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ENHANCING WIND/FUEL CELL HYBRID ENERGY SYSTEM

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Abstract- This paper describe of a renewable energy based hybrid energy system with MATLAB implementation results. In order to meet sustained load demand during varying natural conditions, different renewable energy sources need to be integrated with each other. This paper focuses on the combination of wind/fuel cell hybrid energy system. As wind turbine output power varies with wind speed & FC systems can be integrated to ensure that the system performs under all conditions. The result show that the proposed hybrid energy system can be tolerate the rapid change in natural condition and suppress the effect of the fluctuation on the voltage wind turbine the acceptable range.

Keywords*- component; hybrid renewable energy sources and MATLAB programing.*

I. INTRODUCTION

Energy is vital for the progress of a nation and it has to be conserved in a most efficient manner. Not only the technologies should be developed to produce energy in a most environment-friendly manner from all varieties of fuels but also enough importance should be given to conserve the energy resources in the most efficient way. Energy is the ultimate factor responsible for both industrial and agricultural development. The use of renewable energy technology to meet the energy demands has been steadily increasing for the past few years, however, the important drawbacks associated with renewable energy systems are their inability to guarantee reliability and their lean nature. Import of petroleum products constitutes a major drain on our foreign exchange reserve. Renewable energy sources are considered to be the better option to meet these challenges.

More than 200 million people, live in rural areas without access to grid-connected power. In India, over 80,000 villages remain to be un-electrified and difficult to supply electricity due to inherent problems of location and economy. The costs to install and service the distribution lines are considerably high for remote areas. Also there will be a substantial increase in transmission line losses in addition to poor power supply reliability. Like several other developing countries, India is characterized by severe energy deficit. In most of the remote and non-electrified sites, extension of utility grid lines experiences a number of problems such as high capital investment, high lead time, low load factor, poor voltage regulation and frequent power supply interruptions. There is a growing interest in harnessing renewable energy sources since they are naturally available, pollution free and inexhaustible. It is this segment that needs special attention and hence concentrated efforts are continually provided in implementing hybrid renewable energy system. Traditionally, electrical energy for remote villages has been derived from diesel generators characterized by high reliability, high running costs, moderate efficiency and high maintenance. Hence, a convenient, cost-effective and reliable power supply is an essential factor in the development of any rural area. It is a critical factor in the development of the agro industry and commercial operations, which are projected to be the core of that area's economy.

At present, wind systems and FC system have been promoted around the globe on a comparatively larger scale.

II. WIND ENERGY

A. Wind Farm

Wind farms are the areas of land which are mainly used for developing wind power. They have 5 to 50 units. These areas have continuous steady wind speed range of 6 m/s to 30m/s. Annual average wind speed of 10m/s are considered very suitable.

B. Wind Energy Density

Power density of wind is proportional to cube of velocity, i.e.

$$\mathbf{P_w = k.\ v^3 = 0.6386.\ v^3}$$

If A is the swept area of a wind turbine,

$$\mathbf{P = P_w\ A}$$

C. Energy in wind

Energy is time integral of power. Energy in 'n' hours is given by

E=p.dh watt-hour

Area under P-h curve of the wind turbine gives the energy output of the wind turbine.

D. Efficiency Factor of wind turbine

Efficiency of the wind turbine is given by the ratio,

$$\eta = \frac{\text{Energy o/p by turbine}}{\text{Energy of wind}}$$

Power in a wind stream

A wind stream has total power given by

$$\mathbf{P_t = m.\ (K.E._w) = mV^2_i\ (watt)} \quad \textbf{(1)}$$

Where m=mass flow rate of air, kg/s and V_i= incoming wind velocity, m/s
Air mass flow rate is given by

$$\mathbf{m = \rho A V_i} \qquad \textbf{(2)}$$

Where **ρ** = Density of incoming wind, kg/m² = 1.226 kg/m² at 1 atm., 15 ºC, A = Cross-sectional area of wind stream, m² Substituting the value of 'm' from **(2)** into **(1)**, we get

$$\mathbf{P_t = 1/2\ \rho A V_i^3} \qquad \textbf{(3)}$$

Thus, total power of a wind stream is directly proportional to
1. Density of air, **ρ**
2. Area of stream, **A**
3. Cube of velocity, $\mathbf{V_i}$

Hence the blades of rotor should be long so that the swept area A = Π $D^2/4$ is large

E. Efficiency of a practical propeller type wind turbine
The maximum efficiency of a propeller type wind turbine is 59%. Actual efficiency,

$$\mathbf{\eta_a = (0.5\ to\ 0.7)\ \eta_{max} = 0.6 \times 59 = 35.4\%}$$

F. Effect of height on the wind velocity

In flat, open areas away from cities and forests, the wind speed increases with approximately one seventh power of the height from ground is $\mathbf{V=H^{1/7}}$

This relation is valid for the heights between 50m and 250m.The wind velocity duration curve is drawn with number of hours of wind duration per year on X-axis to wind velocity on Y-axis.

III. WIND TURBINE

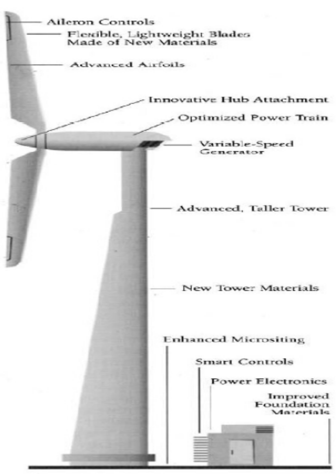

Fig. 1 WindTurbine

G. Wind turbine generation unit
A wind turbine generator consists of the following major units

- Wind turbine with Horizontal or Vertical axis.
- Gear chain
- Electrical generator (Synchronous or Asynchronous generator)
- Civil, electrical and mechanical auxiliaries, control panels etc.

H. Mono-blade horizontal axis wind turbine (HAWT)
Features:

- They have lighter rotor and are cheaper.
- Blade are 15-25 m long and are made up of metal, glass reinforced plastics, laminated wood, composite carbon fiber/ fiberglass etc.
- Power generation is within the range 15 kW to 50 kW and service life of plant is 30 years.

I. Twin-blade HAWT

- They have large sizes and power output in range of 1 MW, 2 MW and 3MW.
- These high power units feed directly to the distribution network.

J. 3-Blade HAWT

- 3 blade propeller type wind turbines have been installed in India as well as in abroad.
- The rotor has three blades assembled on a hub. The blade tips have a pitch control of 0-30 º for controlling shaft speed. The shaft is mounted on bearings
- The gear chain changes the speed from turbine shaft to generator shaft.

IV. COMPARISON OF VOLTAGE PROFILE OF AN AREA BEFORE AND AFTER THE INTRODUCTION OF A WIND ENERGY PLANT (A MATLAB BASED APPROACH)

Problem Statement:
Output of wind farm is not at constant voltage. Also depending on the operating conditions the induction generators installed at wind farms absorb or deliver reactive power. This causes unbalance in the grid to which the wind power plant is connected. The effect of introducing wind energy system or plant in the grid has been presented by a MATLAB Program. The results of output have been presented for a general system.

Approach:

1. Based on Gauss-Seidel method, a load flow study was formulated.
2. Individual bus admittance values were used to form admittance matrix.
3. Bus 1 was taken as slack bus &Buses 2 & 3 were load buses.
4. Bus 4 was a generator bus connected to a wind farm.
5. Wind farm is an area where a large number of wind mills are installed.
6. The wind farm was considered to have 1000 wind mills.
7. Active power output depended on cube of velocity.

8. Since velocity is a stochastic variable, I limited its value within lower and upper bound to perform analysis. The velocity bounds were obtained from past analysis of weather data of the region and were 8 m/s to 20 m/s. Random velocity was generated within the bounds using rand function.

V. OUTPUT OF PROGRAM

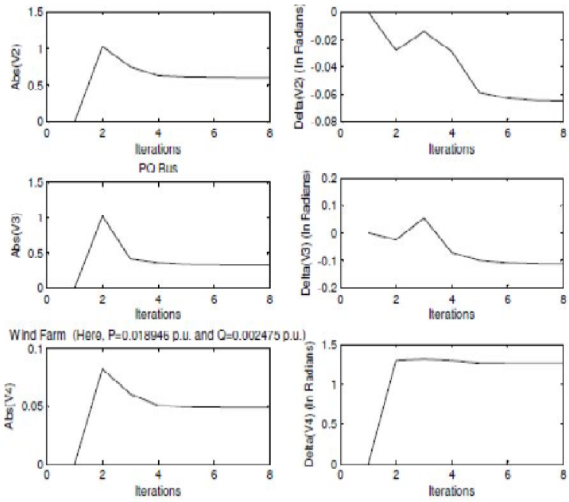

Fig. 2 WindTurbine output

VI. FUEL CELL BASIC

A fuel cell is a device that uses hydrogen as fuel to produce electron, protons, heat and water. Fuel cell technology is based upon the simple combustion reaction given in equation below.

$$2H_2 + O_2 \leftrightarrow 2H_2O$$

K. History of fuel cell technology

The origin of fuel cell technology is credited to **Sir William Robert Grove (1811-1896).** Grove was educated at Oxford and practiced patent law also studying chemistry. Grove developed an improved wet-cell battery in 1838 which brought him fame. Using his research and knowledge that electrolysis used electricity to split water into hydrogen and oxygen he concludes that the opposite reaction must be capable of producing electricity. Using this hypothesis, Grove developed a device which would combine hydrogen and oxygen to produces electricity. Grove had developed the world's first gas battery. It was this gas battery which has become known as fuel cell.

L. Polymer electrolyte membrane fuel cell

PEM fuel cells use a proton conductive polymer membrane as an electrolyte. PEM stands for Polymer Electrolyte Membrane or Proton Exchange Membrane. Sometimes they are also called polymer membrane fuel cells, or just membrane fuel cells. In the early days (1960s) they were known as Solid Polymer Electrolyte (SPE) fuel cells.

This technology has drawn the most attention because of its simplicity, viability, quick startup and it has been demonstrated in almost any conceivable application, from powering a cell phone to a locomotive.

At the heart of a PEM fuel cell is a polymer membrane that has some unique capabilities. It is impermeable to gases but it conducts protons (hence Proton Exchange Membrane name). The membrane, which acts as the electrolyte, is squeezed between the two porous, electrically conductive electrodes. These electrodes are typically made out of carbon cloth or carbon fiber paper. At the interface between the porous electrode and the polymer membrane there is a layer with catalyst particles, typically platinum supported on carbon. A schematic diagram of cell configuration and basic operating principles is shown in Figure. Electrochemical reactions occur at the surface of the catalyst at the interface between the electrolyte and the membrane. Hydrogen which is fed on one side of the membrane splits into its primary constituents – protons and electrons. Each hydrogen atom consists of one electron and one proton. Protons travel through the membrane, while the electrons travel through electrically conductive electrodes, through current collectors and through the outside circuit where they perform useful work and return to the other side of the membrane. At the catalyst sites between the membrane and the other electrode they meet with the protons that went through the membrane and oxygen that is fed on that side of the membrane. Water is created in the electrochemical reaction and then pushed out of the cell with an excess flow of oxygen. The net result of these simultaneous reactions is current of electrons through an external circuit direct electrical current. The hydrogen side is negative and is called the anode, while the oxygen side of the fuel cell is positive and is called the cathode. The electrochemical reactions in fuel cell happen simultaneously on both sides of the membrane the anode and the cathode. The basic fuel cell reactions are:

$$2H_2 + O_2 \leftrightarrow 2H_2O$$

M. Cell components

Typical cell components within a PEFC stack include:

- The ion exchange membrane.
- An electrically conductive porous backing layer.
- An electro-catalyst (the electrodes) at the interface between the backing layer and the membrane
- Cell interconnects and flow-plates that deliver the fuel and oxidant to reactive sites via flow channels and electrically connect the cells.

PEFC stacks are almost universally of the planar bipolar type. Typically, the electrodes are cast as thin films that are either transferred to the membrane or applied directly to the membrane. Alternatively, the catalyst-electrode layer may be deposited on to the backing layer, and then bounded to the membrane.

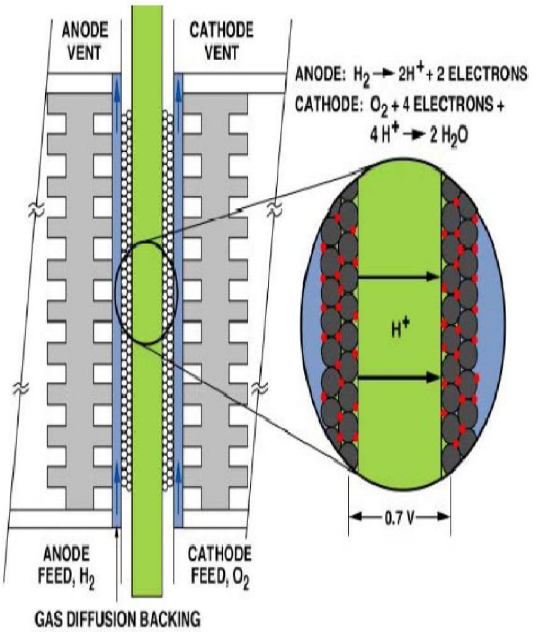

Fig. 3 Schematic of PEFC

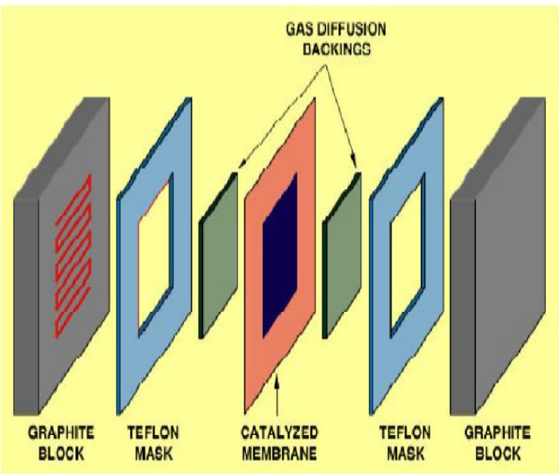

Fig.4 Sigle Structure of PEFC

N. Fuel cell challenge

- Cost Reduction
- System Integration
- Reliability

O. MATLAB implementaion of PEM fuel cell

- Program to study variation of ohmic loss with electrolyte thickness
- Program to calculate the ohmic losses as a function of fuel cell area
- MATLAB code to calculating ohmic voltage loss due to the membrane

P. Output of MATLAB implantation of PEM fuel cell

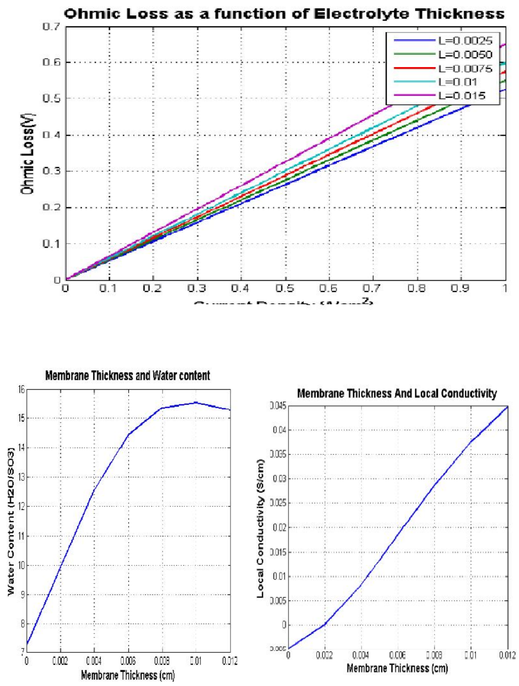

Fig. 5 Output of PEM

S. Output of MATLAB implantation of Wind energy

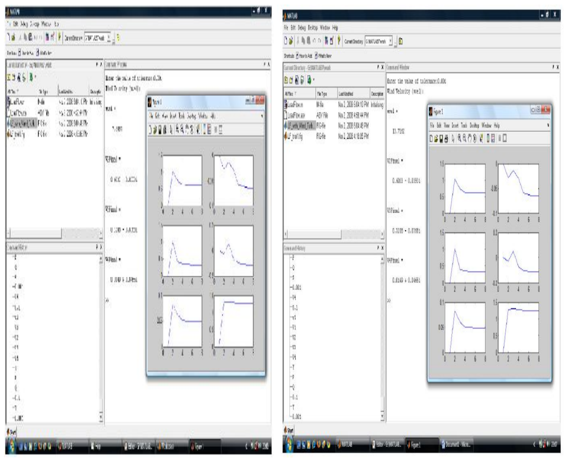

Fig. 6 Output of Wind Energy

VII. CONCLUSION

In this paper, a novel renewable energy based system hybrid energy system is proposed MATLAB based implementation. The available power from the renewable energy sources is highly dependent on environmental conditions such as wind speed, suitable conditions of PEM fuel cell to overcome this aspects, we integrate them wind/fuel cell system using a novel topology. The output is found to be within acceptable range. The output fluctuation of the wind turbine varying with wind speed and used fuel cell as support. Therefore, this system can tolerate the rapid change in load and environmental conditions. This hybrid topology exhibits excellent performance under different wind speed. The proposed system can be used for non-interconnected area or remote isolated communities.

VIII. ACKNOWLEDGMENT

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