ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Evaluation of Grid Dependant-Pem Fuel Cell Using Matlab

Sakthi S, Rajarajeswari.P, Sasikumar M, Sridevi V
Department of EEE, Jeppiaar Engineering College
***Corresponding author: E-Mail:sakthis0703@gmail.com**

ABSTRACT

Wind energy is clean, renewable, and often rises to the top of the list when considering "green" energy alternatives. Many challenging issues also arise when considering wind energy. The biggest issue, some say, is that wind energy is not reliable, dependable, or consistent enough to be taken seriously; any more than on small scale applications. Due to the inconsistent nature of wind, it cannot be a contributor for base load energy production. The industry has, and is currently addressing this issue of "intermittent" power generation from wind by means of energy storage. That is to say, produce the energy when the opportunity arises and store the energy for later use when demand levels increase. Energy storage technology has been continuously being developed for various types of renewable energy. The two primary energy platforms this applies to is wind and solar. Wind doesn't blow 24/7 nor does the sun always shine. In order to overcome these drawbacks, the following modification required in our traditional wind mill structure is by placing hydrogen storage compartment in a turbine tower, the plant could produce hydrogen through an electrolyser when there is excess wind energy available, and then provide electricity to domestic customers via a fuel cell and a hydrogen combustion engine. The proposed solution will be especially useful in areas with insufficient power production or insufficient electricity infrastructure. For instance, stored hydrogen can be used to provide back-up/emergency power or to secure a more reliable and higher quality power supply.

KEY WORDS: Electricity supply system, wind power, hydrogen production, functional assessment

I. INTRODUCTION

Since the wind power is climate-dependent, its power output is not stable In the case of large-capacity wind farms, sudden changes of electricity output can lead to instability in the power system . Thus, the large-scale wind-power system which connected with the existing power grid has the following problems: When the wind drops below a lower limit or goes above a higher limit, the turbine will be shut down and electricity is not produced; Energy is not stored when there is an excess of electricity generated on-site. Because of these problems, wind power has a very low-capacity credit, and backup power is needed to handle large fluctuations in production. To enhance wind power stability and reduce the effect of wind power fluctuations on the power grid, adding an energy-storing installation into the large-scale wind power system has become a key issue of technological research.

An energy-storage system used in a wind turbine system as a power and energy buffer can smooth the power output fluctuations from a wind farm and remedy the volatility of wind energy. The possible solutions for wind energy storage include flywheels, capacitors, upper conducting magnetic energy storages, batteries, compressed air energy storages, hydro pump stations, and hydrogen .The main advantage of integrating wind power with hydrogen energy can be explained as follows: The power generated from wind turbines is applied in electrolyzing water to produce hydrogen, thereby converting and storing wind energy as hydrogen. When the wind turbines are unable to generate power or output weak power, the produced hydrogen can then be used to generate electrical power by means of fuel cells further, the application of wind energy to produce hydrogen can be used to establish a carbon-free and sustainable hydrogen production system. In regions with sufficient wind resources, wind power may be produced at a very low cost. An energy system in which hydrogen is derived from renewable sources is self-sufficient, clean, and represents a permanent energy solution for sustainable development.

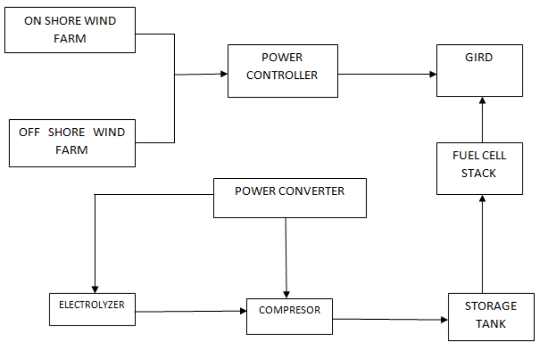

Figure.1.Block diagram of Proposed System

2. METHODS AND MATERIALS USED IN HYDROGEN SYSTEM PEM ELECTROLYZER

Hydrogen System Pem Electrolyzers: PEM electrolysis is also referred to as solid polymer electrolyte, or polymer electrolyte membrane (also PEM), and represents a system that incorporates a solid proton-conducting membrane that is not electrically conductive. The membrane serves a dual purpose: as the gas-separation device and as the ion (proton, H+) conductor. High-purity, de-ionized (DI) water is required in PEM-based electrolysis, requiring a minimum of 1 mega ohm-centimeter (MΩ-cm) resistive water that helps extend stack life. In a PEM electrolyzer, the electrolyte is contained in a thin, solid ion-conducting membrane rather than an aqueous solution as in an alkaline electrolyzer. This allows the H+ ion (proton) or hydrated water molecule (H3O+) to migrate across the membrane from the anode side of the membrane to the cathode side. It also acts as the gas separator between the hydrogen (cathode) and oxygen (anode).

The most commonly used membrane material is Nafion from DuPont. Commercially available PEM electrolyzers utilize a bipolar design and can operate at a high differential pressure (200–2000 psi typically) across the reinforced membrane. De-ionized water is typically introduced at the anode of the cells and a potential is applied across the stack to dissociate the water. The protons migrate across the membrane and rejoin with electrons supplied by the power source at the cathode to form molecular hydrogen (H2) gas. PEM electrolyzers are typically operated at current densities above 1,500 milliamps per centimeter squared (mA cm-2)—two to seven times higher than their alkaline counterparts.

Stack efficiency decreases as current density increases but is traded to increase hydrogen production to offset the higher capital costs of PEM systems. With respect to photovoltaics as an energy resource in the Wind2H2 project, the three modes of operation available for the PEM electrolyzers are: grid only, PV only and PV and grid. In PV and grid mode, the grid will supplement current to the stack when the PV array is supplying less than the rated stack current (135 A). The electrolyzer system requires a total of about 7 kW when operated in grid only mode, which includes about 500 W for ancillary loads. The largest consumer of the ancillary power is a circulation fan (~250 W) that continually forces fresh air through the generation cabinet. The system incorporates a combustible gas (CG) detector that monitors the air flow from the generation cabinet and will shut the system down if twenty-five percent of the lower flammability limit (LFL) of hydrogen in the air is reached.

Table.1. Comparison of Energy Density

Storage of wind energy	Energy Density (Mega Joules per kilogram)
Li-ion Battery	0.54
Gasoline	46.9
Hydrogen	120.0

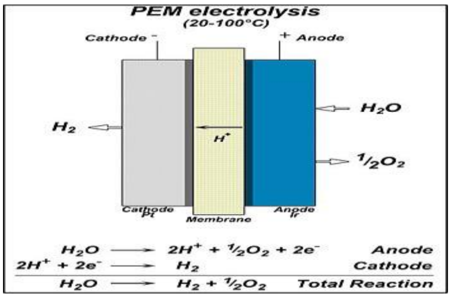

Figure.1. PEM Electrolysis

Modelling: Electrolysis of water is the dissociation of water molecules into hydrogen and oxygen gas. The electrochemical reaction of water electrolysis is given by: H_2O(liquid)+ electrical energy ⇒ H_2(gas)+1/2O_2

The rate of hydrogen reacting is directly proportional to the electrical current in the equivalent electrolysis circuit given by $H_2=\eta F n_c i_e/2F$

The relation between the real hydrogen flow rate and the theoretical one is defined as the Faraday's efficiency. In general, it is assumed to be more than 99%. The Faraday efficiency is expressed by
ηF= 96.5e $(0.09/i_e-75.5/i^2{}_e)$.

A Hydrogen Storage System. The amount of hydrogen required by the PEMFC is sent directly from the electrolyser system based on the relationship between the output power and the hydrogen requirement of the PEMFC system. The remaining amount of hydrogen is sent to the storage tank. The parameters used in the hydrogen storage system are listed in the abbreviations section. In this study, the dynamic of the storage is obtained as Follows $Pb-Pbi= ZN\mathrm{H2}RTb/M\mathrm{H2}Vb$.

Performance Analysis: The calculation method of the available power capacity for the overall wind power and hydrogen energy integrated system in different power consumption ratios of hydrogen production is as follows:

- Annual hydrogen production available power Capacity Annual power consumption for hydrogen production = annual gross power output × power consumption ratio of hydrogen production .For example: if the power consumption ratio of hydrogen production is 0.15, then the annual hydrogen production available power capacity will be 8,700,000 MWh × 0.15 = 1,305,000 MWh.
- Annual hydrogen production output and average daily hydrogen production output Annual hydrogen production output = annual power consumption for hydrogen production / (high heat value of hydrogen / ηE). For example: when the efficiency of the electrolyzer is 0.9, the annual hydrogen production output will be: 1,305,000 (MWh) / [39.33 (kWh/kg) / 0.9] = 29,863 (ton); and the average daily hydrogen production output will be 81,816 kg.
- The annual power output of a fuel cell and average daily power output The annual power output of a fuel cell = annual hydrogen production output × low heat value of hydrogen × ηFC. For example: when ηFC = 0.6, the fuel cell power output will be 29,863,000 (kg) × 33.325 (kWh/kg) × 0.6 = 597,111 (MWh); the average daily power output will be 1,635,920 kWh.
- Annual power consumption of compressor we assumed that the power consumption needed to compress 1 kg of hydrogen is 2.2 kWh. For example: When the power consumption ratio of hydrogen production is 0.15, the annual power consumption of compressor will be 29,863 ton × 1,000 (kg/ton) × 2.2 kWh/kg = 65,699 MWh.
- Annual total available power capacity for LWHIESS Annual increase available power capacity = the annual power output of a fuel cell − annual power consumption of compressor. The total available power capacity = annual gross power output × (1 − power consumption ratio of hydrogen production) + annual increase available power capacity. For example: when the power consumption ratio of hydrogen production is 0.15, the annual increase available power capacity will be 597,111 (MWh) − 65,699 (MWh) = 531,412 (MWh); the annual total available power capacity will be 8,700,000 (MWh) × (1−0.15) + 531,412 (MWh) = 7,926,412 (MWh).
- Available increase power supply capacity Annual increase power supply capacity = total available power capacity / annual power output. For example: when the power consumption ratio of hydrogen production is 0.15, the annual increase power supply capacity will be 531,412 MWh / 2,450h = 217 MW with the installed capacity of onshore wind turbines.
- Available power capacity ratio with hydrogen Production Available power capacity ratio = annual total available power capacity / annual gross power output for example: when the power consumption ratio of hydrogen production is 0.15, the available power capacity ratio will be: 7,926,412 (MWh) / 8,700,000 (MWh) = 0.911.
- Available power ratio multiplication (%) Available power ratio multiplication = (available Power capacity ratio with hydrogen production −available power capacity ratio without hydrogen production) / available power capacity ratio without hydrogen production × 100%. For example: when the power consumption ratio of hydrogen production is 0.15, the available power capacity ratio with hydrogen production will be 0.911; available power capacity ratio without hydrogen production will be 1 – 0.15 = 0.85. Thus, the available power ratio multiplication will be (0.911 – 0.85) / 0.85 × 100% = 7.18%.

3. RESULTS AND DISCUSSION

Wind _ Pem Fuel Cell

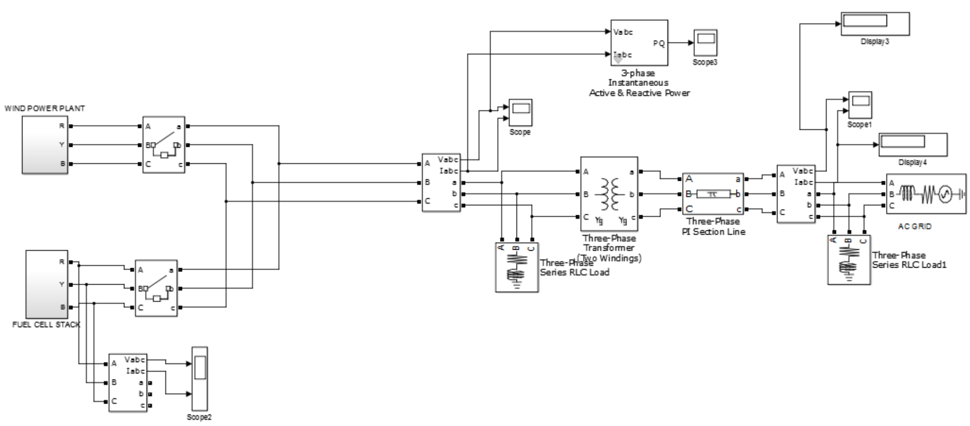

Figure.2. Hybrid power generation simulation diagram

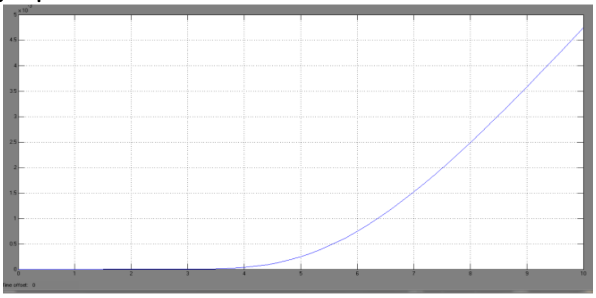

Figure.3.Electrolyzer Output

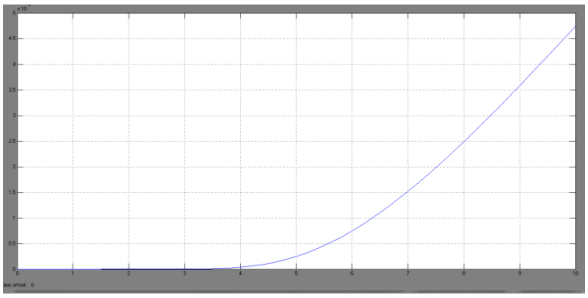

Figure.4. Storage of compressed hydrogen

The above graph shows the amount of hydrogen production with respect to time. The above graph describes about storage of compressed hydrogen with respect to electrolyzer output

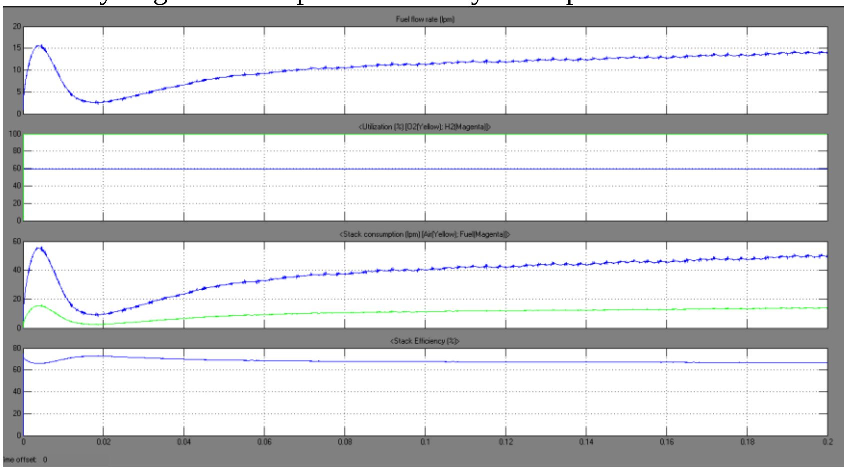

Figure.5. Fuel cell output

Figure 5. first one describes about the flow rate of hydrogen in fuel cell with respect to time. Second one describes about the utilization of hydrogen and oxygen with respect to flow rate. Third one describes about the consumption of hydrogen and oxygen with respect to flow rate. Fourth one voltage of fuel cell stack before dc-dc boost converter.

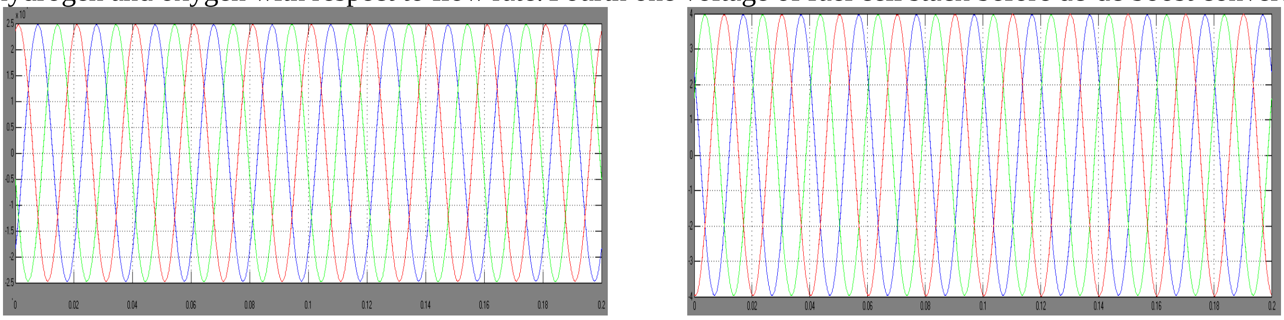

Figure.6.V&I Output From Hybrid System Synchronized 22kv Grid (X-Axis- Time, Y-Axis- A) Voltage, B) .Current)

Table.1.Comparison Chart for Proposed System Parameters

Wind Speed (m/s)	Power Extracted by Turbine @59.2593% in (W)	Energy Stored in Hydrogen @85% in (WH)	Power Derivable by Inverter @65% from Fuel cell @90% in (W)
5.47	314.13	267.01	156.20
4.21	142.82	121.40	71.02
3.67	94.56	80.37	47.02
4.43	166.39	141.43	82.74
5.06	248.77	211.45	123.70
2.88	45.93	39.04	22.84
1.97	14.55	12.37	7.23

4. CONCLUSION

In this study, we analyzed the future of large-scale wind power usage in Tamil Nadu, incorporating hydrogen production, hydrogen storage, and fuel cell functions into the wind-power system and then assessed its functional efficiency. Results showed that a wind to hydrogen system can increase power supply, carbon reduction efficiency, as well as power supply capacity; however the hydrogen production cost was high when the rate of use of the electrlyzers was low. It is also found that there are two disadvantage of energy system: One is the cost of the new equipment and the other is the energy lose due to inefficiencies in the transformation process. It can be expected that in the future by improving hydrogen production and fuel cell technology; we will be able to obtain a stable renewable energy power supply in a reasonable cost.

REFERENCES

Aguado M, Ayerbe E, Azca´rate C, Blanco R, Garde R, Mallor F and Rivas D.M, Economical assessment of awind–hydrogen energy system using WindHyGensoftware, International Journal of Hydrogen Energy, 34, 2009, 2845–2854.

Carton JG and Olabi AG, Wind/hydrogen hybrid systems: opportunity for Ireland's wind resource to provide consistent sustainable energy supply, Energy, 35, 2010, 4536-4544.

Cell Hybrid Energy System for Grid-Connected Applications, Article ID 352765, 2013

Chang PL, Hsu CW, Hsiung CM, Functional assessment for large-scale wind-hydrogen energy integration electricity supply system in Taiwan, 978-1-4799-0986-5/13/ IEEE, 2013.

Jorgensen C and Ropenus S, Production price of hydrogen from grid connected electrolysis in a power market with high wind penetration, International Journal of Hydrogen Energy, 33, 2008, 5335-5344.

Sherif SA, Barbir F, and Veziroglu TN, Wind energy and the hydrogen economy – review of the technology, Solar Energy, 78, 2005, 647–660.

Spahić E, Balzer G, Hellmich B, and Münch W, Wind energy storages– possibilities, Power Tech, IEEE Lausanne, 2007.

TourkiaLajnef, Slim Abid, and Anis Ammous, Modeling, Control, and Simulation of a Solar Hydrogen/Fuel