Research Paper

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Modeling and Simulation of Grid Connected Fuel Cell Distributed Generation using Quasi Z-Source Inverter

Engineering

KEYWORDS : Fuel Cells, Distributed generation, Quasi Z-Source inverter, DC-DC Power Conversion, Power Conditioning Units (PCUs).

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ABSTRACT

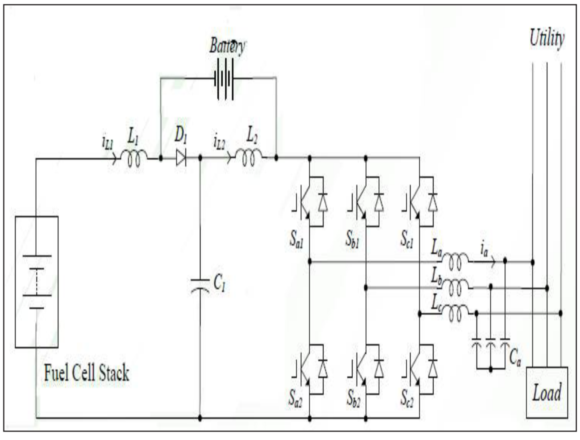
This paper presents a Quasi Z-Source inverter based DC/DC converter for fuel powered system reduces the component stresses and size of the converter. This network provides voltage boost and buck functions in single stage without any additional switches by special switching method. In Presence of this method provides continuous input current on the primary side of this inverter. To maintain the grid voltage and current magnitude at constant value in three phase average model based voltage source inverter is designed. The Quasi Z-Source inverter based fuel cell powered system is analyzed by MATLAB/SIMULINK environment. From this system we can drive the three phase load easily.

I. INTRODUCTION

Today, new advances in power generation technologies and new environmental regulations encourage a significant increase of distributed generation resources around the world. Distributed generation systems (DGS) have been mainly used as a standby power source for critical businesses. For example, most hospitals and office buildings had stand-by diesel generators as an emergency power source for use only during outages. However, the diesel generators were not inherently cost-effective, and produce noise and exhaust that would be objectionable on anything except for an emergency basis [1]. On the other hand, environmental-friendly distributed generation systems such as fuel cells, wind turbines, biomass and photovoltaic arrays can be a solution to meet both the increasing demand of electric power and environmental regulations due to green house gas emission [2].

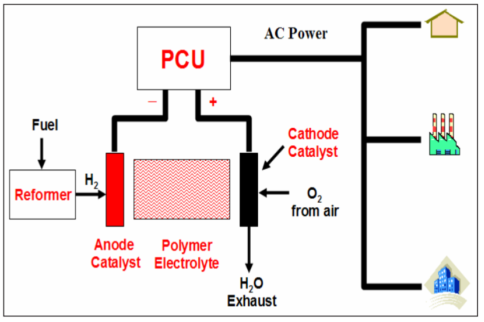
Fig.1 shows the proposed Quasi Z-Source Inverter in the Fuel Cell Battery Based power generation system. It connects the Fuel Cell Stack and outputs three phase 50 Hz, 330 V ac to resistive loads, which is the standard utility level. A three-phase LC Filter is connected in right after the inverter bridge to get 50Hz sinusoidal ac outputs.

Fig.1 Fuel Cell Battery Based power generation system using Quasi Z-Source Inverter



Fuel cells are also well used for distributed generation applications, and can essentially be described as batteries which never become discharged as long as hydrogen and oxygen are continuously provided [3]-[4]. The hydrogen can be supplied directly, or indirectly produced by reformer from fuels such as natural gas, alcohols or gasoline. Each unit ranges in size from 1-250 kW or larger MW size. Even if they offer high efficiency and low emissions, today's costs are high.

Fig.2 Block diagram of fuel cell Distribution system



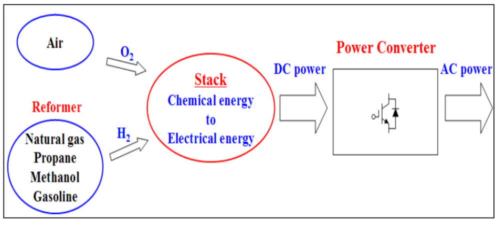
Phosphoric acid fuel cell is commercially available in the range of the 200 kW, while solid oxide and molten carbonate fuel cells are in a pre-commercial stage of development. The possibility of using gasoline as a fuel for cells has resulted in a major development effort by the automotive companies [5]-[6]. The recent research work about the fuel cells is focused towards the polymer electrolyte membrane (PEM) fuel cells. Fig. 2 shows a block diagram of fuel cell system which consists of a reformer, fuel cell stack and a PCU (Power Conditioning Units).

II. MODELING OF FUEL CELL

A fuel cell is a device that combines hydrogen and oxygen electrochemically, with no combustion to produce electricity. The only byproducts are heat and water. A fuel cell has a structure similar to a battery, but battery stores electricity, while a fuel cell generates electricity from fuel. The fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied.

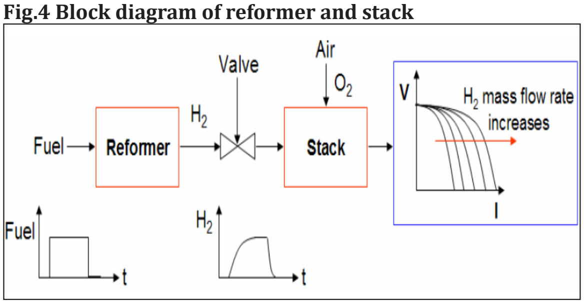
As shown in Fig.3, in case that hydrogen is indirectly produced by the reformer, the fuel cell generation system consists of three parts: a reformer, stack, and power converters. The reformer produces hydrogen gas from fuels and the stack generates DC electric power by an electrochemical reaction of hydrogen and oxygen. The power converters convert a low DC voltage from the fuel cell to a high DC voltage or a sinusoidal AC voltage.

Fig.3 Block diagram of the fuel cell system



For dynamic modeling of the fuel cells, the reformer and stack are further described because a dynamic response of the fuel cell systems is determined by them. Fig.4 shows a block diagram of the reformer and stack to illustrate DC power generation. The reformer affects the dynamics of the fuel cell system because it takes several to tens of seconds to convert the fuel into the hydrogen, depending on the power demand. Therefore, the dynamics of the reformer may be represented by a second order model or a first order time delay model.

Fig.4 Block diagram of reformer and stack



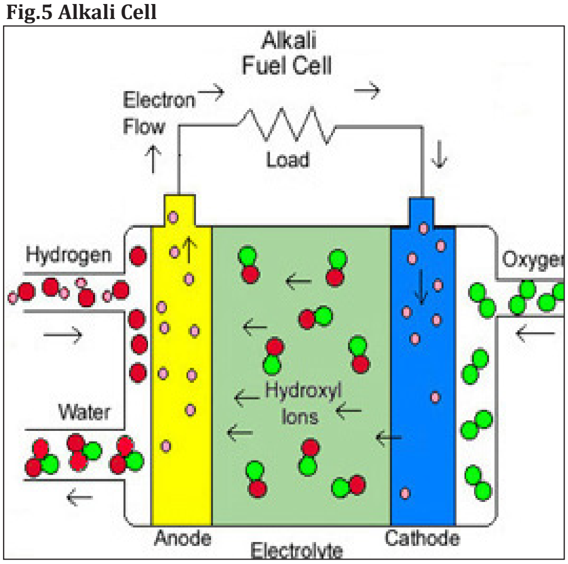
The dynamic response of the stack is considered to have a faster response due to the electrochemical process of hydrogen and oxygen compared to that of the reformer. In Fig.4, the output of the stack shows a family of voltage-current curves for various hydrogen mass flow rates. That is, the maximum cell current and stack voltage increase as the hydrogen mass flow rate increases. As a result, the dynamic response of the reformer and stack and a cell voltage-current curve need to be modeled for more realistic analysis of the fuel cell systems.

III. DIFFERENT TYPES OF FUEL CELLS

ALKALI FUEL CELL:

Fig.5 shows the Alkali fuel cells operate on compressed hydrogen and oxygen. They generally use a solution of potassium hydroxide (chemically, KOH) in water as their electrolyte. Efficiency is about 70 percent, and operating temperature is 150 to 200 degrees C, (about 300 to 400 degrees F). Cell output ranges from 300 watts (W) to 5 kilowatts (kW).

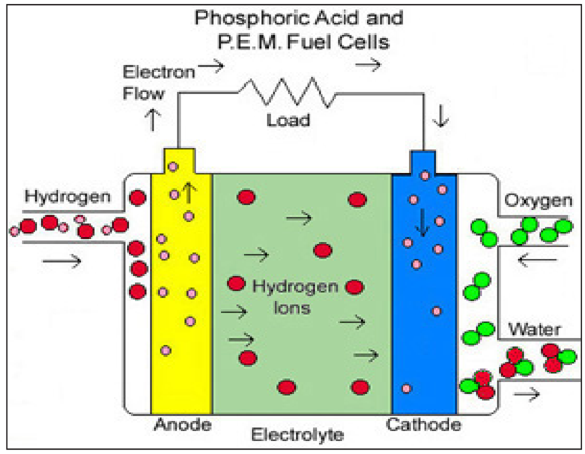
Fig.5 Alkali Cell



PROTON EXCHANGE MEMBRANE FUEL CELL:

Fig.6 Shows the Proton Exchange Membrane (PEM) fuel cells work with a polymer electrolyte in the form of a thin, permeable sheet. Efficiency is about 40 to 50 percent, and operating temperature is about 80 degrees C (about 175 degrees F). Cell outputs generally range from 50 to 250 kW. The solid, flexible electrolyte will not leak or crack and these cells operate at a low enough temperature to make them suitable for homes and cars. But their fuels must be purified, and a platinum catalyst is used on both sides of the membrane, raising costs.

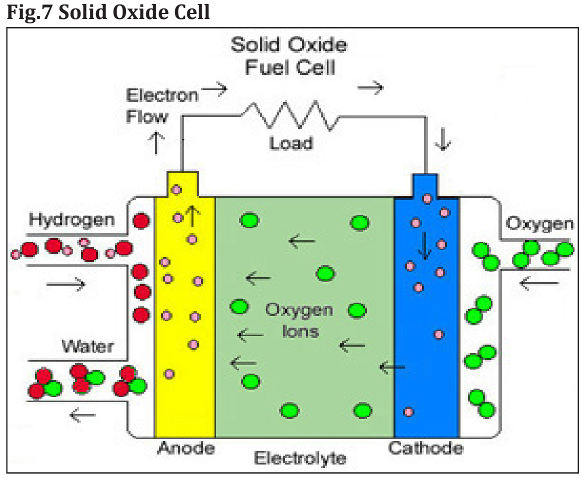
Fig.6 Proton Exchange Membrane Cell



SOLID OXIDE FUEL CELL:

Fig.7 Shows the Solid Oxide fuel cells (SOFC) use a hard, ceramic compound of metal (like calcium or zirconium) oxides (chemically, O_2) as electrolyte. Efficiency is about 60 percent, and operating temperatures are about 1,000 degrees C (about 1,800 degrees F). Cells output is up to 100 kW. At such high temperatures a reformer is not required to extract hydrogen from the fuel, and waste heat can be recycled to make additional electricity. However, the high temperature limits applications of SOFC units and they tend to be rather large. While solid electrolytes cannot leak, they can crack.

Fig.7 Solid Oxide Cell



IV. SIMULATION RESULTS & DISCUSSION

Fig.8. Simulation Circuit for Quasi Z-Source Inverter using Fuel Cell Stack with Battery

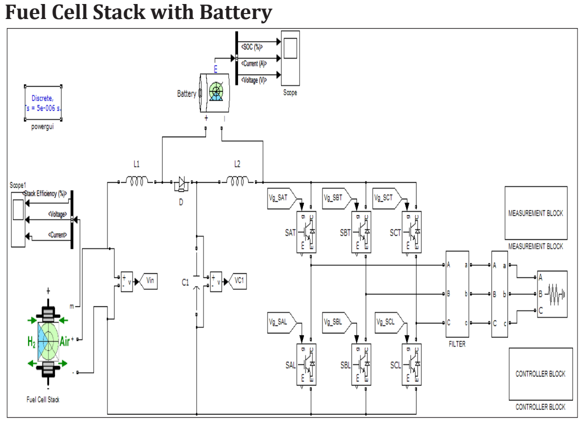


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Fig.9 Input Voltage

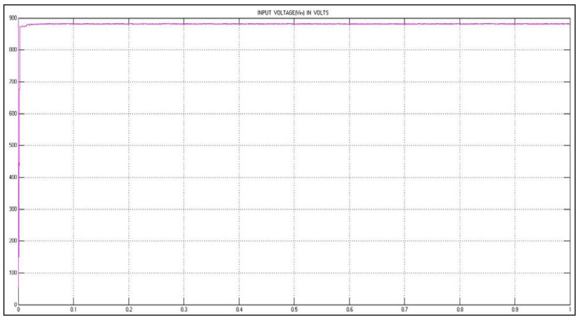


Fig.10 Capacitor Voltage

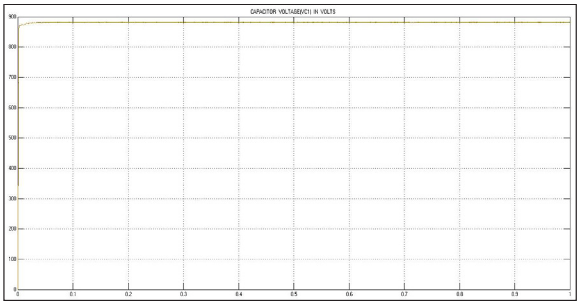


Fig.11 Three Phase Grid Voltage

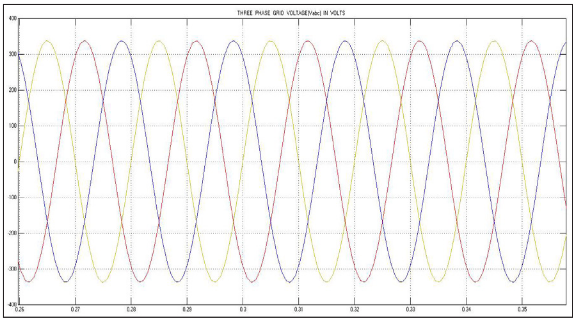
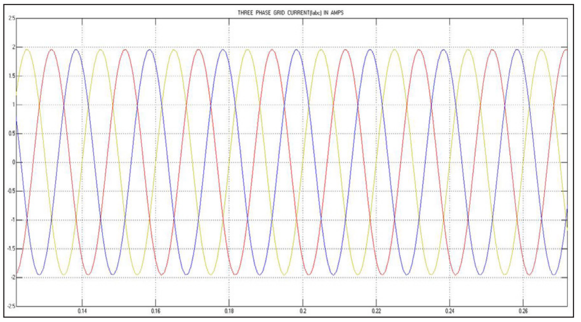


Fig.12 Three Phase Grid Current



APPENDIX: Operating Data of the System

System Parameters	Values
Capacitance, C	400µF
Inductance, L	500µH
Hydrogen Composition, H_2	99.95%
Oxygen Composition, O_2	21%
H_2O (Air)	1%

V. CONCLUSION

The Quasi Z-Source inverter based DC/DC converter for fuel cell powered system is designed with the help of MATLAB/SIMULINK. In this converter it does not need energy pre regulation converter and it reduces the overall size of the converter. It increases the efficiency of the converter by the use of LC filter, reducing Threshold Harmonic Distortion (THD) and Noise. In Quasi Z-Source inverter regulates the fuel cell output voltage variation by shoot through and non-shoot through mode based on creation of gating signals. This converter provides voltage boost and buck functions in a single stage without any additional switches and maintain continues input current on the primary side of inverter. Finally this converter is connected to grid through voltage source inverter and it gives pure sinusoidal waveform with constant magnitude.

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