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Energy Management in Hybrid Power System

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Abstract- The demand for new and environmentally friendly energy system is growing worldwide. Renewable energy sources and conversion units such as Photo voltaic, Wind turbines, and Fuel cells have been found to be promising energy sources toward building a sustainable and environment friendly energy economy in the next decade. The dynamic interaction between the load demand and the renewable energy source can lead to critical problems of stability and power quality that are not very common in conventional power systems. Therefore, managing the flow of energy throughout the hybrid system is essential to increase the operating life of the membrane and to ensure the continuous energy flow. In this , a management system is designed to manage the power flow between the hybrid power system and energy storage elements in order to satisfy the load requirements based on fuzzy logic controllers. The advance fuzzy logic controller is developed to distribute the power among the hybrid system and to manage the charge and discharge current flow for performance optimization. The developed management system performance was assessed using a hybrid system comprised PV panels, wind turbine (WT), battery storage, and proton exchange membrane fuel cell (PEMFC).

Index Terms- Hybrid power system, Battery State of Charge, Energy Management System.

1. INTRODUCTION

Renewable energy sources such as hydro, solar, wind, biomass, geothermal and tidal can act as an alternative power sources in standalone power system applications, as they provide clean power for remote communities. In general, there is huge potential for utilizing renewable energy sources in most remote areas which can provide a clean and environmentally friendly power supply to the community. However, the main challenge of using renewable energy sources for standalone power system applications is that the availability of power has daily and seasonal patterns that may not match the load demand. Combining renewable energy generation with a standby generator or energy storage device will render the renewable energy sources more reliable and adorable. This kind of electric power generation system with a main power source from renewable energy and back up generation or energy storage is known as a hybrid power system.

The main objective of such systems is to produce as much energy as possible from the renewable sources while maintaining acceptable power quality and reliability. The hybrid power plant is a complete electrical power supply system that can be easily configured to meet a broad range of remote power needs. There are three basic elements to the system the power source, the battery, and the power management center. The power sources are a wind turbine, diesel engine generator, and solar arrays. The battery allows autonomous operation by compensating for the difference between power production and use. The power management center regulates power production from each of the sources, controls power use by classifying loads, and protects the battery from service extremes[1].

1.1. *AC and DC Microgrid*

Microgrid is defined as a cluster of distributed generation sources, distributed storage devices and distributed loads that operate so as to improve the reliability and quality of the local power supply and of the power system in a controlled manner [3]. The microgrid concept naturally arose to cope with the penetration of renewable energy sources, which can be realistic if the final user is able to generate, store, control and manage part of the energy that it will consume [2]. The power connection between microgrid components, i.e. distributed generation sources, storages and loads, can be done through a direct current (DC) link or an alternating current (AC) link. A microgrid is defined as an independent distribution network comprising various DGs, energy storage systems (ESSs), and controllable loads. There are two different microgrid concepts: the AC microgrid and the DC microgrid. Most systems adopt the AC microgrid concept, because it can utilize existing AC grid technologies, protection schemes, and standards. However, the DC microgrid concept has been introduced as the more suitable interconnection concept for DC loads and DC output DGs, such as photovoltaic systems, fuel cells, and batteries [3].

The power connection between microgrid components can be done through a DC link or an AC link. Many nonconventional energy sources generate low-voltage DC power, e.g. photovoltaic panels, fuel cells etc. Most of these sources supply power to an AC utility grid and require costly and inefficient power converters, even where the power may ultimately be delivered to a DC device. However, power transmission through a low-voltage DC link produces more losses than transmission through a high-voltage AC link. With development of a microgrid control methods along with cost-effective and efficient power converters, a DC link microgrid can become a promising solution for integrating distributed generation sources, storages and loads. Adding intelligence to a DC microgrid controller further enables consumer engagement with utility grid through smart metering and ultimately with dynamic demand management and this could reduce costs associated with periods of high and low power consumption [1s].

The dynamic interaction between the load demand and the renewable energy source can lead to critical problems of stability and power quality that are not very common in conventional power systems. Therefore, managing the flow of energy throughout the hybrid system is essential to increase the operating life of the membrane and to ensure the continuous energy flow. The dynamic simulation model is described for a hybrid power system consists of a PV panels, wind turbine, PEM fuel cell, lithium-ion (Li-Ion) battery bank, and dc-dc and dc-ac converters.

2. DYNAMIC MODELING OF HYBRID SYSTEM

In this section, the dynamic simulation model is described for a hybrid power system consists of a PV panels, wind turbine, PEM fuel cell, lithium-ion (Li-Ion) battery bank, and dc-dc converters. The mathematical models describing the dynamic behavior of each of these components are given below.

2.1 Solar photovoltaic

A solar cell is basically a p-n junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation.

The photovoltaic panel can be modeled mathematically as given in equations.

Module photo-current:

$$I_{ph} = [I_{scr} + K_i(T - 298)] * \lambda / 1000 \qquad (1)$$

Modules reverse saturation current - Irs:

$$I_{rs} = I_{scr} / [\exp(qV_{oc} / N_s kAT) - 1] \qquad (2)$$

The module saturation current Io varies with the cell temperature, which is given by

$$I_o = I_{rs} \left[\frac{T}{T_r} \right]^3 \exp \left[\frac{qEgo}{Bk} \left\{ \frac{1}{T_r} - \frac{1}{T} \right\} \right] \qquad (3)$$

The current output of PV module is

$$I_{pv} = N_p I_{ph} - N_p I_o \left[\exp \left\{ \frac{qV_{pv} + I_{pv} R_s}{N_s AkT} \right\} - 1 \right] \qquad (4)$$

Where $V_{pv} = V_{oc}$, $N_p = 1$ and $N_s = 36$

A Solar photovoltaic of 2.5KW with an open circuit voltage of 43.2 V with dc to dc boost converter for an output voltage of 211 V is designed. Maximum power from the solar photovoltaic is continuously tracked with a perturb and observe mppt algorithm. These are all modeled in Matlab Simulink software.

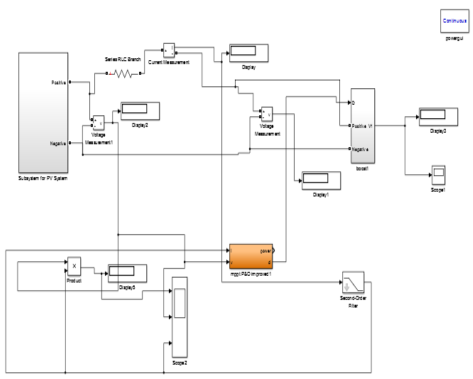

Fig. 1. Solar Photovoltaic with boost converter

2.2 Wind Turbine

The wind energy component will make a more significant contribution in the hybrid system than solar energy. Although the energy produced by wind during night can be used directly without storage. The proposed WT model is based on the wind speed versus WT output power characteristics. The output power of the wind turbine is given by

$$P_m = C_p(\lambda, \beta) \frac{\rho A}{2} \upsilon^3 \qquad (5)$$

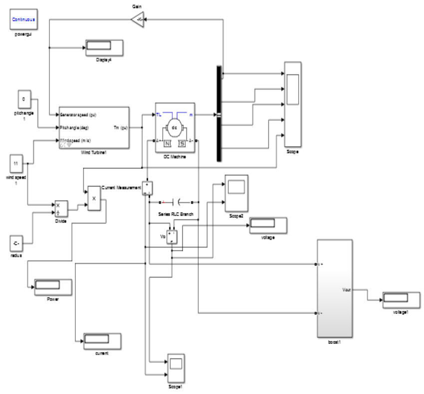

Fig. 2. Wind turbine induction generator with boost converter

2.3 Fuel Cell

Alternate energy conversion systems such as PV panels and wind turbines can be combined with FC power plants to satisfy sustained load demands. An FC power plant uses hydrogen and oxygen to convert chemical energy into electrical energy. In this study, among the various types of FC systems, a Proton Exchange Membrane (PEM) FC power plant is used because PEMFC power plants have been found to be especially suitable for hybrid energy systems since they have low operating temperature (80-1000 ^{0}C) and fast startup. Moreover, PEMFC is suitable for using the hydrogen produced from the electrolysis of water since hydrogen is free from any carbon monoxide [4].

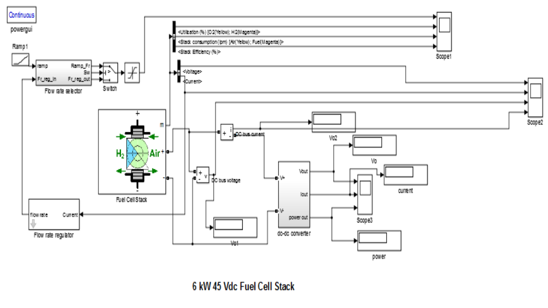

Fig. 3. 6KW Fuel cell with boost converter

2.4 Lithium –ion Battery

Batteries are the main technology to be used when continuous energy supply is vital, whereas technologies such as flywheel and super capacitors are more suited to power storage applications and where very brief power supply is required. The use of lithium-ion batteries currently is predominant in the portable electronics market, their use for automotive and renewable energy storage applications is very plausible in the not so distant future.

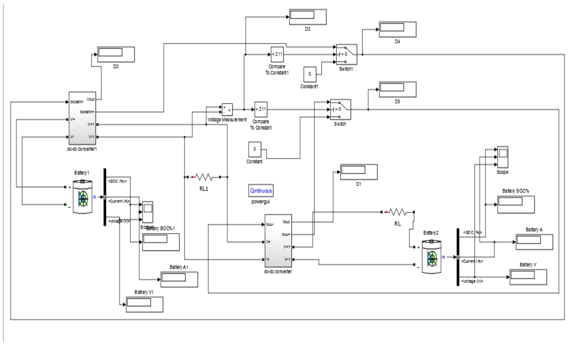

Fig. 4.Lithium-ion battery with control system

3. ENERGY MANAGEMENT IN HYBRID POWER SYSTEM

For the study, the hybrid power system consists of 2.5 KW Solar photovoltaic, 3.2 KW wind turbine induction generator, 6KW fuel cell and Lithium –ion battery with a capacity of 6.5 Ah.

The energy management strategy (EMS) should determines the split power between the photovoltaic, wind turbine, fuel cell stack and battery while satisfying the load power requirement with respect to dynamic restrictions to the battery and fuel cell stack. Frequent power demand variations and unpredictable load problem are unavoidable. Adding to this, the nonlinear subsystems add to the complexity of the structure of hybrid system. So an advance fuzzy expert system according to the weather variations, load demand and SOC is presented. Fig 3.2 shows the proposed fuzzy expert system.

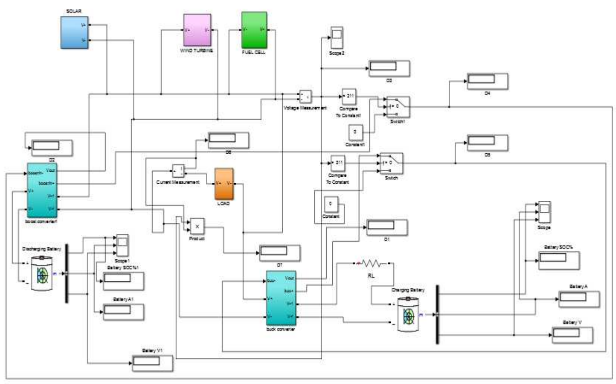

Fig. 5. Hybrid power system with dc loads

A fuzzy logic controller (FLC) is used to decide the optimum operation of the PEMFC/battery system. There are five possible operating modes they are Hybrid mode, Battery mode, Hybrid power recharge mode, Fuel cell recharge mode and Fault mode.

The battery management system maintains the SOC at a reasonable level (40%-80%). Also, it protects against voltage collapse by controlling the power level required from the battery (PB). An SR flip-flop type has been used for storing battery status (BS). The power management system controls the reference power of the PEMFC stack (FCP ref) by splitting the power demand (PL) as a function of the available power of the battery and the PV/WT system (PH). The FLC relates the outputs to the inputs using a list of if then statements called rules [1]. The if part of the rules describes the fuzzy sets (regions) of the input variables. In this, the fuzzy variables PH, PL, and SOC are described by fuzzy singleton, i.e. the measured values of these variables are used in the interface process without being fuzzified and degrees of membership are evaluated to obtain the output controller, and the then parts of all rules are averaged and weighted by these degrees of membership.

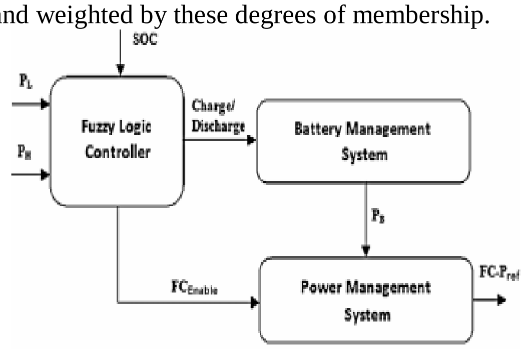

Fig. 6.Lithium-ion battery with control system

4. CONCLUSION

The main objective of the work is to manage the power flow between a standalone hybrid power system and energy storage elements in order to satisfy the load requirements, and to maintain the battery state of charge at a reasonable level. For this work, Energy management strategies of hybrid power system were studied. Modeling of Hybrid power system were completed in matlab Simulink. Performances of the different components were obtained with different load condition and weather conditions.

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