MICROGRID BASED RENEWABLE ENERGY SOURCES WITH ENERGY MANAGEMENT SYSTEM

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ABSTRACT :

This paper describes the need for renewable based microgrid and gives the information about characteristic features of a standalone microgrid. The necessity of energy management system and its performance with microgrid has been explained. Renewable energy sources such as wind turbines, Geothermal power, bio-mas and photovoltaic panel require perfect control for harnessing maximum available energy, energy storage system demand, efficient management, and DC-link voltage must be maintained constant. These requirements are fulfilled by energy management system, thus it provides intelligence to the system and makes the microgrid reliable. An isolated renewable microgrid having proposed features and energy management system has been simulated using MATLAB/SIMULINK. The designed system sustains dynamic conditions and simulation results validate feasibility of microgrid and energymanagement.
Keywords—Renewable, microgrid, energy management, DC link, energy storage system, power converters.

I. INTRODUCTION

Renewable based microgrid is at the upfront for achieving rural electrification, especially in developing nations such as India. Microgrid is a self-sufficient and independent power system which includes one or more generating sources, energy storage system, energy management and loads. Such a system may or may not be connected to the grid. The need for renewable based microgrid arises to fulfill energy requirement of rural, isolated regions. Grid connected systems are mainly established in cities and have sparsely reached villages or isolated regions. The regions where grid connected supply is available pay for poor quality of supply, the supply is time-limited and this hampers the social and economic growth of that region. Even in cities where the grid is stronger comparatively, load shedding and poor quality of supply make the grid unreliable. Limitations of AC grid create a need for localized power systems or microgrids, which are not limited to a certain region, which are cost-efficient and reliable, and contribute towards sustainability rather than degradation of the environment. Renewable based microgrid harness inexhaustible energy resources which are available in plenty and are free of cost. Microgrid can utilize DC-DC power converters having efficiency more than 95%, and reduce the need of AC/DC converters. Centralized AC power grids face severe transmission and distribution losses. Earlier, majority of the loads were AC, such as induction machine and incan-descent lamps.

Nowadays, many DC loads are used such as LED lights, Heating Ventilation and Air Conditioning (HVAC) equipment, variable speed motor drive [1]. This paper is organized as follows: Section II explores microgrid and highlights certain characteristics essential for microgrid. Section III elaborates need for energy manage- ment in microgrid. A microgrid has been modeled and simulated using MATLAB/SIMULINK, as shown in Section IV. Section V concludes the paper, affirming feasibility of renewable based microgrid.

II. MICROGRID

Fig.1 represents a generalized block schematic of microgrid.Permanent magnet synchronous generator (PMSG) is suitable to be used as a generating source in microgrid as it has several advantages over other WTG topologies. PMSG is fully controllable variable speed topology which uses full power converters (VSC) [2]. It has high power-to- weight ratio and does not have reactive power requirement for magnetization, which makes it easier to control.
Out of the different storages available, supercapacitor, fuel cell and battery have certain unique characteristics which complement each other, thus these could form a hybrid energy storage system. Supercapacitor has quick charge-discharge cycles and can be used to supply high amount of power for a short duration of time. Battery is generally used as standby and fuel cell can be used to provide huge amount of energy during high load of demand.

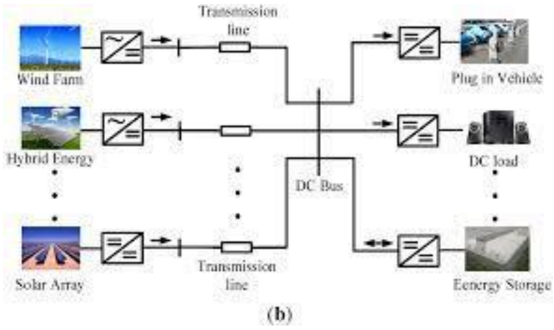

Fig.1 Block diagram of Microgrid

The following characteristics of microgrid have been proposed.

• The microgrid must be reliable. Power supply quality should be maintained to a suitable level.

• The microgrid must solely utilize renewable en- ergy resources.

• The microgrid must be stable. It should be able to sustain dynamic load conditions and variation in generating power due to intermittent nature of wind and solar energy.

• The system should have least maintenance require- ment and minimum cost of installation.

• The microgrid should be able to adapt changes even after initial sizing and installation. These may be changes in storage or generation capacity, and changes in the load pattern.

III. NEED FOR ENERGY MANAGEMENT

Energy management algorithm and power converters to- gether provide the necessary control to the system [3]. WTG and photovoltaic panel can be controlled to extract maximum power from the available natural sources. Energy storage sys- tem requires management for deciding which storage should be used in case of a hybrid energy storage system, and for deciding the charge-discharge cycles of chosen storage. The DC-link voltage must be maintained constant for balanced flow of energy among the multiple sources and loads, in a microgrid. Also, a variation of DC-link voltage would disrupt normal operation of the system and could cause the whole system to collapse [4].

Energy management algorithm (EMA) provides intelligence to the system and controls the functioning of each block of the system. Energy management algorithm has several significant roles:

• Reliability: providing uninterrupted supply to the load.

• Quality: maintaining quality of supply.

• Stability: maintaining DC-link voltage constant.

• Maximum utilization of generating sources using MPPT algorithm.

• Efficient management of storages.

Sizing of generating sources and storages is a prime concern while designing any isolated system, since the load demand should be met completely by generating sources and the ESS, without grid intervention [5]. Inspite of this, sizing is not the fundamental requirement of the microgrid presented here. The microgrid would be able to adapt changes in storage or generation capacity. Battery would play a primary role of supplying voltage to the system. This is also essential for wind turbine generator and photovoltaic panel. Thus, battery should rarely be discharged and would be used as standby. Battery management in this manner leads to increased lifetime of the battery, reduced maintenance, cost and size of the battery.

IV. SIMULATION OF MICROGRID

An isolated microgrid has been designed and validated using MATLAB/SIMULINK. It consists of four main parts: generating sources, energy storage system, loads and energy management system. Energy management algorithm monitors DC link voltage and state-of-charge of battery and superca- pacitor. Energy management system consists of field oriented control for WTG, MPPT algorithms for WTG and PV, charge- discharge algorithm (Fig. 2), fuel cell control and critical load shedding control.

Fig. 3 to Fig. 8 shows the characteristic behavior of PMSG wind turbine generator. Varying wind speed is applied to PMSG having nominal power rating 2.8kW. As shown in Fig.6, the WTG is stable as per Swing equation. Fig. 7 shows that field oriented control, i.e., vector control [6] is used to control the rotor speed of PMSG, with respect to power generated. Modified hill climb search (HCS) MPPT algorithm which uses variable step is used to obtain maximum power point for WTG, as can be inferred from Fig. 3 and Fig. 8 [7].

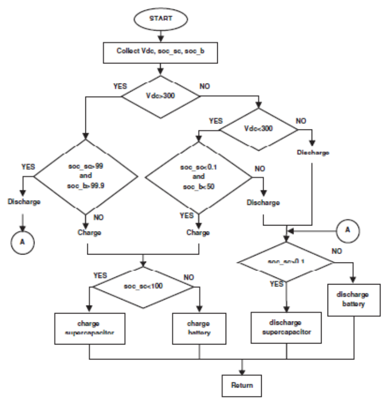

Fig. 2: Flowchart of Charge-Discharge Algorithm

Photovoltaic panel harnesses solar irradiance and produces DC power. Since the system has been simulated for 1sec, the solar irradiation changes from 1000*W/m*2 to 500*W/m*2 at 0.5sec, as seen in Fig. 9. 14 PV modules with rated power 215W are connected in parallel to design a 3kW photovoltaic panel [8]. Fig. 12 shows that maximum power is obtained from PV panel by controlling duty cycle of boost converter with the help of MPPT algorithm [9].

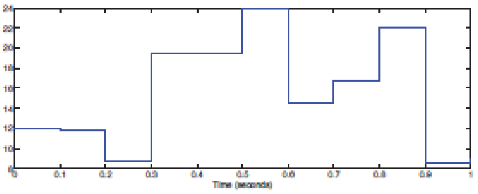

Fig. 3: Wind velocity (m/s)

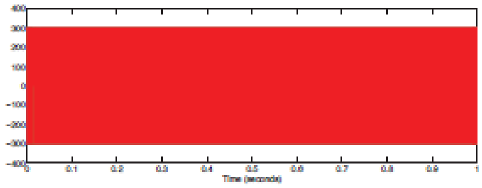

Fig. 4: Generator voltage (V)

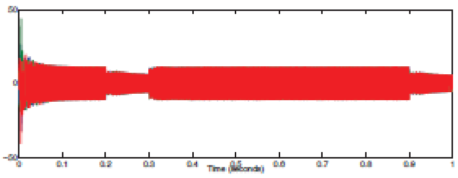

Fig. 5: Generator current (A)

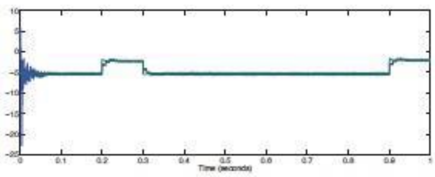

Fig. 6: Electromagnetic and mechanical torque (Nm)

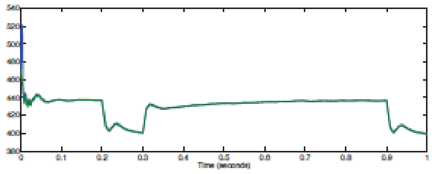

Fig. 7: Reference and obtained rotor speed (rad/sec)

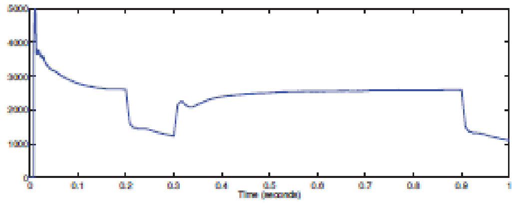

Fig. 8: Power generated by WTG (W)

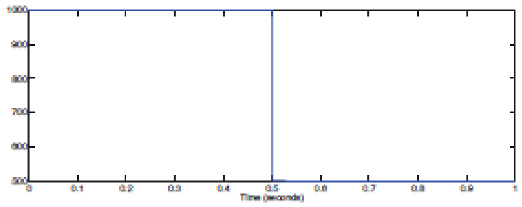

Fig. 9: Solar irradiation (W/m^2)

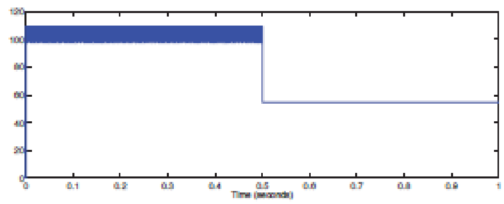

Fig. 10: Photovoltaic current (A)

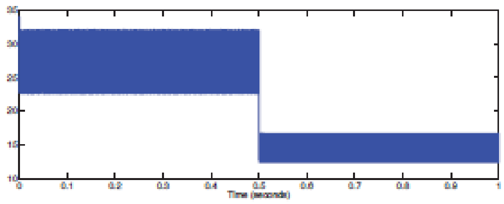

Fig. 11: Photovoltaic voltage (V)

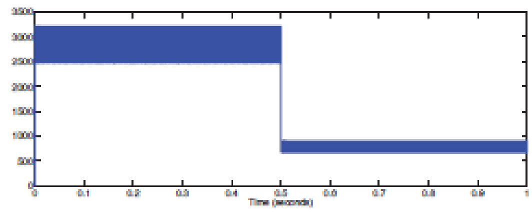

Fig. 12: Power generated by PV (W)

A hybrid energy storage system consisting of battery, supercapacitor and fuel cell is used. The battery and super- capacitor are connected to DC-link via a charge controller and fuel cell is connected to the DC-link through a DC-DC boost converter. Although there are variations in DC-link voltage due to changes in load conditions and variation in power generated by generating sources, Fig. 13 shows that the DC- link voltage remains almost constant. This indicates that energy management algorithm maintains system stability. Fig. 14 and Fig. 15 show supercapacitor and state-of-charge of battery. respectively. A 7.5kW induction motor load is connected to the microgrid through sinusoidal PWM inverter. Fig. 16 and Fig. 17 show the dynamic response of induction motor load. Mechanical torque of induction machine is changed from 25Nm to 50Nm at 0.15sec, and Fig. 18

shows electromagnetic torque which follows mechanical torque. An additional load of 10kW is added to the system at 0.6 sec and Fig. 20 shows increase in load current due to this load. The voltage drop seen in Fig. 21 is due to mismatch of load and generating capacity, which has been done for operating fuel cell at worst condition, as seen from Fig. 19.

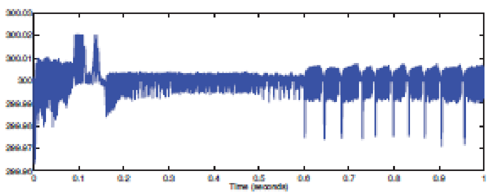

Fig. 13: DC link voltage (V)

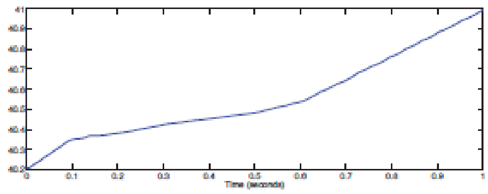

Fig. 14: State-of-charge of supercapacitor

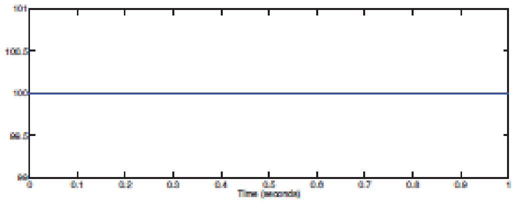

Fig. 15: State-of-charge of battery

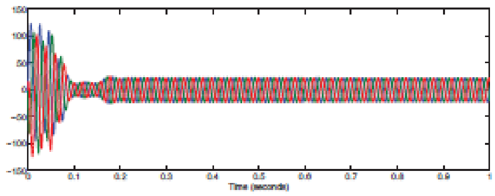

Fig. 16: Stator current of induction motor (A)

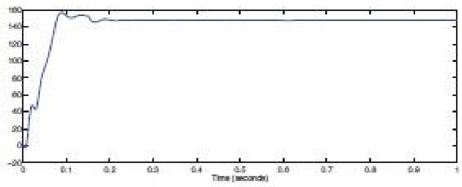

Fig. 17: Rotor speed of induction motor (rad/sec)

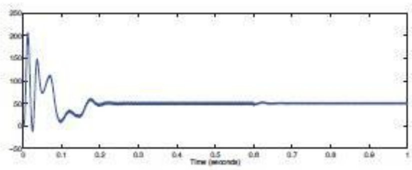

Fig. 18: Electromagnetic torque of induction motor (Nm)

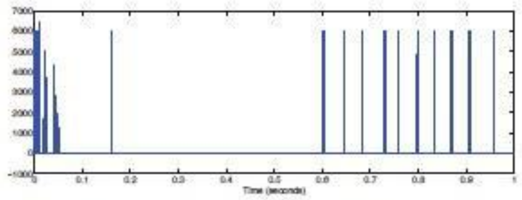

Fig. 19: Power supplied by fuel cell (W)

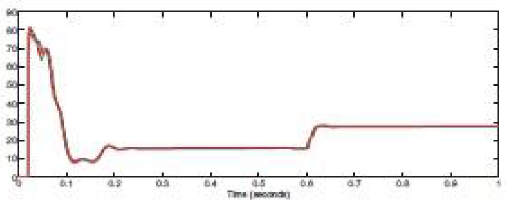

Fig. 20: RMS load current (A)

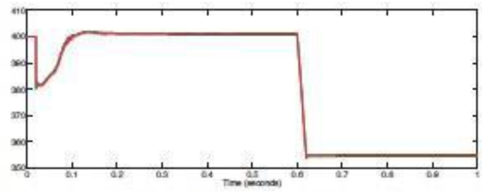

Fig. 21: RMS load voltage (V)

V. CONCLUSION

The paper reviews limitations of conventional AC power grid and presents renewable based microgrid as an op- timum solution for fulfilling energy requirement. This paper proposes adaptable renewable based microgrid with energy management system. Microgrid is expected to be reliable, maintain power supply quality and solely utilize renewable energy resources.It is proposed that the microgrid should be able to adapt changes in generating or storage capacity, and this can be achieved using energy management system. Energy management system enhances the virtues of mi- crogrid. The simulation results exhibits stable operation of an isolated microgrid using various control strategies. DC- link voltage of simulated microgrid is constant in spite of varying wind speed and solar irradiance, induction motor load and addition of extra load. Energy storage system has been managed excellently. Artificial neural network (ANN) and fuzzy logic would make the energy management system intelligent. In order to improve efficiency and reduce cost, power converters for microgrid may be designed. Co- generation using fuel cell and photovoltaic panel would also add to the benefits of microgrid [10]. Electrical energy is necessary for the growth and development of humankind. Since renewable energy sources such as wind and solar energy are available everywhere, renewable based microgrids can be used to realize the dream of making electrical energy available at all places.

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