Phosphoric Acid Fuel Cell (PAFC) Energy based Three Phase Inverter Topology with LC Filter for Improving Power Quality

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Abstract:- Phosphoric Acid fuel cell is an rising technology in the field of renewable power assets which has the capability to replace traditional strength generation resources. Phosphoric Acid (PA) fuel cell makes use of hydrogen Power to supply power. The electricity generated by using the PA fuel cell can't be at once used for a specific application because it needs proper electricity conditioning. Furthermore, the output energy fluctuates With extraordinary operating situations. To get a stable output energy at an economic charge, electricity conditioning circuit is critical for hydrogen fuel cell. This work implements a -staged power conditioning unit for PA fuel cell based totally distributed technology the usage of LC filter technique The economic feasibility of gas cells rests at the cost of the gasoline cell gadget and Operating performance and fuel value. The proposed electricity converter topology includes DC-DC converters, and one phase and three phase different mode of conduction with and without Low pass LC filter. Benefits of the proposed topology are reduced enter ripple modern-day, excessive performance, low renovation cost, smaller size, modularity, redundancy.

Keyword:- Renewable Energy; Fuel Cell; Boost Converter; Filter; Inverter

INTRODUCTION

Energy is one of the significant contributions for the development of any economy. If there should arise an occurrence of creating nations, the vitality region expect an extraordinary significance. The world faces a categorization with regards to the usage of the planned existing resources. As the demand for power increases with the increasing population, so is the use of fossil fuels for the generation of excess power. This leads to amplify in the absorption of poisonous and greenhouse gases in the environment, such as SOX, NOX, CO2 and CO. The effect of such impact can be seen in the form of global warming i.e. the rise in atmospheric temperature of the Earth. Such serious challenges or threats to the environment have made power industry realize the importance of alternate sources of energy. A new field of enthusiasm for control age, keeping in mind the end goal to determine the issue of expanding vitality request, has developed which focuses on the non-conventional energy resources or the renewable energy resources. Different types of renewable and non-renewable sources of energy are as shown in Fig. 1.

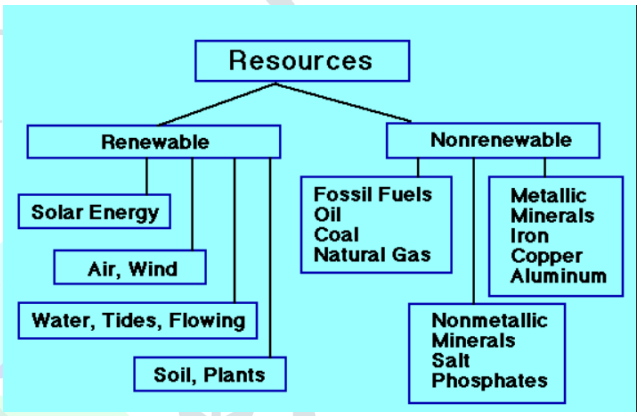

Fig. 1.Classification of The Renewable And Non-Renewable Sources

Renewable vitality is acquired from sources that are basically endless. The most vital element of the inexhaustible assets is that it can be bridled without Introduction the arrival of hurtful poisons. As appeared in the Fig. 1.1, the options mentioned under renewable category are of such nature. One such innovation is energy unit, which others the possibilities of new, noiseless, measured, with few or no issue of emanation and less moving parts. Its secluded nature suits to moderately little, circulated age where it can offer high efficiencies than warm engines. Energy component structures a work in advance for rational use are Molten Carbonate Fuel Cell (MCFC), Solid Oxide Fuel Cell (SOFC), Phosphoric Acid Fuel Cell (PAFC) and Proton Exchange Membrane Fuel Cell (PEMFC). Phosphoric Acid energy unit and Proton Exchange Membrane power device are the nearest of these frameworks to commercialization. The report discusses about the literature survey, simulation and dynamics of SOFC. SOFC can proficiently create high power densities, in this manner making the innovation appealing for car and stationary applications. Specifically, the weight, volume, and ultimately cost are the primary factors of acceptance. SOFC innovation separates itself from the other power modules advances in that of strong stage polymer film are utilized as the cell separator/electrolyte. Since the cell separator is a polymer

_lm, issues, for example, fixing, gathering, and taking care of are less mind boggling than most other power module frameworks. PAFCs commonly work at low temperatures (60º 80ºC), enabling quicker startup and prompt reaction to change sought after of power. Other than the itemized investigation of energy unit demonstrating, investigation of energy electronic converters is likewise made. It is always desirable to connect the load through a power electronic interface when powering source is fuel cell. Different topologies administering managed control from power module are portrayed in writing. Since in the energy units with low power rating (ordinarily in the scope of 500W to few kW) we can't get higher voltages, henceforth we require a legitimate power electronic interface to change over the low voltage levels of power device to alluring voltage levels.

MOTIVATION OF THE STUDY

Fuel Cells are a promising technology in distributed generation. A few examiners even recommend that if perspectives like cell toughness and assembling cost are enhanced, energy components can uproot a portion of the conventional age sources with regards to the generation of an energy unit plant demonstrate for a power framework test systems, this paper proposes that the vitality part plant be proposed to be equipped for conveying subordinate administrations and in addition control keeping in mind the end goal to encourage their market passage with included esteem highlights. In any case, a power device plant with every one of these capacities does not exist yet, and this includes various troubles related with the making of a plant dynamic model. This paper also reports on the modeling of the different plant subsystem in order to understand how such a plant will operate in the future.

The power modules are considered as a standout amongst the most encouraging gadgets for independent/framework associated conveyed ages (DGs) because of its neatness, measured quality and higher potential ability. The hindrances in the broad utilization of energy units are their moderate reaction for sudden load changes and higher establishment cost. In this paper a recreation investigation of dynamic conduct of 8.32 KW PA energy unit with DC/DC help converter is completed for minimized outline of PCU. The need for the necessity of lift converter contrasted and fell two stack power module displays is additionally tended to. Besides the execution of the basic DC/DC support converter as power modulator for 8.32 KW PA energy unit show is examined for fluctuating burdens with a specific end goal to control flow for enhanced performance.

MAIN OBJECTIVES OF THE STUDY

Following are the main objectives of the study

1. Broad writing review with respect to fuel cell. Its description, classification, electrochemistry, performance measures, applications and comparative study (more emphasis is given on proton exchange membrane fuel cells).
2. Study fuel cell is the powering source.
3. Performance analysis of simulink implementation of fuel cell system.

MATHEMATICAL MODELING OF FUEL CELL

A fuel cell device is an electrochemical cell that changes over a source fuel into an electrical current. It creates power inside a cell through responses between a fuel and an oxidant, activated within the sight of an electrolyte. The reactants stream into the cell, and the reaction things stream out of it, while the electrolyte remains inside it. Power modules can work tirelessly as long as the critical reactant and oxidant streams are kept up. Power device has higher vitality stockpiling ability, in this way improving the scope of task for car applications and is a cleaner wellspring of vitality. Power module likewise has the further favorable position of utilizing hydrogen as fuel that could diminish world's reliance on nonrenewable hydrocarbon sources. Lately unique sorts of advancements have been produced ,, for example, the: Alkaline Fuel Cell (AFC);Proton Exchange Membrane (PEM) Fuel Cell; Phosphoric Acid Fuel Cell (PAFC); Molten Carbonate Fuel Cell (MCFC);Solid Oxide Fuel Cell (SOFC) and Direct Methanol Fuel Cell(DMFC). A standout amongst the most diffused, the PA power module, has a high proton conductivity film as electrolyte. The Fuel Cell show used as a piece of this Proposed Work is recognized in MATLAB and Simulink. The stack model will be established on the going with suppositions.

The gases are ideal.The stack is sustained with hydrogen and air. In the event that flammable gas rather than hydrogen is utilized as fuel, the progression of the fuel processor must be incorporated into the model, upstream of the hydrogen gulf; a first-arrange exchange work 6.The exchange work pick up ought to mirror the adjustments in creation happening amid the procedure. The impact of the fuel processor in the model will be tried later on. The channels that vehicle gases along the anodes have a settled volume, yet their lengths are little, with the goal that it is just important to characterize one single weight an incentive in their inside. The fumes of each channel is by means of a solitary or if ice. The proportion of weights between the inside and outside of the channel is sufficiently huge to consider that the hole is stifled. The temperature is steady constantly. The main wellspring of misfortunes is ohmic, as the working states of intrigue are not near the upper and lower extremes of current. The Nernst condition can be connected. As indicated by Ref. 7, a hole that can be viewed as stifled, when sustained with a blend of gases of normal molar mass M_kgrkmol.and comparable particular warmth proportions, at a steady temperature, meets the accompanying trademark:

$$\frac{W}{P_U} = K\sqrt{M}$$

Where W is the mass stream kg/s; K is the valve consistent, basically relying upon the territory of the opening . P is the weight up stream inside the channel. u

For the specific instance of the anode, the idea of fuel use U can be presented, as the proportion between the f fuel stream that responds and the fuel stream infused to the stack is likewise an approach to express the water molar division at the f debilitate. As indicated by this definition, Eq. 4.1. can be composed as:

$$\frac{W_{an}}{P_{an}} = W_{an}\sqrt{(1-U_f)M_{H2} + U_f M_{H_2O}}$$

where W is the mass move through the anode valve a kg/s; Kan is the anode valve consistent ; M are the sub-atomic masses of hydrogen H2. H2O and water, separate kg/kmol; P is the weight an inside the anode channel [atm]. On the off chance that it could be viewed as that the molar stream of any through the valve is corresponding to its fractional weight inside the channel, as per the articulations:

$$\frac{q_{H_2}}{p_{H_2}} = \frac{K_{an}}{\sqrt{M_{H_2}}} = K_{H_2}$$

and

$$\frac{q_{H_2O}}{p_{H_2O}} = \frac{K_{an}}{\sqrt{M_{H_2o}}} = K_{H_2o}$$

where q , q are the molar streams of hydrogen and H2 H2O water, individually, through the anode kmol/s; p , p are the halfway weights of hydrogen and water, H2 H2O separately (atm); K , K are the valve molar con-H2 H2O stants for hydrogen and water, individually kmol/(satm); the accompanying articulation would be derived:

$$\frac{W}{P_{an}} = K_{an}\left[(1-U_f)\sqrt{M_{H_2}} + U_f\sqrt{M_{H_2o}}\right]$$

$$p_{H_2}V_{an} = n_{H_2}RT$$

Calculation of the Partial Pressures

Each individual gas will be thought about independently, and the ideal gas condition will be connected to it. Hydrogen will be considered for instance.

$$\frac{d}{dt}pH_2 = \frac{RT}{V_{an}}qH_2$$

where q is the time subsidiary of n , and speaks to the H2 hydrogen molar stream kmol/s. There are three applicable commitments to the hydrogen molar stream: the info stream, the stream that participates in the response and the yield stream,
consequently

$$\frac{d}{dt}pH_2 = \frac{RT}{V_{an}}\left(q_{H2}^{in} - q_{H2}^{out} - q_{H2}^{r}\right).$$

where *q*in is the input flow of kmol/s; *q*out is the output H2 H2 flow of kmol/s; *q*r is the hydrogen flow that reacts H2 kmol/s. As per the fundamental electrochemical connections,
the molar stream of hydrogen that responds can be figured as:

$$q_{H2}^{r} = \frac{N_0 I}{2F} = 2K_r I$$

where N is the quantity of cells related in arrangement in the 0 stack; F is the Faraday's steady/kmol; I is the stack current [A]; K is a consistent characterized for demonstrating pur-r postures kmol/(s a). Coming back to the figuring of the hydrogen fractional weight, it is conceivable to compose:

$$\frac{d}{dt}pH_2 = \frac{RT}{V_{an}}\left(\left(q_{H2}^{in} - q_{H2}^{out} - 2K_r I_i\right)\right)$$

Supplanting the yield stream by Eq. _3., taking the Laplace change of the two sides and segregating the hydrogen halfway weight, yields the accompanying articulation:

$$p_{H_2} = \frac{1/K_{H_2}}{1+\tau_{H_2}s}\left(q_{H_2}^{in} - 2K_r I_j\right)$$

where ., communicated in seconds, is the H2 a H2 estimation of the framework shaft related with the hydrogen stream. (2.4)

Calculation of the stack Voltage

Applying Nernst's condition and Ohm's law _to think about ohmic misfortune. The stack yield voltage is spoken to by the accompanying articulation:

$$V = N_0\left(E_0 + \frac{RT}{2F}\left[\ln\frac{p_{H_2}p_{o_2}^{0.5}}{p_{H_2O}}\right]\right) - rI \quad (2.5)$$

where *E* is the voltage associated with the reaction free vitality V; R is similar gas consistent as past, however care ought to be taken with the framework unit ; r portrays the ohmic misfortunes of the stack. (2.6)

MATLAB SIMULATION MODEL AND RESULTS

The name MATLAB stays for arrange inquire about focus. MATLAB® is a world class tongue for specific figuring. It coordinates calculation, perception, and programming in a simple to-utilize condition where issues and arrangements are communicated in commonplace numerical documentation. (2.7) Over the most recent couple of years, Simulink has turned into the most generally utilized programming bundle in the scholarly world and industry for demonstrating and reenacting dynamic frameworks. is a product bundle for demonstrating, mimicking, and dissecting dynamic frameworks. It bolsters direct and nonlinear frameworks, displayed in constant time, examined time, or a half breed of the two. Frameworks can likewise be multi-rate, i.e., have distinctive parts that are inspected or refreshed at various rates. Simulink urges the client to give things a shot. (2.8) User can easily build models from scratch, or take an existing model and modify it. Reenactments are intelligent, so client can change parameters on the spot and instantly observe what happens. What's more, in light of the fact that MATLAB and Simulink are joined together; client can reenact, break down, and reconsider the models in either condition anytime. With Simulink, client can move past admired straight models to investigate more practical nonlinear models, figuring in contact, air protection, outfit slippage, hard stops, and alternate things that depict true marvels. (2.9) Simulink transforms the client PC into a lab for displaying and investigating frameworks that basically wouldn't be conceivable or reasonable. Be it the conduct of a automotive clutch framework, the vacillate of a plane wing, the elements of a predator-prey demonstrate, or the impact of the money related supply on the economy .Simulink is practical to the point that a large number of specialists around the globe are utilizing it to display and take care of genuine issues. Knowledge of this

software will serve the user well throughout his/her professional career.

The topology used in this study for the different components of Fuel Cell, chopper, Inverter and Standalone System. Reproduction comes about are acquired by building up a point by point MATLABTM, Simulink based programming bundle utilizing the numerical and electrical models of the framework depicted before.

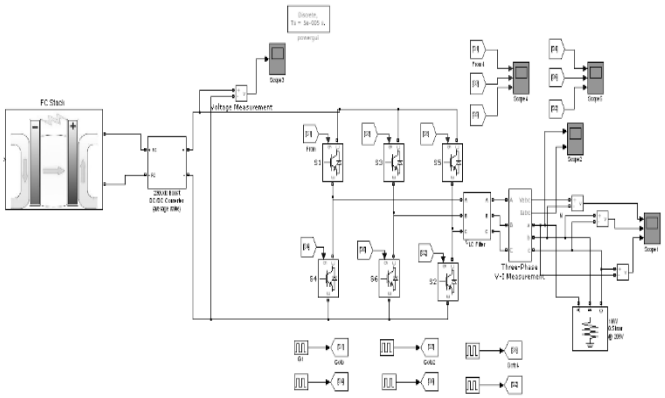

Fig.2 MATLAB Model of Phosphoric Acid Fuel Cell (PAFC) Energy based Three Phase Inverter Topology with LC Filter for Improving Power Quality

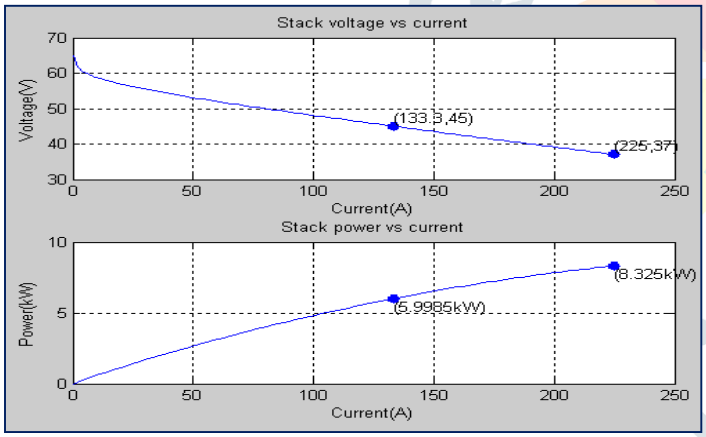

Fig.3. Power, Current and Voltage waveform for fuel cell system

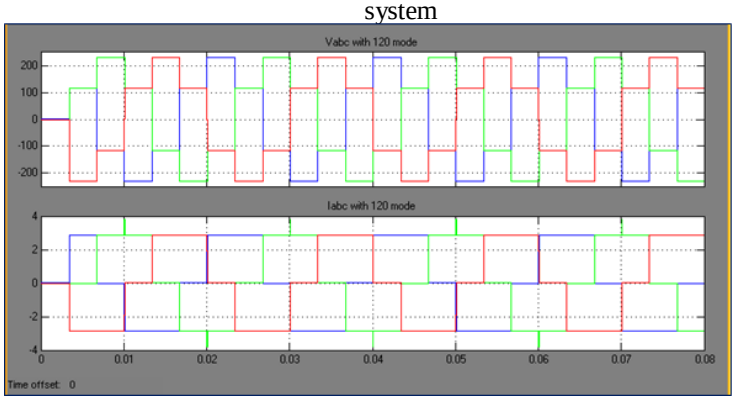

Fig.4.Three phase Load Current and Load Voltage waveform for inverter without LC Filter

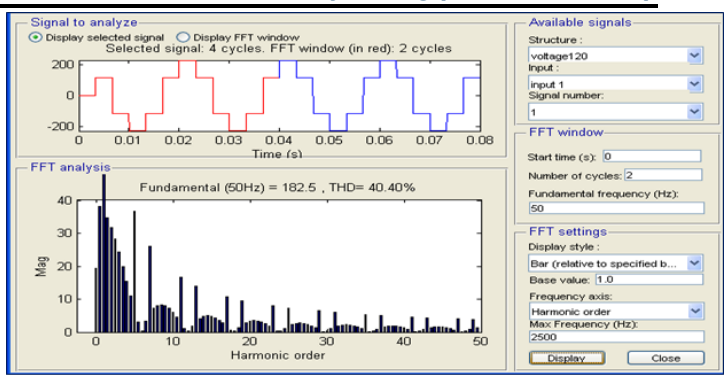

Fig.5.THD spectrums for Voltage waveform for inverter without LC Filter

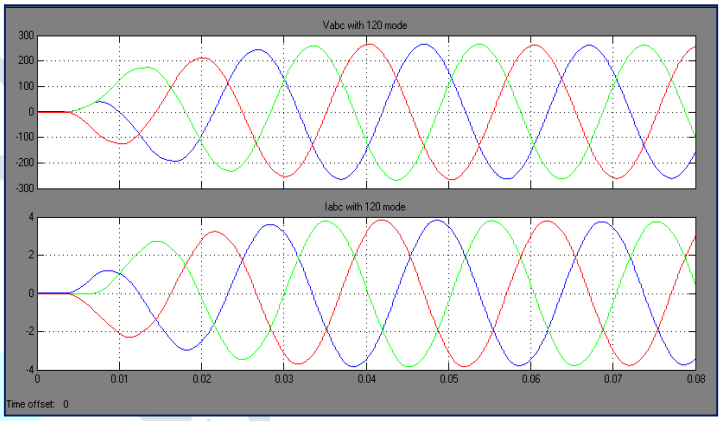

Fig.6.Three phase Load Current and Load Voltage waveform for inverter with LC Filter

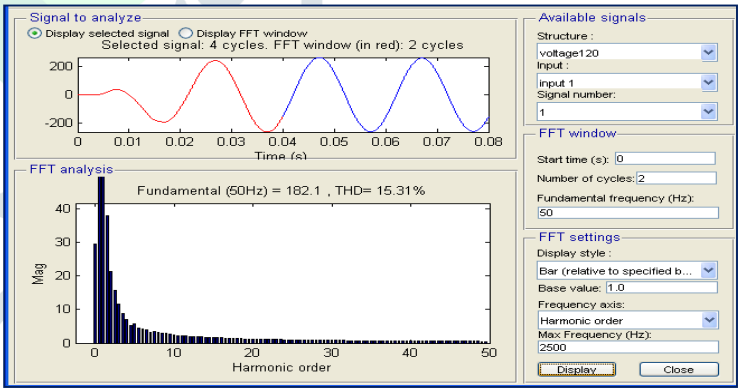

Fig.7.THD spectrums for Voltage waveform for inverter with LC Filter

CONCLUSION

In this paper PA Fuel Cells are preferred which have high voltage ratings and low current profile. This is because at higher current the losses within the fuel cell will be more and hence the efficiency of the system, for which it is known, will deteriorate. But the main drawback of higher voltage fuel cells is that voltage level can be increased only by adding series stacks. This adds to the system cost. In low power rating PA fuel cells, low voltage is an issue. Boost converter provides solutions to raise the voltage level of the PAFC stack. Besides this bi-directional DC to DC converters are

also used for boosting and isolation. This increases the bulkiness of the whole application. For AC applications the inverter discussed in the above theory is a good candidate for single phase inverter, three phase inverter with and without filter and analysis THD of these conditions.

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