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IMPLEMENTATION OF THREE PHASE HIGH VOLTAGE GAIN CONVERTER FOR FUEL CELL

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Abstract

Generally, the power generating from the Fuel cell is an electrochemical reaction between H2 and oxygen and it generates electric energy, and the by-product is water vapour. However, the output from the fuel cell systems is very low, then it becomes necessary to connect more number of cells in series to improve the output. The proposed method electrically divides the fuel cell stack into different sections, and each stack is powered by a direct boost inverter. This project proposes a concept of high voltage dc-dc boost converter topology for a three phase system to a typical output voltage from the fuel cell as a stand-alone supply. The main advantage of the proposed boost inverter method include ability to deliver the operations of both boosting and inversion of the power in only one stage, compactness, and economical. The output voltage from the fuel cell is a voltage controlled method and output from the battery is a current controlled method. Analysis, and Simulation are taken from a 2kW prototype.

Introduction:

Day by day the fossil fuel reserve is decreasing, increasing the price beyond the affordable limit. Moreover, the vehicles using fossil fuels are polluting the environment, rising new regulations to lessen the emission of [illegible] . Because of this, world researchers are heading towards the renewable energy systems. Fuel cells and photovoltaic systems, for example, have become the prominent sources of renewable energy. Fuel Cell, in particular, has been as an emerging technology in today's world, making it possible to achieve a green and clean environment. However, the output voltage obtained from this source is very low.

As this system is normally integrated with the gird or fed to ac loads shown in Fig. 1 via a high dc input inverter, large voltage gain dc-dc step up converters are required to lift the small output voltage of the fuel cell [1]. Also, high gain dc-dc converters are used in various applications, for instance, automobile, LED lighting, switch mode power supply, telecommunications etc. Hypothetically, a conventional dc–dc boot converter can secure a large output voltage by using large duty cycle [2]-[4], resulting in different major problems, for instance, reverse recovery, electromagnetic interference, conduction loss at the switches, increased ripple inductor current and ripple output voltage etc.

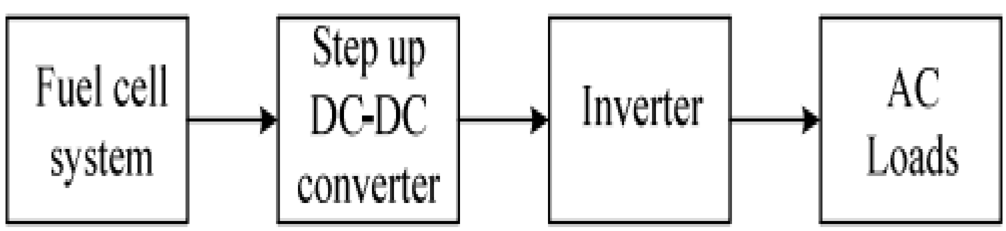

Figure 1: Typical fuel cell systems

To obtain high gain dc-dc conversion several dc-dc converters are employed which are basically divided into two categories- non-isolated and isolated converters. The conventional boost converter, cascaded converter, switched inductor and capacitor converters are the examples of the nonisolated converters. These converters can give a high output to input voltage ratio, but they need high duty cycle which causes ripple current of inductor and reverse recovery problem. Thus, the power loss grows, declining the overall efficiency. Cascaded step up converters can acquire large voltage gain easily. But they involve more devices which increases the size and cost of the converter. Thus, the efficiency goes down. Very large voltage at the output is achievable by the switched capacitor converters. However, the supply current is fluctuating in nature and the load regulation is not good enough.

Therefore, it is evident that a highly efficient step up dc-dc converter is needed which can overcome the above mentioned issues and fulfill the demand. This paper presents a very high gain dc-dc step up converter which works at a very low duty ratio (i.e, duty ratio < 0.5). A single control signal is used to control the switches, cutting the operation complexity short and increasing the efficiency. Moreover, the discrepancies found during the operation are within the tolerable limit. Finally, the rigorous steady-state analysis is justified by the simulation results obtained from the software Simulink.

PROPOSED CONVERTER AND ITS WORKING PRINCIPLE:

Typically, during day time, electrical load in Indonesia is lower compared to peak load. Therefore in order to improve generation efficiency, during day time energy from the grid is used to generate hydrogen through electrolyzer. Then, stored hydrogen is required to generate electricity for the peak load. To achieve a high converter output the boost converter circuit, it is combined with a voltage multiplier circuit. The advantages of this circuit boost converter is a simple system circuit so that economically reduce the cost of construction and able to generate high gain with decreasing MOSFET rating as the automatic switch. Disadvantages of this converter circuit are less efficient level and the number of power losses that occur in the circuit. Fig. 2 shows a series of a boost converter with a voltage multiplier.

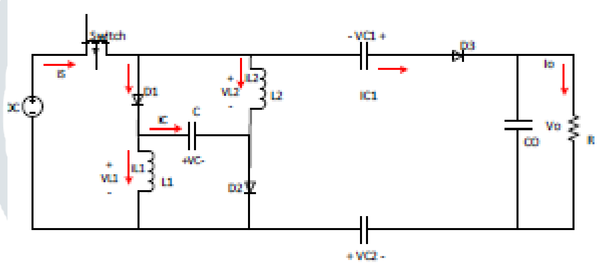

Figure 2: Boost Converter Using Voltage Multiplier Circuit

There are two switching modes condition to operate the converter. Mode 1 is in the switching on condition and mode 2 is in the switching off condition. To find the output voltage of the converter can be calculated by determining the voltage of the inductor during one switching period as follows:

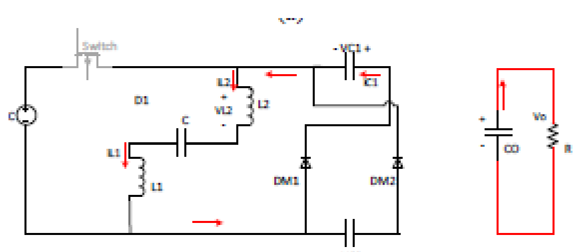

Figure 3: Switching state condition, (a) during Mode 1, (b) during mode 2

The main objective of this paper is to propose a 3-phase FC stand-alone power supply having only single energy conversion converter along with a back-up unit is shown in Figure 4. The cost of this proposed system is reduced by making the multi stage conversion system with a single stage system, i.e. boost-inverter due to this the switching losses and conduction losses are also reduced.

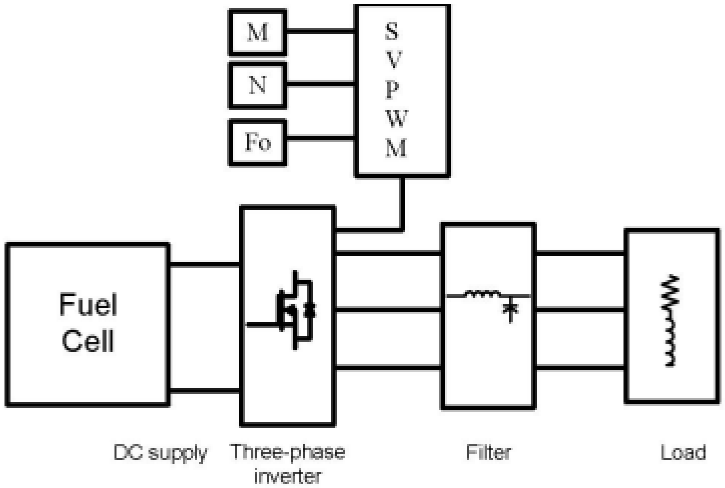

Figure 4: Three-phase inverter system

Generally, the diagram shown in figure 4 shows that boost-inverter is followed by the Fuel Cell and the back-up energy storage system, these two converter are connected at the same bus and output from the boost inverter is a three phase AC and it is connected to three phase balanced star connected resistive load. The Fuel Cell system has operated in current mode controlled bidirectional converter for battery converter to support the Fuel Cell.

In this paper the three phase boost inverter is separated to three individual converter for three phase arms and connected to three individual balanced loads, as shown in Fig 4. The dc-biased three phase output voltages are described by

$$V_a = V_{\mathrm{dc}} + A_o \cdot \sin\theta$$

$$V_b = V_{\mathrm{dc}} + A_o \cdot \sin\left(\theta - \frac{2\pi}{3}\right)$$

$$V_c = V_{\mathrm{dc}} + A_o \cdot \sin\left(\theta + \frac{2\pi}{3}\right)$$

Three-Phase Pwm Inverters

Six-step modulation uses a sequence of six switches patterns for three-phase legs of a full-bridge inverter to generate a full cycle of three-phase voltages. A switch pair connected the positive dc bus and the negative dc bus represents a phase leg the output terminal is the midpoint of the two switches. Only one switch of a phase leg may be turned on at any time to prevent short circuit between the dc buses. Six switching signals are used to operate the inverter such that its output nearly sinusoidal voltage and current with 1200 different. Each of the SVPWM signals connected to one of the three-phase inverter legs such as the upper switches SA, SB, and SC are connected to the SVPWM output signals Phase A, Phase B and Phase C respectively, and the lower switches

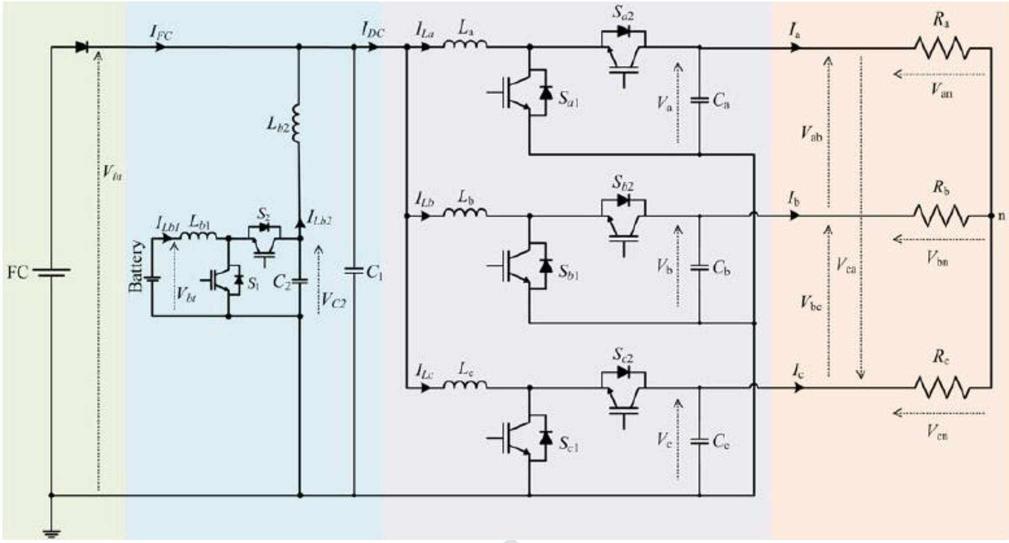

Fig 5: FC sourced based on the three-phase boost-inverter

SIMULATION DIAGRAM AND WAVEFORMS:

The experiments for the fuel cell system along with boost inverter is obtained by the figure shown in 4. These experiments are verified in Matlab/Simulink and the parameters considered for this system is shown in table 1. In this case study we considered the input voltage from the fuel cell is nearly 42V and the ac line to line output voltage obtained is 210V.

PARAMETER	RANGE
AC OUTPUT VOLTAGE	210V, 50Hz
Switching Frequency	20kHz
Rated Power	1kW
La=Lb=Lc	700 micro H
Lb1=Lb2	700 micro H
Ca=Cb=Cc=C1=C2	20 micro F

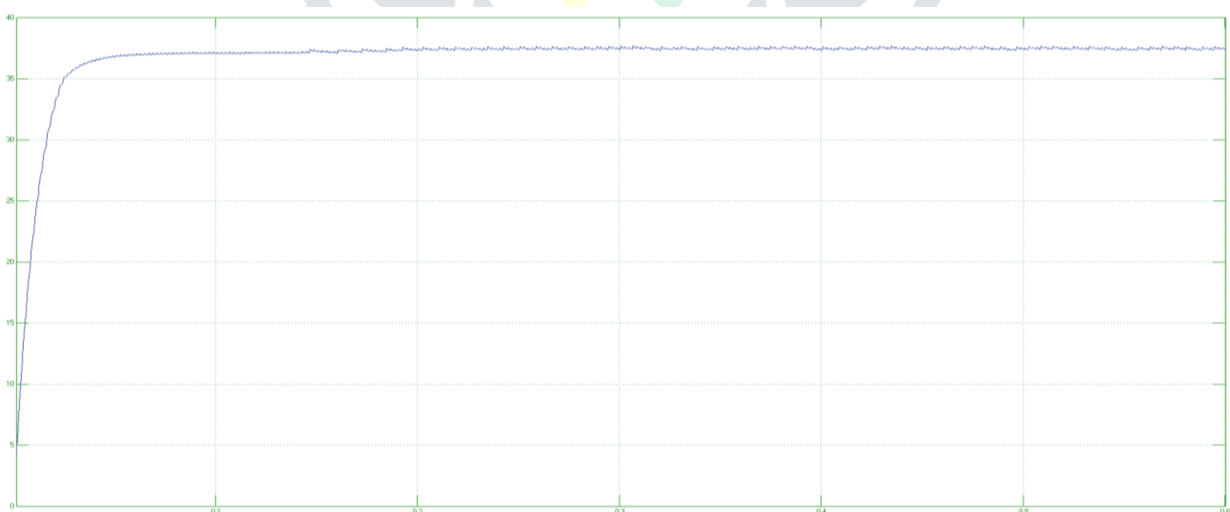

Figure 6: Simulation Result for Fuel Cell Output Voltage

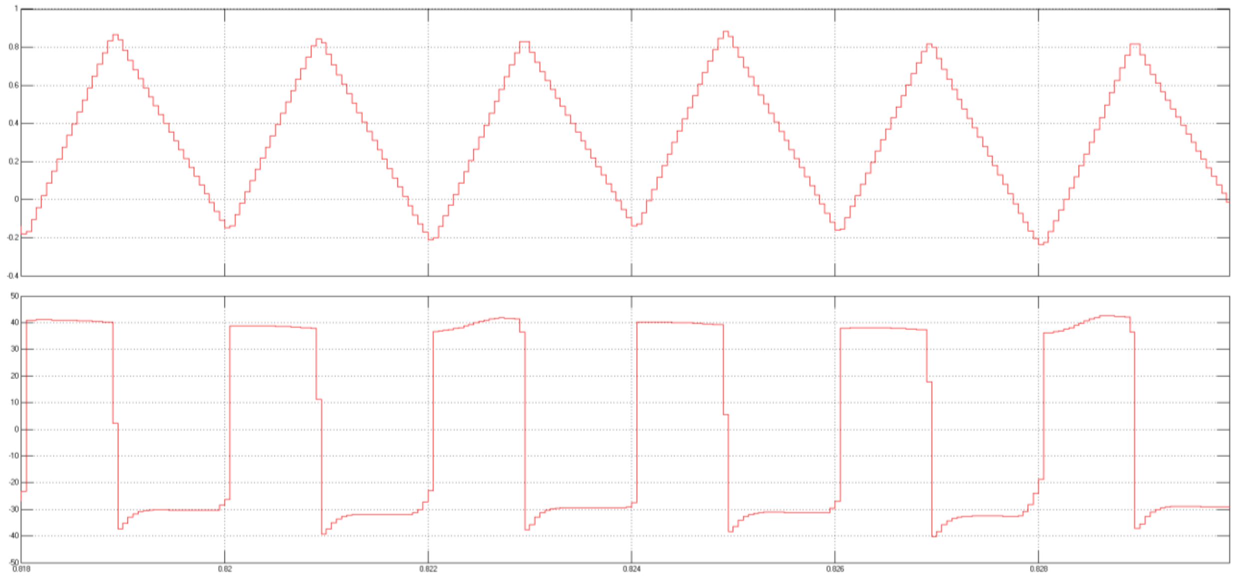

Figure 7: Simulation Result for Inductor Voltage and Current

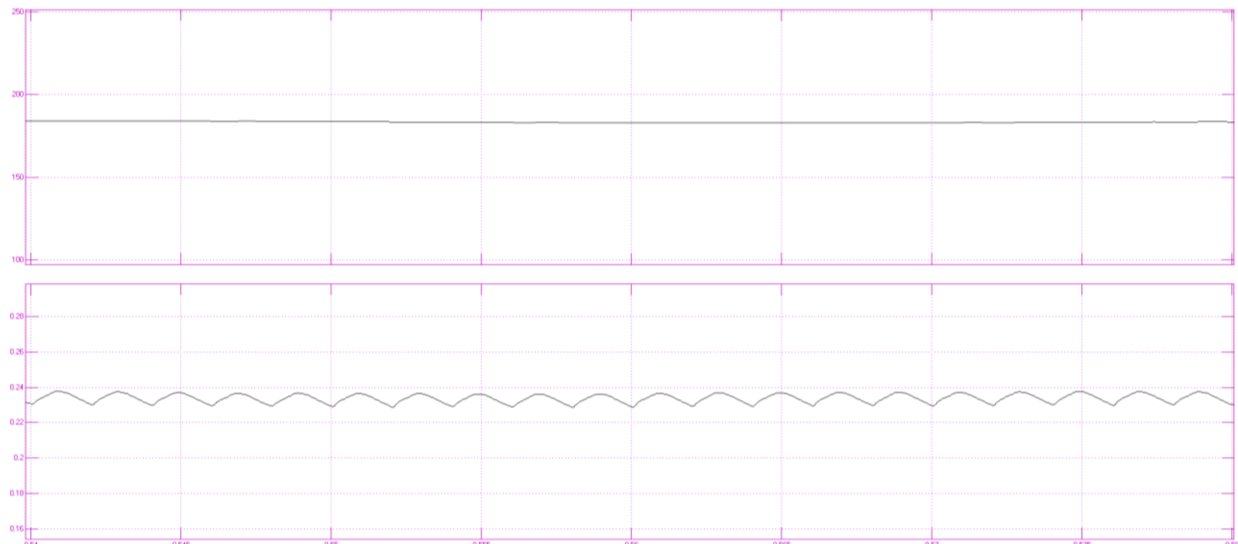

Figure 8: Simulation Result for High Voltage Converter Output Voltage and Current

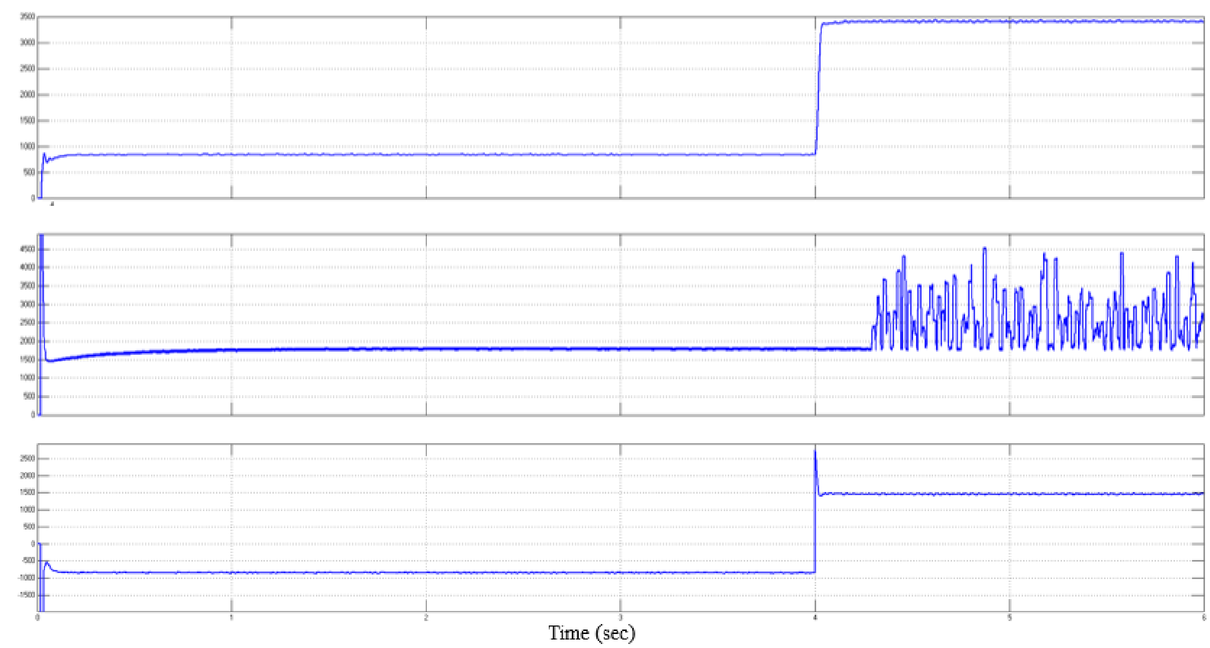

Figure 9: Simulation Result for Load Power, Fuel cell Power and Battery Power

CONCLUSION

A stand-alone three-phase Fuel Cell power supply based boost-inverter along with a battery energy storage system has been successfully proposed. With these simulation results the operational characteristics of FCBI has been understand. The results of the proposed three-phase FC supply have confirmed its satisfactory performance in delivering boosting and inversion functions in one conversion stage to generate 210 Vac at rated power. The back-up unit key function is to support the slow variations of the Fuel Cell. Finally, the efficiency of this proposed boost inverter fuel cell system is improved with its single stage conversion process and from economical point of view it is better than all other conventional converters. It is in compact size because of usage of less number of switching devices.

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