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Analysis of PEM Fuel Cell Power Supply for Grid Interface Using ANN Controller

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ABSTRACT: A non-conventional energy system has developing to supply electricity in rural areas as well as distributed generation. Fuel Cell systems supply electricity in peak load time is the most advantages than compared to the other non-conventional methods. The applications for various purposes are due to its purity, movability, and suitability for electricity and heat generation. Designing of a suitable power electronic interface to make the technology viable is still a challenge. This project presents simulation of PEM Fuel Cell Power Plant using ANN controller to improve the system efficiency. Hydrogen-based PEM fuel cells have no onsite emissions other than water vapour and heat, making them ideal for indoor electricity generation requirements. PEM fuel cells operate quietly and cause almost no vibrations. Because they operate at low temperatures, dissipated heat from PEM fuel cells has limited cogeneration potential. The simulation model is developed in MATLAB environment.

KEYWORDS: Distributed generation, Fuel Cell (FC), grid interface, Backpropagation, power quality, stand-alone system.

I. INTRODUCTION

Day to day population increasing with simultaneously increasing of the power demand and also global pollution increasing, so other chance to move the non-conventional power resources to free the earth from pollution. Photovoltaic cells, wind turbine are the seasonal resources that are these are the secondary power to supply the grid. We have to mix these powers with base power like thermal power plant and nuclear power plants power.

Fuel cell power plant can act as a base loads. It has to deliver the power during the peak load and also for the residential applications during peak load. It can also be used in low and medium power residential applications, as an uninterruptible power supply particularly for houses, industries, and remote places, and for the hybrid vehicles. The FC delivers dc power to be inverted and stepped up to be able to use for household applications as well as for distributed generation. The problem with FC is voltage decreases almost linearly with the increase in load current. The output voltage must be regulated at a desired level using the ANN controller. The THD value can also be reduced within the limit which is used to interface with the grid.[1] proposed the fuel cell that can be used in both low and medium-power residential applications as an uninterruptible power supply particularly in the houses, industries, hybrid vehicles and in the remote places also. Several topologies of switched-mode dc–dc converter followed by inverter are proposed and compared based on their performance. [2] proposed the Proton Exchange Membrane (PEM) fuel cells generate electrical power from air and from hydrogen or hydrogen rich gas mixtures. High PEMFC system efficiency levels can be achieved only with intensive heat integration within the PEMFC systems. Hence, heat integration system studies are most importance along with the development of novel reforming catalysts, clean-up systems and PEMFC components if on-board hydrogen production is desired.[6] proposed a detailed power-quality evaluation was carried out for the proposed PEMFC-based power system. The available harmonics in the system are the products of inverter and nonlinear loads generally present in a residence. The resultant THD of voltage stay below 5% limit and individual harmonics in the voltage waveform does not exceed the 3% limit, which are within the IEEE requirements. [11] proposed an integrated dynamic model for a fuel cell power plant. The proposed dynamic model includes a fuel cell model, a gas reformer model, and a power conditioning unit block. The model introduces a scenario to control active and reactive power output from the fuel cell power plant.

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II. PROPOSED CONTROLLER

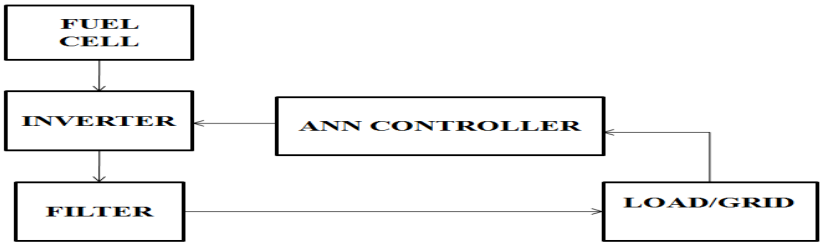

Fig.1. Block diagram.

The fig. 1 represents the block diagram of the proposed single-stage FC- based power supply system. FC operates in low voltage range (26–48 V) and load/grid voltage is relatively high (120V), a step-up transformer is used to meet desired voltage level. It also provides the isolation between FC and load. It is preferred here for three-phase application suitable for grid interface. The bridge use six IGBT switches at low voltage level (less than 100 V), which is economical and efficient. Inverter-side placement of filter results in high current rating of the filter inductor, where as capacitors are rated at a reduced voltage. If the load increases, the FC voltage decreases.

In order to operate the FC efficiently, the flow rate of hydrogen must be adjusted with the change in load. However, depending on the type of FC system, this flow change is a very slow process and has time constant as large as 30s. Therefore, some type of energy storage is required. Series of batteries can be placed across the FC stack but require additional circuitry for regulated dc bus. Also, the numbers of cells in series are not only expensive but also have a short lifetime. Unlike batteries, ultra capacitors have a short charge time and much longer lifetime. The filter is used to reduce the harmonics. Here LC filter is used to reduce the harmonics.

III. ANALYSIS OF FUEL CELL

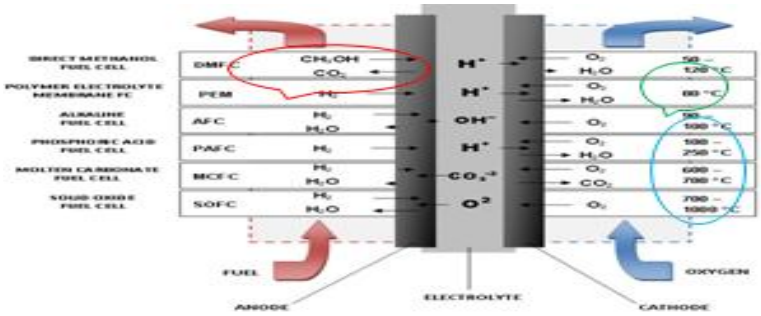

Fig.2. Types of fuel cell

In fig.2 Red color circle shows the CO_2 emission, blue color circle shows the high temperature which requires the high cost cooling system. The green color circle has the low temperature range which is the PEM fuel cell and also outlet has no pollution. PEM is the most promising fuel cell at the moment. Its cheapness and versatility allows it to be implemented in almost every available applications ranging from power plants, vehicles, miniaturized or emergency power supply, marine applications and to daily equipments. It is controllable and high power density.

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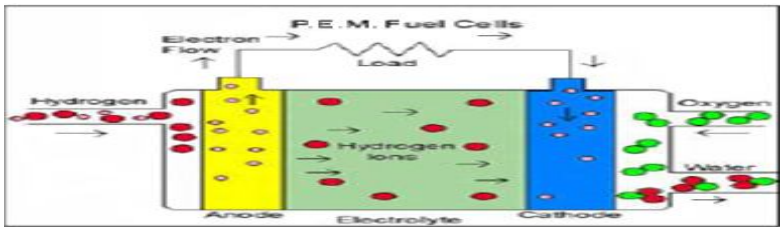

Fig.3. PEM fuel cells.

TABLE I FUEL CELL DESIGN

Parameter	**Range**	**unit**
Fuel cell resistance	0.07833	ohms
voltage of one cell [En]	1.1288	V
Nominal utilization of Hydrogen[H_2]	99.56	%
Nominal utilization of oxygen [O_2]	59.3	%
Nominal consumption of Fuel	60.38	slpm
Nominal consumption of Air	143.7	slpm
System Temperature	338	Kelvin
Fuel Cell supply pressure [Pfuel]	1.5	bar
Air supply pressure [PAir]	1	bar
Parameter	Range	unit
Fuel cell resistance	0.07833	ohms
voltage of one cell [En]	1.1288	V

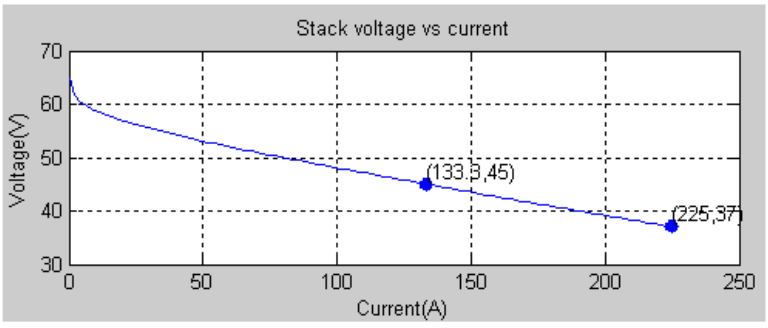

Fig.4. V-I Characteristics of fuel cell.

The fig. 3 shows the V-I characteristics of the fuel cell. When the load increases, the FC voltage decreases. In the graph two co-ordinate points are taken as an example. The first co-ordinate (133.3, 45) and the second co-ordinate (225, 37) clearly show that when the load current increases, the FC voltage is decreases.

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TABLE III FUEL CELL PARAMETERS

Electrolyte	Solid polymer membrane
Catalyst	Platinum is the most active catalyst
Operating Temperature	Around 175-200^{0}F
Electrical Efficiency	40-60 %.

IV. LC- FILTERS

In numerous power system conditions, harmonics are generated not only a single frequency but can spread over a wide range of frequencies. A six-pulse converter generates harmonics of 5th, 7th, 11th, 13th etc, and electronic power can generated inter harmonics coverage the wide range of frequencies. A low-pass broadband filter is used to block multiple or widespread harmonic frequencies. The low-pass filter is designed to achieve a low cutoff frequency; it is called a low-pass broadband filter. In distribution system application, the effect of low-pass filters can be obtained by installing a capacitor bank on the low-voltage side of a transformer. It is capable of preventing harmonics above the cutoff frequency from penetrating the high-voltage side of the transformer. If the voltage remains high the voltage regulator or the transformer load tap changer must be used to lower the voltage to an acceptable level.

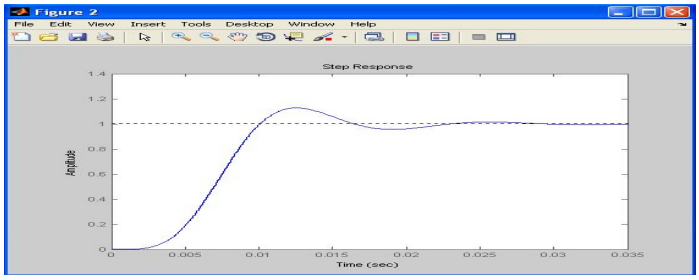

Fig.5. Step response of filter.

TABLE IIIII LOWPASS FILTER DESIGN

Parameter	**Specifications**
Filter Type	Low pass
Mag	1.2
Phase	60 (degrees)
Frequency	50 Hz
Capacitance	70 micro farad
Branch type	LC
Inductance	03 milli henry

V. ARTIFICIAL NEURAL NETWORK

The Neural network will help to select data create and train a network and evaluate its performance. This means that the artificial neurons are organized in layers, and send their signals “forward “, and then the errors are propagated backwards. The network receives inputs by neurons in the input layer, and the output of the network is given by the

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neurons on an output layer. There may be one or more intermediate hidden layers. The backpropagation uses supervised learning algorithm which means that we provide the algorithm with examples of the inputs and outputs we want the network to compute, and then the error (difference between the actual and expected results is calculated. The idea of the backpropagation algorithm is to reduce this error until the ANN learns the training data. The training begins with the random weights, and the goal is to adjust them so that the error will be minimum.

The most common function is the sigmoid function .The sigmoid function is very close to the large positive numbers 0.5 at zero, and very close to the zero for the large negative numbers. This allows the smooth transition between the low and high output of the neuron. The backpropagation algorithm now calculates the how the error depends on the output, input, and weights.

VI. ADVANTAGES OF THE SYSTEM

Less production of fuel cost, Hydrogen and oxygen can be produced anywhere, Most fuel cells operate silently so it can use within buildings such as hospital, Fuel cell power plant is compact and requires less space, The wastage of FCPP is water. It can be recycled and used various purpose, There is no transmission loss, High efficiency, No cooling water is required, The heat can be easily removed and discharged to the atmosphere, There is no pollution in PEM Fuel cell, The overall system performance can be improved by the ANN controller.

VII. SIMULATION RESULTS AND DISCUSSION

The simulation diagram contains stacks of 65 cells. It has the 45 volts DC output and that is fed to the inverter which is made up of IGBT switches. The switches are controlled by the ANN controller by giving pulse. The output of the inverter is fed to the load after filter out the lower order harmonics which is very dangerous. Inverter-side placement of filter results in high current rating of filter inductor, where as capacitors are rated at a reduced voltage. If the load increases, the FC voltage decreases. The filter used by here is low pass LC filter.
Then the output is connected to the grid or the residential load. The ANN controller is used to control the inverter to improve the efficiency of the total system.

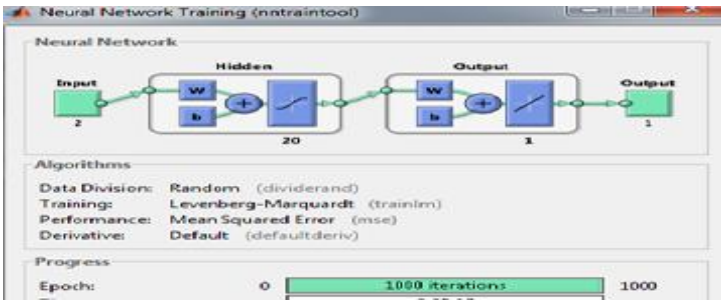

Fig.6. Neural network training tool

The fig.6.shows the backpropagation technique consists of two inputs, 20 hidden layers, 1000 iterations.

REGRESSION: Regression “R” values measure the correlation between outputs and targets. An R value of “1”means a close relationship, “0” a random relationship
MEAN SQUARE ERROR: Mean is the average squared difference between outputs and targets. Lower values are better. Zero means no error.

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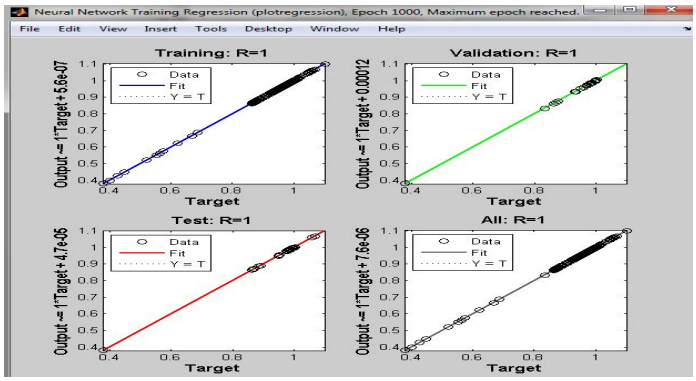

Fig.7. Regression of ANN

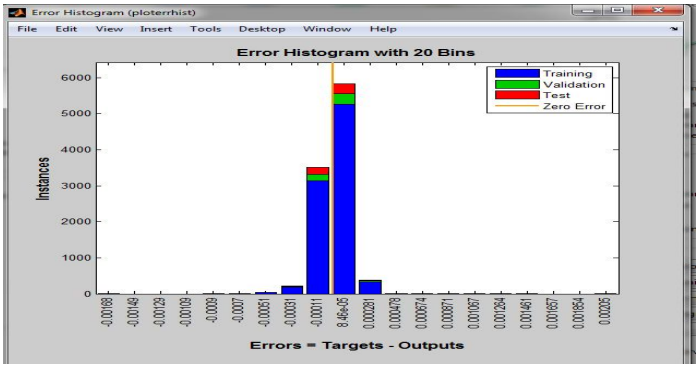

Fig.8. Mean square error

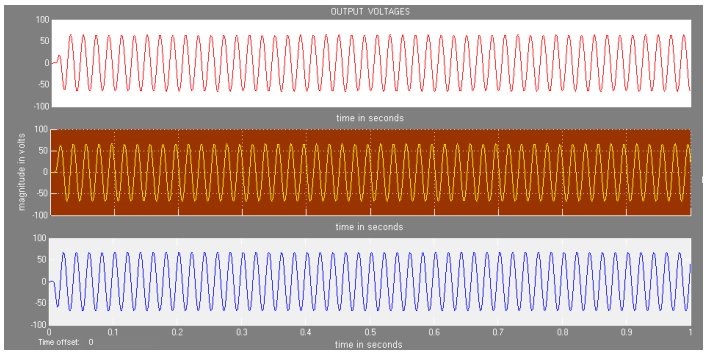

Fig. 9.Output voltage

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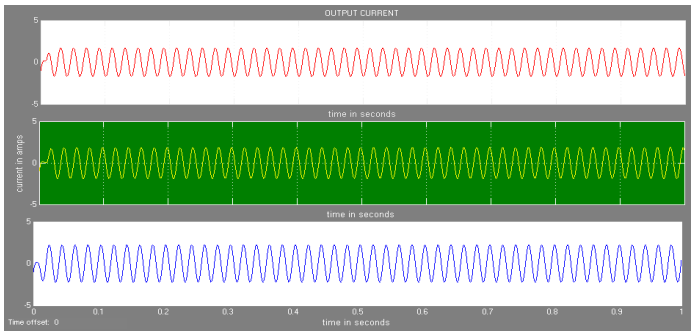

Fig.10. Output line current.

The fig.9 & fig.10 shows the line voltage and the line current respectively.Both having the pure sinusoidal value. For this the THD value 0.75% which is less than 5%

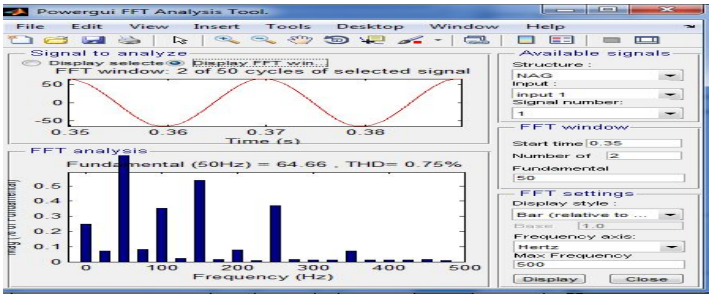

Fig.11. THD analysis

The fig. 11 shows the FFT analysis in the MATLAB. In this window "Display FFT Window" is chosen for the required signal. To find THD value Frequency (Hz)-Magnitude (% of fundamental) characteristics of the line voltage to be analyzed. The result shows that the THD value of 0.75 % which less than 5% making the system used to interface with grid and also for the standalone system.

VIII.CONCLUSION

Fuel cell systems supply electricity in peak load time is the most advantages than any other non- conventional methods. It can be applied for applications for various purposes. The simulation results and investigations of a single stage power electronic interface for PEM FC have done. The expected power was achieved with less number of component count, low losses and increased reliability. The THD values of output voltage and current are maintained below 5% limit, making the system suitable for grid interface/stand-alone use. The system can support desired VAR for a rated active power loading with the same capacity of the FC. The overall system performance was improved using the ANN controller.

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BIOGRAPHY

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