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On Recent Advances in Electrical Engineering

Sustained power generation by Dynamic Modelingof wind/fuel cell/ultra-capacitor-based hybrid power generation system

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ABSTRACT :*The world has turned its focus towards renewable energy sources due to the depletion of fossil fuels. Nuclear energy seems to hold the long term solution to this energy problem. However we know that nuclear energy has its own downfall in the production and the disposal of the radioactive waste produced. Wind energy and solar energy have gained considerable importance. The main problem associated with wind energy is that, due to unpredictable and varying wind speed, the system cannot be used to supply a constant load demand. This also leads to problems in attaching the wind generation system to a common bus. To overcome this problem schemes with fuel cell, ultra capacitor stack acts as an auxiliary energy source. This energy source is used to supply the power demand during lack of wind. Among the various types of FC systems, proton exchange membrane (PEM) FC power plants have been found to be especially suitable for hybrid energy systems with higher power density and lower operating temperature. However, assisting an FC power plant with a parallel ultra-capacitor (UC) bank makes economic sense when satisfying the peak power demands or transient events. In this work, a detailed dynamic model, design and simulation of a wind/FC/UC-based hybrid power generation system along with Fuzzy Controller is proposed. Modeling and simulations will be performed using MATLAB, Simulink and SimPowerSystems software packages to verify the effectiveness of the proposed system. This work is very exhaustive and we have to build several models working in integrated fashion to achieve task of generation as well as control. The parameters of simulation will be taken from existing case studies.*

Keywords- *Dynamic model, Fuel cell, fuzzy Logic,hybrid power generation, Wind power*

I. INTRODUCTION

Wind as a type of renewable energy has received considerable attention for producing electricity because of its cost competitiveness in comparison with other types of energy which are conventionally used for power generation. Wind is a free and abundant source of energy and hence, is attractive in terms of the cost and energy security. However, wind is in nature intermittent and its energy has a large range of variations. This causes significant technical challenges for a wind energy conversion system, particularly when compared with the conventional energy Sources which have a controllable output power. Wind energy is the world’s fastest growing energy source, expanding globally at a rate of 25–35% annually over the last decade. The main disadvantage of wind turbines is that naturally variable wind speed causes voltage and power fluctuation problems at the load side. This problem can be solved by using appropriate power converters and control strategies.

Another significant problem is to store the energy generated by wind turbines for future use when no wind is available but the user demand exists. This is achieved by storing the energy generated by the wind by passing it through an electrolyzer. This electrolyze splits water into hydrogen and oxygen. The hydrogen produced is then stored inside hydrogen storage tanks which can be later used. The generated hydrogen is then used as input to the fuel cell. Fuel cells produce a DC voltage corresponding to the input hydrogen. Thus the fuel cell is used as an auxiliary energy source. The concept of storing the excess wind energy as hydrogen is new and it is significant because hydrogen storage has higher energy density when compared to the use of a conventional battery.

By using an electrolyzer, hydrogen conversion allows both storage and transportation of large amounts of power at much higher energy densities. FC power plants use oxygen and hydrogen to convert chemical energy into electrical energy. Among the various types of FC systems, proton exchange membrane (PEM) FC power plants have been found to be especially suitable for hybrid energy systems with higher power density and lower operating temperature. However, assisting an FC power plant with a parallel ultra-capacitor (UC) bank makes economic sense when satisfying the peak power demands or transient events. Ultra-capacitors are electrical energy storage devices with extremely high capacitance values (a few Farads to several thousand Farads per cell) offering high energy densities when compared to conventional capacitors. Without the UC bank, the FC system must supply all power demand thus increasing the size and cost of the FC power plant.

This proposed work introduces a wind conversion system with integrated energy storage. The energy storage serves as an auxiliary source for the wind conversion system during dynamics resulted from the wind power fluctuations and/or load changes. A control strategy will be developed that manages the flow of power among the wind-turbine generator, energy storage and the grid, so as the overall wind conversion system is turned into a dispatchable power source.

II. RESEARCH METHODOLOGY

We are going to simulate hybrid power generation consisting of Wind, Fuel Cell and Ultra Capacitor Bank. These power generations have their own equations and parameters. Following model as reported by O.C. Onar, M. Uzunoglu, M.S. Alam, works on the hybrid power generation of wind/fuel cell/ultra-capacitor to make sustained power generation for remote areas where power is not easily available. Here we will simulate the hybrid power system using MATLAB SIMULINK and SIMPOWERSYSTEM. Later on Fuzzy controller will also be incorporated in the scheme for control using certain parameters such as load demand, and technical and economical parameters to improve performance of hybrid power generation.

The dynamic system model is described for the wind/ fuel cell auxiliary storage. The system consists of a wind turbine which is coupled to an asynchronous induction generator. The generator is then connected to a double bridge thyristor controlled rectifier which is fired by pulses from a discrete pulse width generator. This forms the DC bus to which the electrolyser is connected. The electrolyser is then connected to the hydrogen storage system. The hydrogen storage system is connected to the fuel cell and ultra-capacitor stack. Two IGBT controlled inverters are employed for inverting the DC voltage. This is then supplied to the load. The entire system is depicted as shown in the above Fig1.

The main idea of fuzzy logic controller implemented in control loop is to ensure maximum energy efficiency by maximizing captured wind power. In order to achieve that, tracking control of optimal rotor speed must be ensured. Tuning of the parameters for the *low*, *average* and *high* generator torque *Tem* is done by expert knowledge and after many simulation trials.

Switches for connection can be controlled by Fuzzy Logic for addition or elimination of different power generating modules. Hence injection of power will be done in a smart fashion.

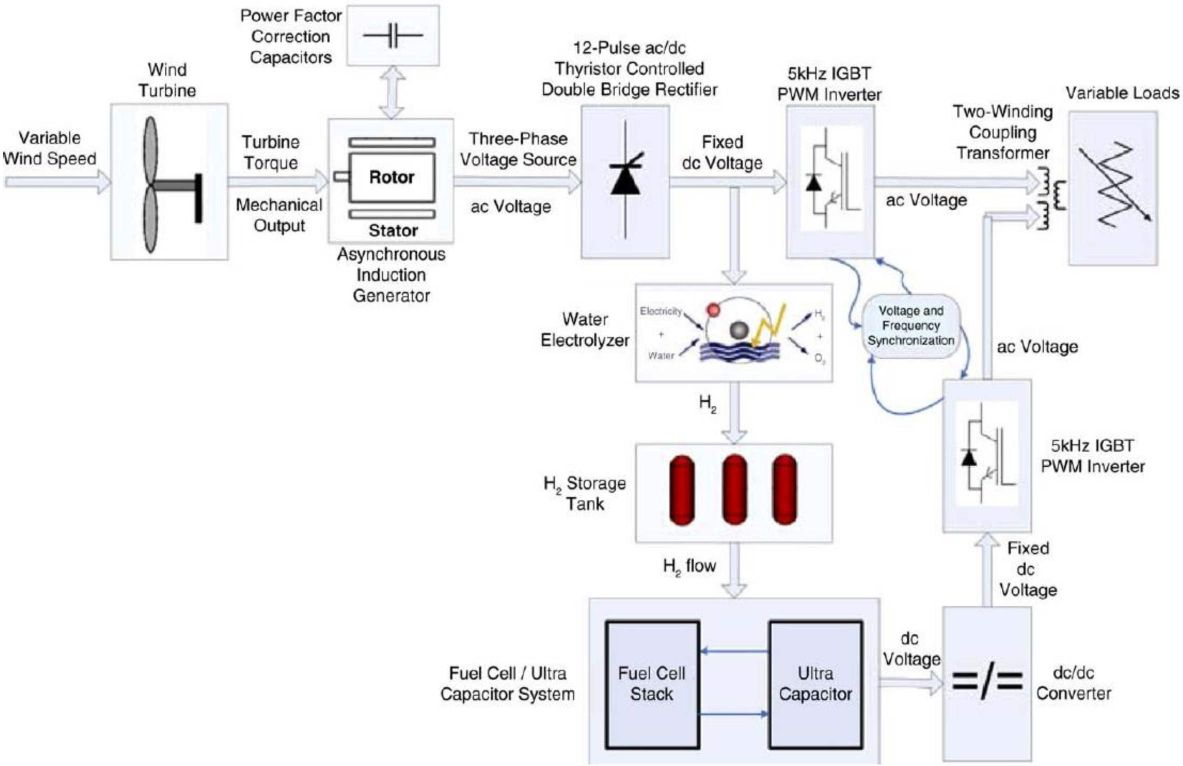

Fig1. block diagram of proposed system

We will be simulating models as per [15].Wind Power model will be implemented by blocks available in Simulink Library of MATLAB.The following model has a equation which will be discussed during the course of research work.

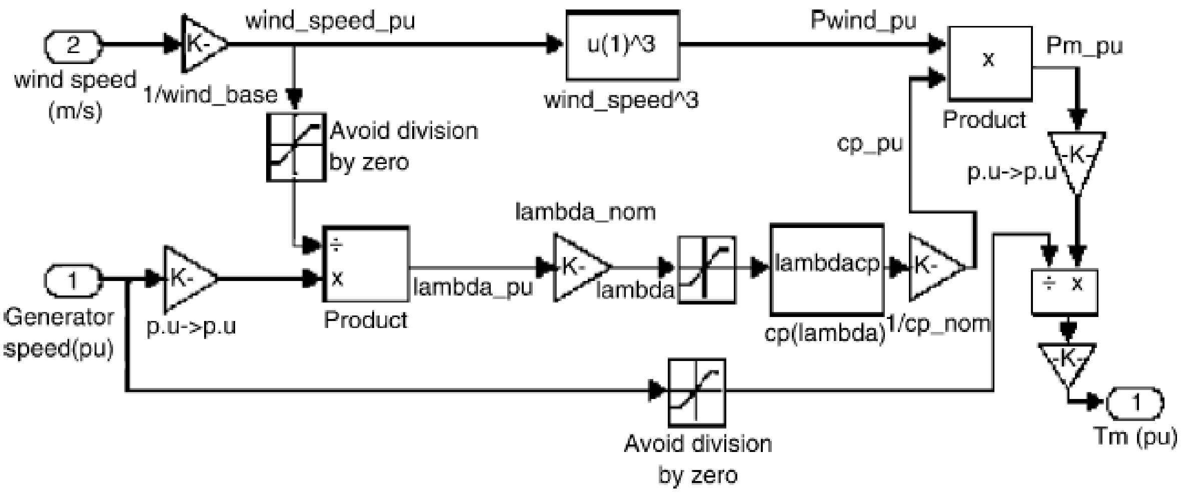

Fig.2. Simulink model of wind turbine

According to Faraday's law, hydrogen production rate of an electrolyzer cell is directly proportional to the electrical current in the equivalent electrolyzer circuit.

nH2= <u>*nFnci*e</u>

2*F*

*F*Faraday's constant [C kmol]*i*e electrolyser current [A]

nc the number of elctrolyser cells in series

nF Faradays efficiency

nH2 produced hydrogen moles per second

The equation of electrolyser will also be modeled as shown by Diagram below.

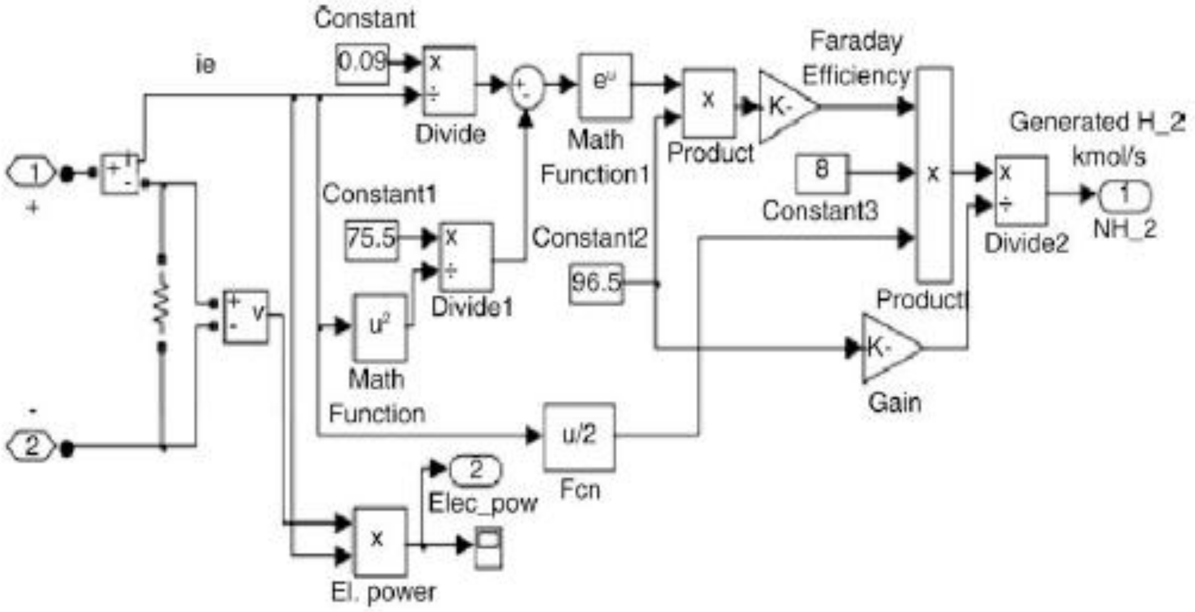

Fig.3. The Simulink model of electrolyser

In this research work, a detailed dynamic model, design and simulation of a wind/FC/UC-based hybrid power generation system will be developed using a novel topology to complement each other and to alleviate the effects of wind speed variations. The dynamic PEMFC/UC hybrid power system model reported in [15] will be modeled for this study, and integrated with the wind turbine, generator, electrolyzer and storage models. Modeling and simulations will be performed using MATLAB, Simulink and Sim Power System software packages to verify the effectiveness of the proposed system. Performance of the wind conversion system will be evaluated under the presence of fuzzy controller for improvement in performance.

Some work has been reported in the literature on steady-state fuel-cell modeling, as well as dynamic modeling. These studies are mostly based on empirical equations and/or the electrochemical reactions inside the fuel cell. In recent years, attempts have been made to study the dynamic modeling of fuel cells with emphasis on the electrical terminal characteristics [12],[13] and [15].

At last we will be using Fuzzy Logic Controller to improve performance under dynamic condition of operation like an expert. Rules will be framed in it which will be like managing hybrid power under different conditions. This will enhance the objective of design of such integrated scheme.

Managing the flow of energy throughout the proposed system to assure continuous supply of the load demand will be done. The main objective of the power management system is to supply the load with its full demand while monitoring the pressure in the hydrogen tank (hydrogen threshold pressure ‘‘PTH’’). Such aim will be achieved through the following steps:

1. Monitoring the state of the stored hydrogen, as well as that of the wind and solar power generated and comparing them with the load demand.
2. Issue Fuzzy Logic based controller commands to the fuel cells control valves and the control circuits to control the power flow to the load.
3. Issue Fuzzy Logic based controller commands to operate the electrolyzer in order to use the excess energy to generate hydrogen for future use, i.e. when needed.

III. RESULTS

Following results were obtained from simulation of hybrid system with the effect of switching Fuel cell and Ultra Capacitor at Variable Load Demand. They work hand in hand to meet load demand as and when required by fuzzy logic controller.

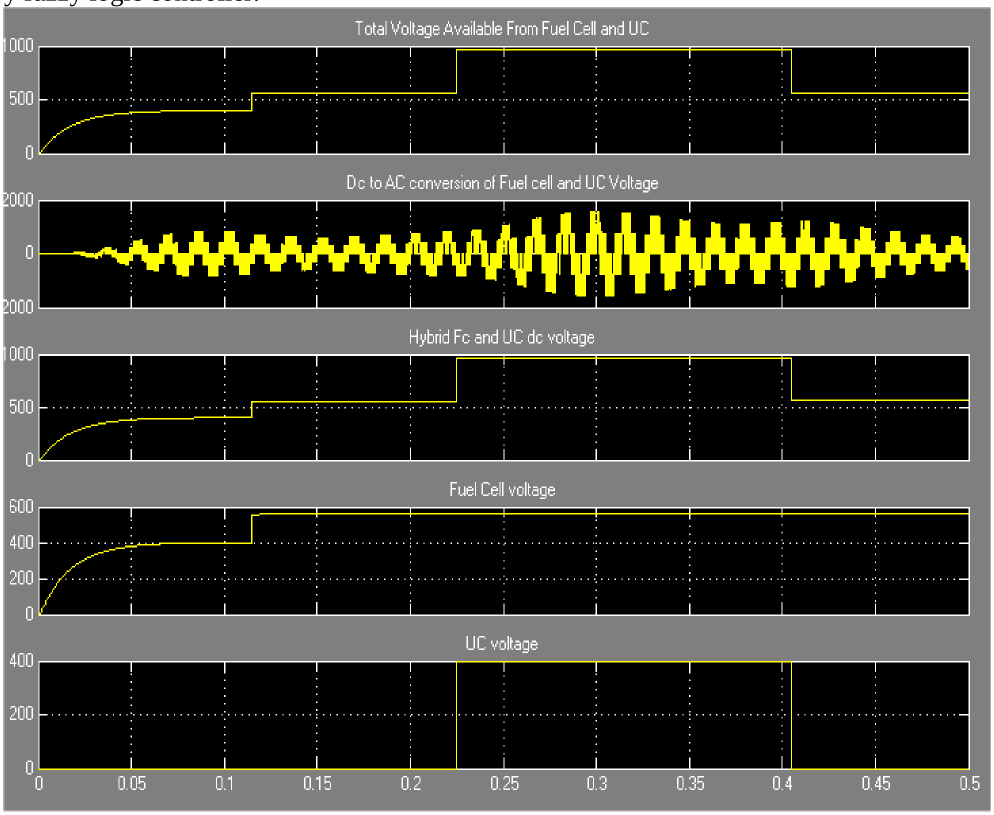

Fig Hybrid addition and removal of Fuel Cell and Ultra Capacitor Voltage as and when required

III. CONCLUSION

In this work a new method of combating the fluctuations of the wind speed from affecting the system is developed by using a combined hybrid system comprising of an electrolyzer, hydrogen storage mode land a fuel cell ultra capacitor stack. The components will be modeled in the Sim Power System blocks of MATLAB Simulink. The simulations will be carried out for certain finite time with a change in the wind speed. This hybrid topology exhibits excellent performance under variable wind speed and load power requirements. The proposed system can be used for non-interconnected remote areas or isolated cogeneration power systems with non-ideal wind speed characteristics. When the produced energy is greater and the loads are low, the wind turbine must be arranged to produce hydrogen at fuel cell and produced energy will be stored to supply when necessary and control of power supply will be done in smart fashion. Fuzzy logic controller will be an added feature which will improve control aspect of complete integrated system. This controller works like human expert on which complete management of power system relies.

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