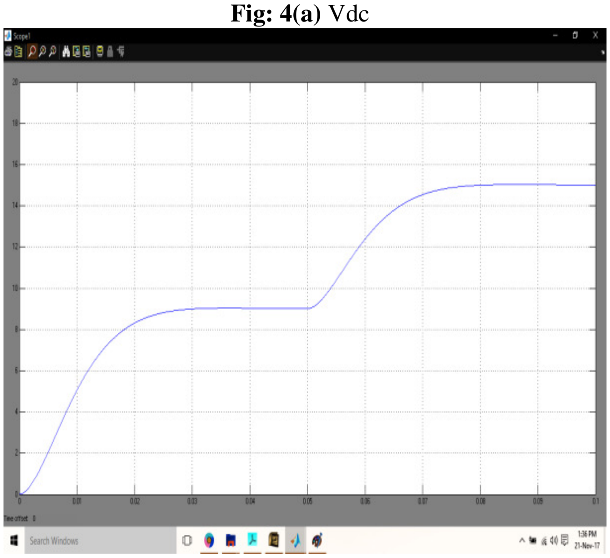

Fig: 4(b) Idc

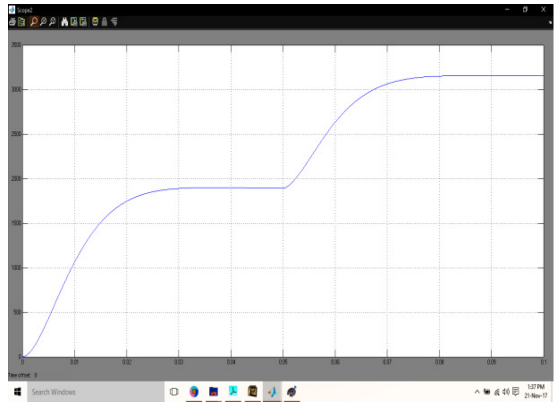

Fig: 4(c) Pdc

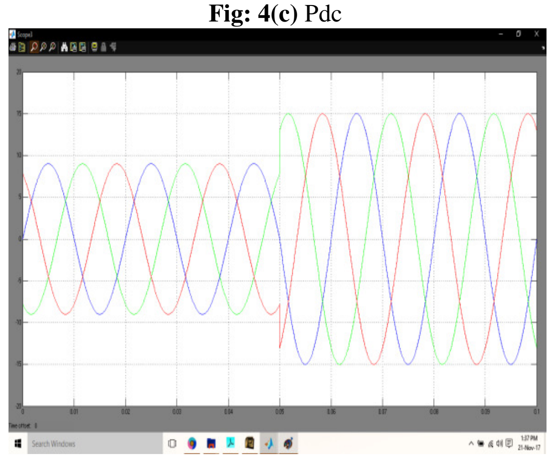

Fig: 4(d) Ipmbldc

Fig: 4. Performance of WECS under varying wind speed.

The corresponding performance of the MPPT algorithm under variable wind operation is shown in Fig. 4. The results with constant wind speed are shown in Fig. 4 until *t*= 0.05s. The wind speed is changed from 7 to 12 m/s at *t* = 0.05 s. The dynamic behavior of the system is demonstrated during such variation in wind speed. From these results, it is seen that with an increase in the wind speed, the power output of the WECS increases and also it can be seen that the PMBLDCG current has also increased.

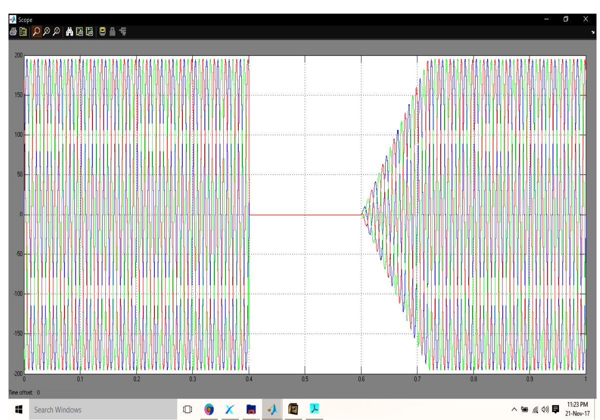

Fig: 5(a). Vsabc

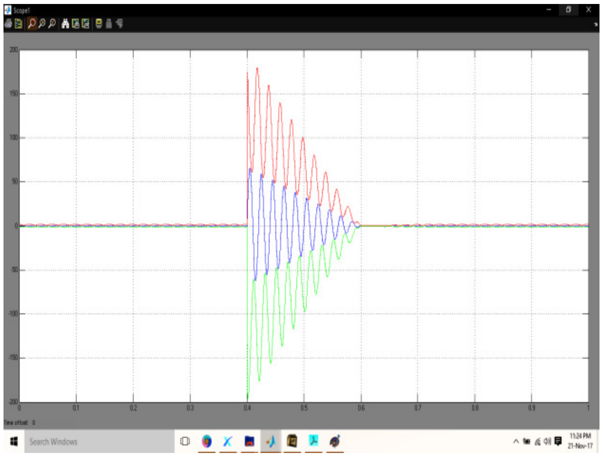

Fig: 5(b) Isabc

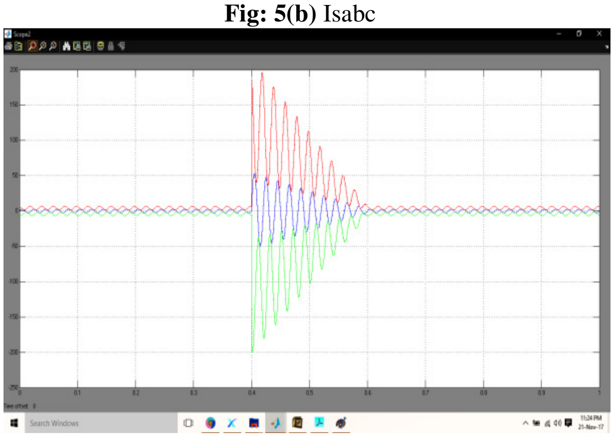

Fig: 5(c) Ilabc

Fig: 5(d) Icabc

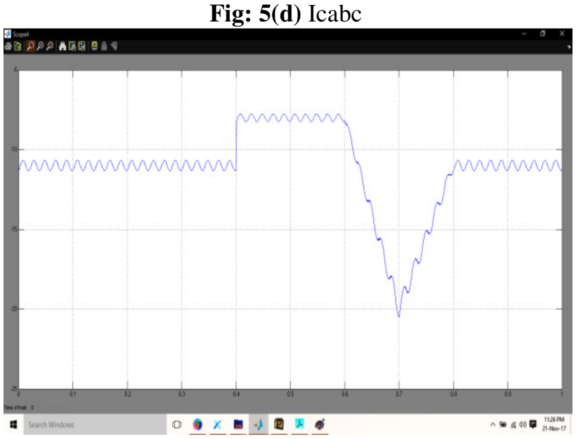

Fig: 5(e) Ibat

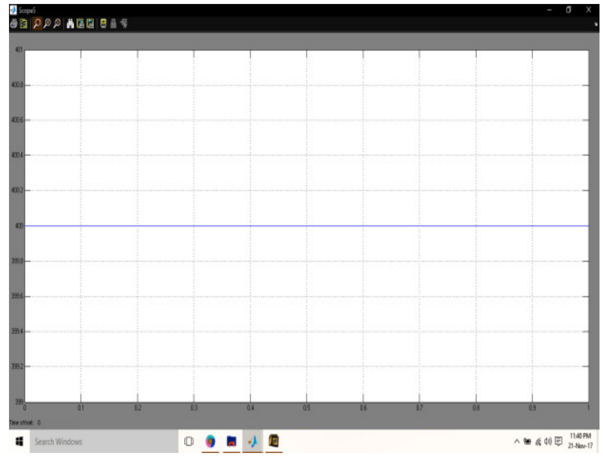

Fig: 5(f) Vbat

Fig: 5- System performance under faulted condition.

This section provides a brief understanding of how the system will behave under some fault conditions. The fault situations are created and analyzed using simulation tool. First case is taken where the fault is created at the ac bus. Current through the converter is controlled within the control algorithm. As the currents are non sinusoidal, a hard current limit is used to protect the devices and the system. If the switching devices have their own protection system (like desaturation for IGBTs), then an indirect current control can be used, which requires only source currents. But those protections are latchable (shutdown the system), so it is better to limit the current without disrupting the operation. That is why a direct current control incorporating compensator currents is used. The results are shown in Fig. 5. As shown in Fig. 5, the reactive power support to the generator is mostly provided by the converter and with the fault on the ac line, the reactive power diverts to the low-impedance fault path and the generator's voltage collapses. But as soon as the fault is cleared, the generator picks up again. Another advantage of this system is that it is a machine-based system and hence the generator majorly contributes to the fault current, which has a large short circuit rating compared to the semiconductor devices.

V. CONCLUSION

Hybrid energy systems (HES) can provide environment friendly and cost effective energy solutions with higher reliability and power quality. Instead of conventional energy, stand-alone solar-wind-diesel based HES can provide decent supply of electrical energy in remote locations. In these days, HES is an economic reality to reduce the dependency on a diesel fuel for off-grid communities. A diesel driven power generator is often provided in remote HES in case of unavailability of electrical power from renewable energy sources. Furthermore, HES can substantially reduce a fuel consumption and emission compared to the conventional power systems. However, a complex power management strategy is required to ensure proper power sharing between multiple sources and optimize the power quality. A brief study through simulation is focused in this research with an objective to develop a power management strategy and control systems for stand-alone solar-wind-diesel hybrid energy systems (SWDHES). The proposed micro grid topology with a single voltage source converter and brushless generators has been implemented under various operating conditions. An integrated operation of control algorithms is also tested for system's voltage and frequency control, mitigation of power quality issues, 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. Matlab/simulink results have confirmed the suitability of this topology for rural/isolated areas as the topology is simple and cost effective.

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