Design and Analysis of Reduction of Current Ripple and Total Harmonic Distortion in Fuel Cell Generating System

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Abstract— In this paper, a ripple current reduction by using a fuel cell method is proposed that does not require additional switching devices. The proposed circuit realizes a dc active filter function without increasing the number of switching devices, because the energy buffer capacitor is connected to the center tap of the isolation transformer. In addition, the buffer capacitor voltage is controlled by the common-mode voltage of the inverter. The above system has been modeled in the MATLAB/SIMULINK environment. The features of the proposed circuit, control strategy, and experimental results are described, including the result of ripple reduction. Also comparative analysis of the THD values has been done for the conventional and proposed convertor topologies.

Keywords: Ripple Reduction, Fuel Cell, Total Harmonic Distortion, Simulink

I. INTRODUCTION

Recently, energy sources such as wind power systems, photovoltaic cells, and fuel cells have been extensively studied in response to global warming and environmental issues. The fuel cell is an important technology for new mobile applications and power grid distribution systems. For power distribution, fuel cell system requires a grid interconnection converter to supply power to the power grid. A grid interconnection converter using an isolation transformer is preferable for power grid distribution systems in terms of surge protection and noise reduction. In addition, size reduction and high efficiency are essential requirements. One of the problems in the fuel cell system is that the lifetime is decreased by the ripple current. Therefore, in order to extend the lifetime, the fuel cell ripple current must be reduced in the grid interconnection converter. However, when a single-phase pulse width-modulated (PWM) inverter is used for grid connection system, the power ripple is twice the frequency of the power grid. Therefore, in conventional grid connection inverters, large electrolytic capacitors are connected in parallel to the fuel cell in order to reduce the current ripple. However, the use of large-sized electrolytic capacitors increases both the device volume and cost. In order to reduce the current ripple in the fuel cell, some approaches use high-speed current control. This method incorporates a current-loop control within the existing dc–dc converter voltage loop. However, a large capacitor or reactor is required as an energy buffer. Other approaches have been proposed that do not require the use of large-sized electrolytic capacitors. This could be by using an active filter in the dc-link part. The dc active filter consists of a small capacitor as an energy buffer, a reactor to reduce the switching ripple, and a dc chopper. The dc chopper injects the ripple current to avoid a power ripple. In the above configurations, the number of the switching devices is increased, requiring a high-cost dc chopper and resulting in a large volume device. Other configurations of dc active filters have similar problems. In this project a new circuit topology, including a DC active filter function without extra switching devices. The proposed circuit consists of an isolated dc/dc converter and interconnection inverter, and achieves the dc active filter function using the center tap of the isolation transformer. One feature of the proposed converter is that the primary-side inverter in the dc/dc converter is individually controlled by the common-mode voltage and the differential voltage. The ripple current is suppressed by the common-mode voltage control of the dc/dc converter, and the main power flow is controlled by the differential-mode voltage. Conventional and proposed circuit topologies with the principle of current ripple suppression are first introduced. The various converter topologies mentioned above, have been implemented and simulated in MATLAB/SIMULINK environment. The waveforms of source current of the various converter circuits are of prime importance.

A. Fuel Cell System (FCS)

Usually battery and capacitor system are used in energy storage system to meet out the demand of the load and fault conditions. Also battery is available in cheap and it is placed with capacitor system. But the battery is not for long time process and having less life time and capacitor are required unit per volume ratio. So the ultra-capacitor is placed to replace an ordinary capacitor, but it does not have conventional dielectrics. So a fuel cell system is introduced with ultra-capacitor in the present research. The Fuel cell system is more attractive in the present era of engineering field because it has of long time power distribution by its electrochemical reaction(Jain et al. 2012). This is generated electrical power from hydrogen or other fuels with high efficiency and low emission (Friede 2004),(Anahara 1993).This system is familiar to load conditions which include acceleration, breaking periods and distortion periods. A Fuel Cell converts chemical energy into electrical energy by electrochemical conversion and Fuel cells produce DC voltage. The PEMFC operating temperature is 60C-100C and efficiency 50-60%. One of the properties of the fuel cell is a slow dynamic response; super capacitor will improve this response(Zhang2005). Fuel cells also one of the Green Energy sources.

II. PROBLEM IDENTIFICATION

The areas of harmonics issue and remedial measures have received considerable attention from the power utilities, power consumers and power equipment manufacturers over the last decade. The large-scale use of bulk power thyristor converters and industrial electronic equipment resulted in waveform pollution at all levels in the power systems from mid-eighties onwards. The problem became more serious with the proliferation of nonlinear loads (rectifiers, arc furnaces, variable speed drives, UPS, computer load, printers and domestic electronic equipment) in the industrial, commercial and residential sectors in the past decade. These loads draw non sinusoidal currents from the supply and lead to voltage distortion and related system problems. With the widespread use of power electronics at all levels, the polluting loads spread out system wide. Power quality improvement measures concentrated on a few bulk power points and they turned out to be insufficient in mitigating system wide problems.

Harmonic currents, generated by non-linear electronic loads, increase power system heat losses and power bills of end-users. These harmonic-related losses reduce system efficiency, cause apparatus overheating, and increase power and air conditioning costs. As the number of harmonics-producing loads has increased over the years, it has become increasingly necessary to address their influence when making any additions or changes to an installation. Harmonic currents can have a significant impact on electrical distribution systems and the facilities they feed. It is important to consider their impact when planning additions or changes to a system. In addition, identifying the size and location of non-linear loads should be an important part of any maintenance, troubleshooting and repair program.

A. Motivation and Aim:

This gives us the motivation and aim for developing a system for reduction of current ripple and harmonics in the power system by using the fuel cell for power generation.

III. METHODOLOGY

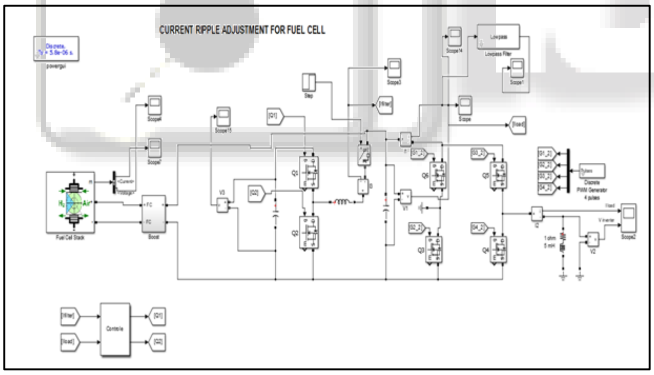

Fig. 3.1: Simulink model of current ripple adjustment for fuel cell

A. Fuel Cell:

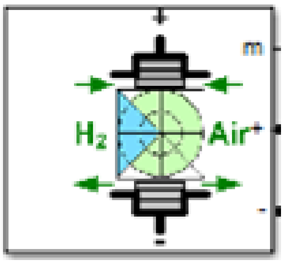

Fig. 3.2: Fuel Cell

Implements a generic hydrogen fuel cell model which allows the simulation for the following types of cells:

- Proton Exchange Membrane Fuel Cell (PEMFC)
- Solid Oxide Fuel Cell (SOFC)
- Alkaline Fuel Cell (AFC)

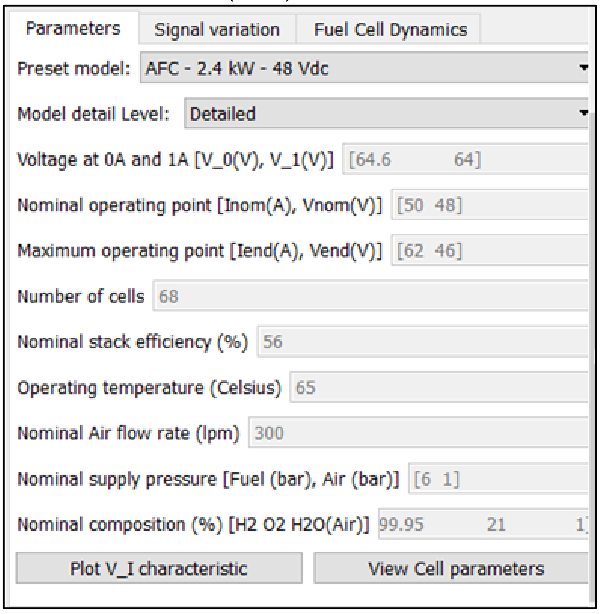

Fig. 3.3: Parameters of fuel cell

B. Boost Converter:

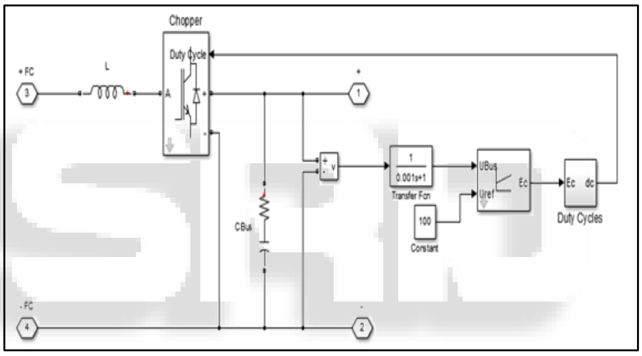

Fig. 3.4: Boost Converter

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load).

Chopper implements an average-value buck converter. "Duty Cycle" contains the duty cycle of the internal IGBT device.

In Ideal voltage measurement the Output signal parameter is disabled when the block is not used in a phasor simulation. The phasor simulation is activated by a Powergui block placed in the model.

In transfer function block the numerator coefficient can be a vector or matrix expression. The denominator coefficient must be a vector. The output width equals the number of rows in the numerator coefficient.

C. MOSFET:

MOSFET and internal diode in parallel with a series RC snubber circuit. When a gate signal is applied the MOSFET conducts and acts as a resistance (Ron) in both directions. If the gate signal falls to zero when current is negative, current is transferred to the antiparallel diode.

D. Pulse Width Modulation:

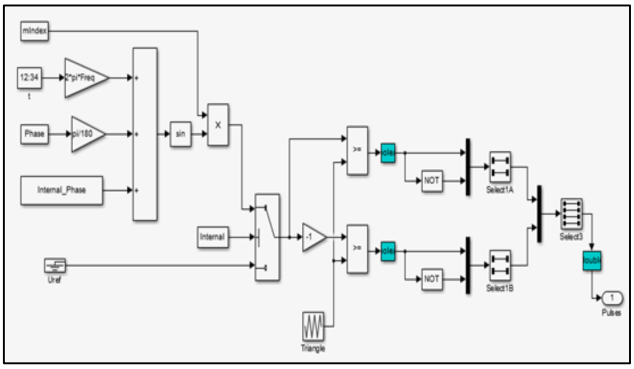

Fig. 3.5: PWM Circuit

Pulse width modulation (PWM), or pulse-duration modulation (PDM), is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up into discrete parts. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load. Along with MPPT maximum power point tracking, it is one of the primary methods of reducing the output of solar panels to that which can be utilized by a battery. PWM is particularly suited for running inertial loads such as motors, which are not as easily affected by this discrete switching, because they have inertia to react slow. The PWM switching frequency has to be high enough not to affect the load, which is to say that the resultant waveform perceived by the load must be as smooth as possible.

IV. RESULT

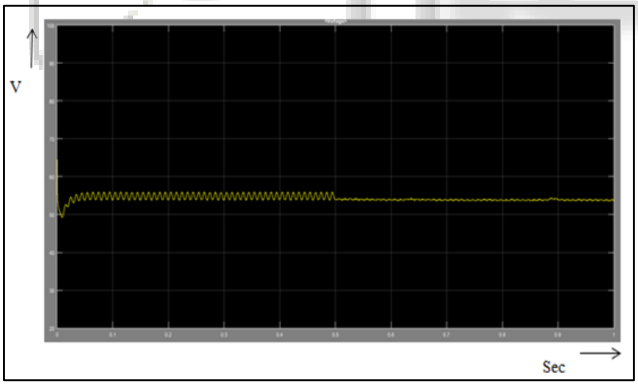

Fig. 4.1: Fuel cell voltage

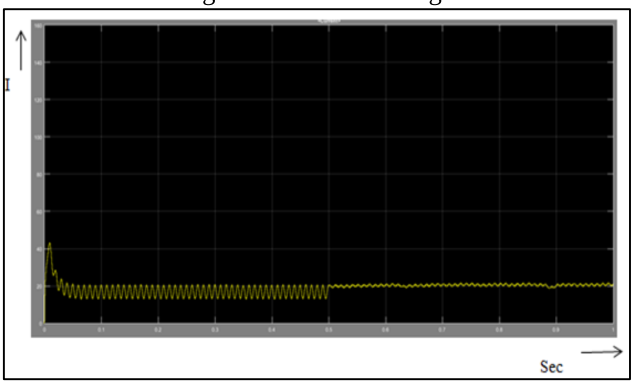

Fig. 4.2: Fuel cell current

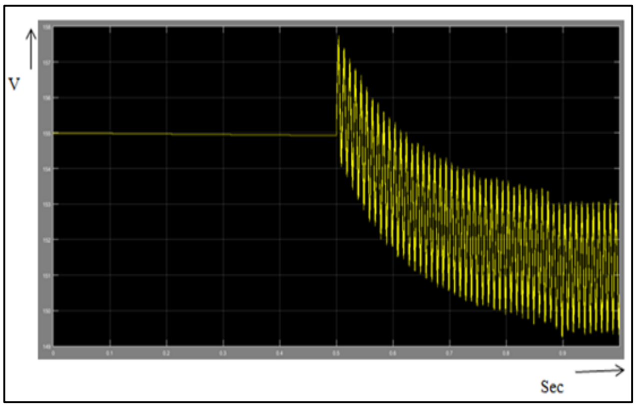

Fig. 4.3: Firing voltage

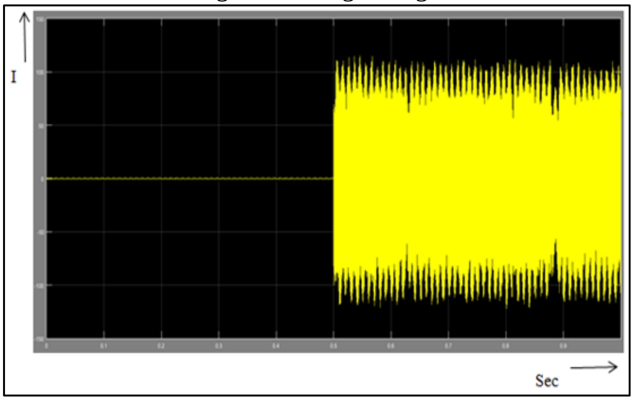

Fig. 4.4: Noise in input current

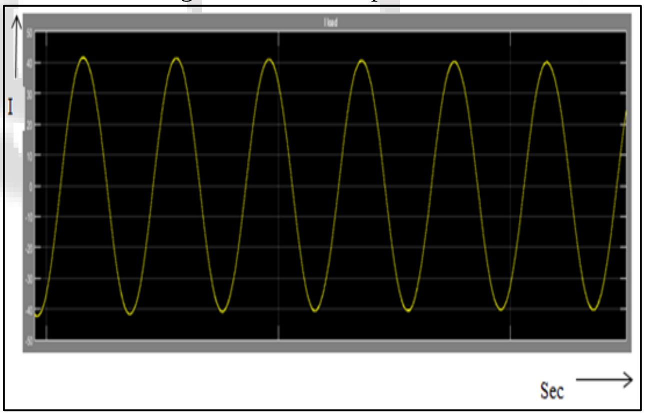

Fig. 4.5: Load current

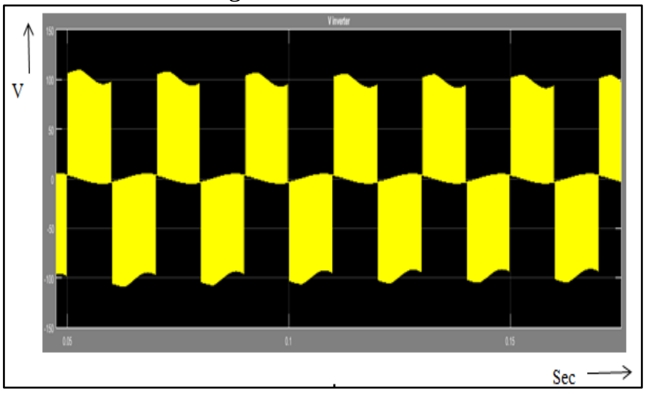

Fig. 4.6: Inverter output

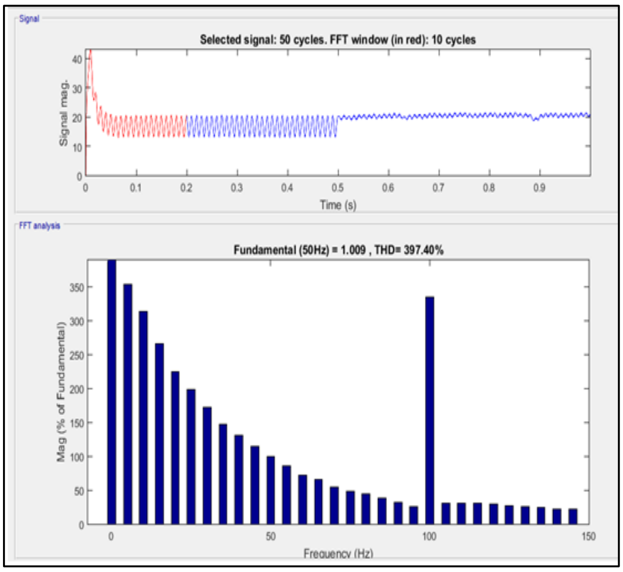

Fig. 4.7: Fast Fourier Transform and Total Harmonic Distortion of the input signal

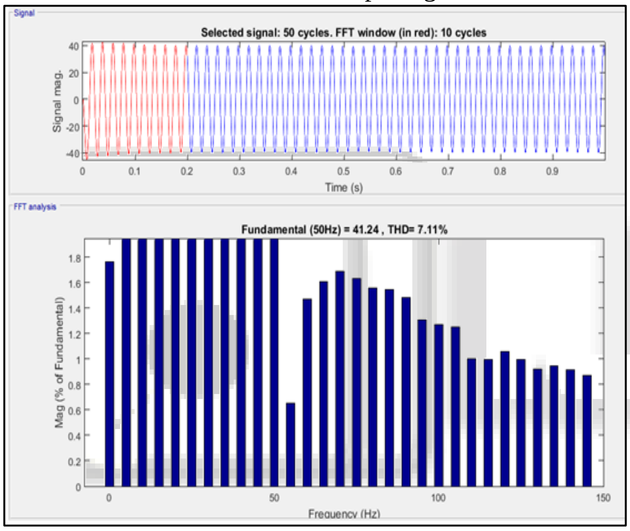

Fig. 4.8: Fast Fourier Transform and Total Harmonic Distortion of the output signal

V. CONCLUSION

A fuel cell is one of the recently identified electrical energy resources which undergoes certain chemical reactions to produce electrical power using hydrogen as fuel and oxygen as an oxidizing agent.

The load voltage harmonics, load current harmonics and unbalanced load which occur due to non-linearity and unbalanced load are present in the distribution system. These effects of load voltage and load current harmonics affect the overall performance of the distribution system. It also affects the voltage across the point of common coupling. Due to this, other linear loads connected to the point of common coupling also get degraded.

The boost converters provide the advantage of reduced ripple in the source current thus providing increased life to the sources like battery. By adopting the current mode control scheme in converters, better dynamic performance of the system is achieved. The reduced ripple in the source current provides the advantage of reduced electromagnetic interference. The features of the converters provide an advantage of having lesser filter capacitor. Converters provide the option of adopting higher switching frequency and thus by reducing the size and cost of the system.

VI. FUTURE SCOPE

1) The implementation of Fuzzy Logic Controller for load variation to Fuel Cell is discussed in this thesis. However, the chemical activity of FC can also be considered as the other controllable parameters by the Fuzzy Logic Controller.
2) The Fuel Cell technology is extensible for large scale and small scale standalone systems. The digital controllers for Shunt Active Power Filter, Hysteresis Current Controller using Field Programmable Gate Array can be designed as an integral part of the standalone modules of fuel cells so as to develop automated FC.
3) In the future, when the cost of fuel cells reduce because of its development, the FCPS can be modelled for use in any size of irrigation system with adequate suction heads.

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