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Modeling and Optimum Design of a Hybrid Diesel - Wind-PV-FC Based Energy Generation System

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ABSTRACT

In power systems, meeting the electricity demand of remote regions is an imperative issue. Considering economic aspects, reliability and pollution concerns, combination of diesel generator and renewable energy sources like wind turbines(WTs), photovoltaic (PV) systems and fuel cells (FCs) can be an effective way to meet the demand of off-grid loads. 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.

KEYWORDS: *hybrid energy systems, Brushless generator, composite observer, power quality, standalone micro grid.*

I. INTRODUCTION

Diesel generators are employed in hybrid power systems to meet the electricity demand in deficit conditions. Since use of diesel fuel is costly and increases the pollution emissions, especially CO2, wind turbines (WTs) and photovoltaic (PV) systems are also regarded to reduce using fossil fuels and decrease pollutants. For a ProfessorPV/WT/diesel system, a device must be used for storing the energy. This device saves the excess energy when the renewable sources generate more energy than the load demand and delivers that to the load when the renewable energies are not enough. Although lead acid batteries are usually used for energy storage, the resultant environmental concerns limit their application. On the other hand, fuel cells (FCs) can considerably reduce the amount of the emitted greenhouse gases. Such combination (PV + WT + diesel + FC) makes a more reliable system with low pollution. Figure 1 illustrates a typical PV/WT/diesel/FC hybrid system.

Recently, using hybrid systems based on renewable sources, diesel generators and hydrogen power have received much attention. For using solar and wind resources more efficiently and economically, the optimum sizing is the main issue. For such system, optimum sizing is defined by determining the number of PV panels, WTs, and hydrogen tanks to simultaneously meet the load demand and minimize the total annual cost. If the system is optimally sized, it can be cost-effective and reliable. This approach makes use of a method to find out the optimum number of the units by the aim of minimizing the total cost and ensuring the energy availability.

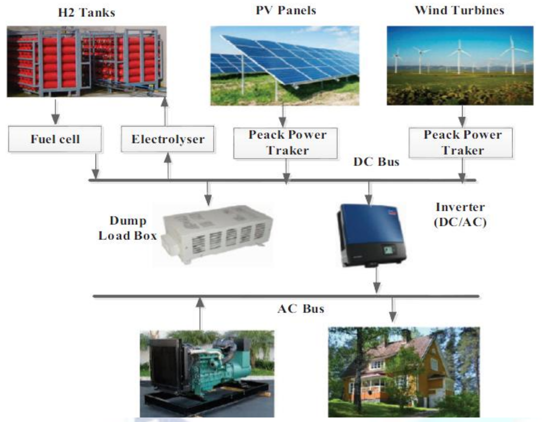

Fig:1.Schematic of the PV/ WT/ diesel / FC-based hybrid system.

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. 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-FC 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. A mechanical sensor less MPPT algorithm is used for WECS and an incremental conductance based MPPT algorithmis used for solar PV system.

II. SYSTEM MODELING

The proposed system is a diesel-wind-solar-PV-FC 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. 4, the WECS is connected at the dc link of theVSC through a diode rectifier and a boost converter. PMBLDCG is best suited for an uncontrolled rectification due to trapezoidal back EMF.

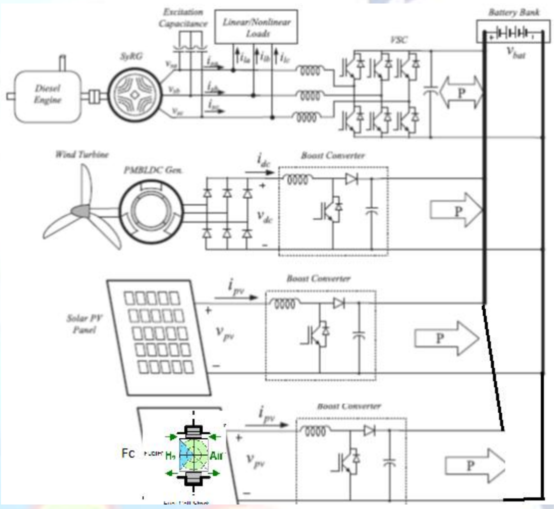

Fig.2.Proposed single VSC and the brushless generation-based standalone micro grid system.

The proposed system topology has manysources, 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 theDG only. A constant frequency of the system means the constant speed of the generator (as the generator is SyRG). 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.

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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.

III. SIMULATION RESULTS

The complete system is simulated usingMATLAB/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.

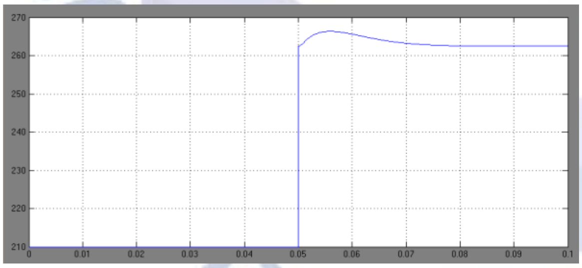

Fig:3.(a) Vdc

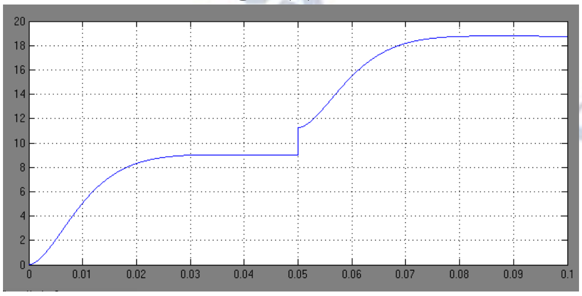

Fig:3.(b) Idc

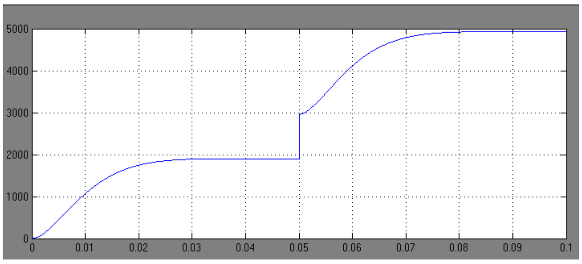

Fig:3.(c) Pdc

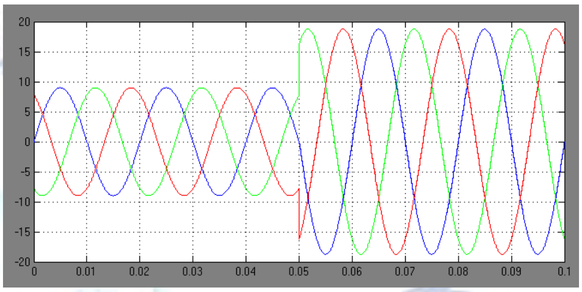

Fig:3.(d) Ipmbldc

Fig:3- Performance of WECS under varying wind speed.

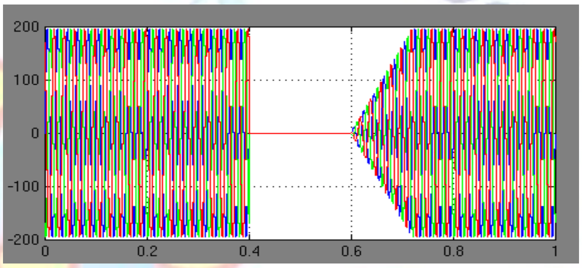

Fig:4.(a) Vsabc

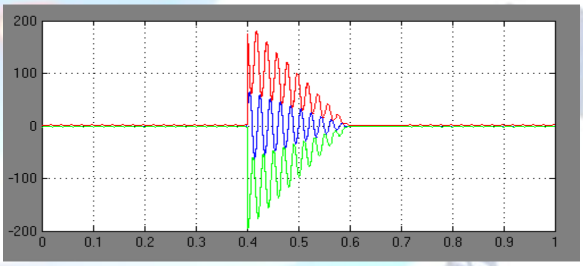

Fig:4.(b) Isabc

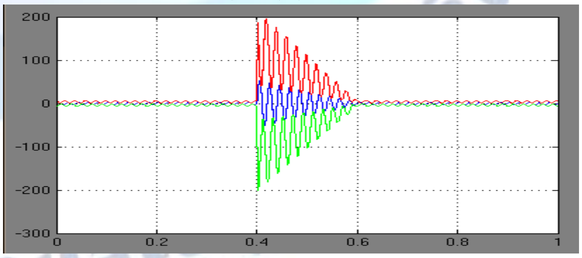

Fig:4.(c) Ilabc

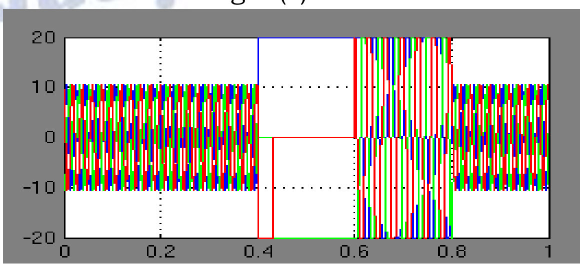

Fig:4.(d) Icabc

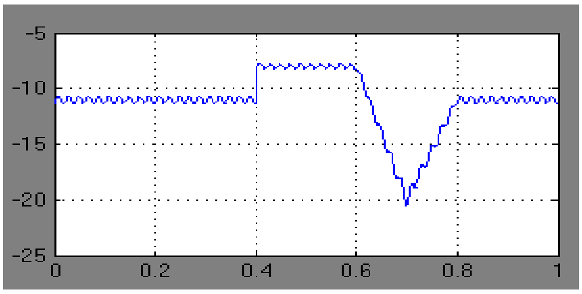

Fig:4.(e) Ibat

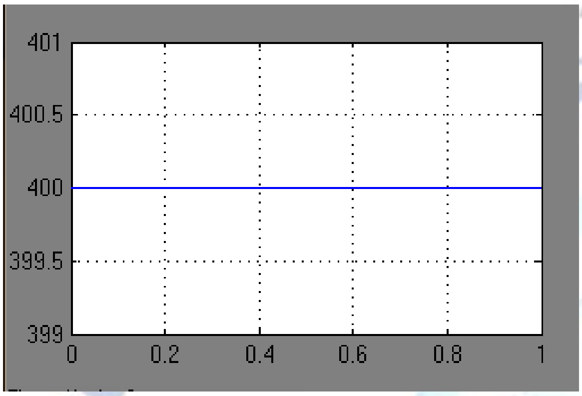

Fig:4.(f) Vbat

Fig:4- System performance under faulted condition.

IV. CONCLUSION

This paper performs the cost analysis of a PV/WT/Diesel/FC based hybrid generation system. For this aim, an economic model is introduced and an effective optimization technique is used to optimally size the system components. This paper has reviewed several typical case studies on hybrid renewable energy systems, including their modeling and simulation, control and management, reliability and economic studies, and the optimal size design by using intelligent computing methods. An integrated operation of control algorithms is alsotested 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. Simulation results indicate that the conventional diesel generator alone system is more cost-effective than the other systems. Nevertheless, with the increase in the fuel price of the diesel generator, PV/diesel/FC is the most cost-effective system for power generation. In terms of the pollution emissions, PV/ WT/diesel/FC system is the best choice.

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