Implementation of Soft-Switching Techniques For Fuel Cell Power Conversion

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Abstract- *The aim of this project is to implementation and simulate soft-switching techniques for efficiency gains in half-bridge fuel cell power conversion open loop and closed loop controlled DC-DC converter are molded and simulated using the blocks of simulate. Traditional auxiliary elements in the primary, such as series inductors that are impractical for realizing due to the extreme input current, are avoided and reflected to the output of the rectifier to minimize circulating current. As a result, the proposed combined techniques successfully reduce conduction losses, minimize reverse-recovery losses in the output rectifiers, minimize transformer ringing, and ensure low stress in all the switches. The high efficiency is maintained in the entire range of loading conditions (0%–100%) while taking into consideration remarkable challenges associated with FC power conversion: high input current, low voltage and wide range of loading conditions.*

Keywords- DC-DC converter, Fuel cell, and simulation

I. INTRODUCTION

A. Fuel Cell

FUEL Cells are power sources that convert electrochemical energy into electrical energy with high efficiency, low emissions, and quiet operation. A basic proton exchange membrane (PEM) single-cell arrangement is capable of producing unregulated voltage below 1Vand consists of two electrodes (anode and cathode) linked by electrolyte The output current capability of a single cell depends on the electrode effective area, and several single cells are connected in series to form a FC stack. Due to the mechanical challenges associated with stacking several single cells, FC are typically low-voltage high current power sources and can continuously run while reactant is fed into the system.

Successful power conditioning for FC systems requires dealing with poor voltage regulation, high input current, and a wide range of output loading conditions while maintaining high efficiency and low switching stress. While the trend for high-input-voltage converters has been to minimize switching losses and deal with relatively small line regulation, FC power conversion presents the opposite scenario with low input voltage, poor regulation, and very high input current.

Unlike applications with high input voltage, achieving ZVS with low voltage does not lead to substantial efficiency gains, given the small energy stored in the IGBTs output capacitance. By taking into consideration the aforementioned technical challenges, it becomes critical to address the following relevant points in FC power conversion: 1) need for reduction in conductions losses, and thus, unnecessary circulating current in the primary 2) impracticality of realizing high-current inductors and using series capacitors in the primary 3) minimize substantial reverse-recovery losses in the output rectifiers 4) minimize the associated transformer oscillations and 5) ensure that the high efficiency, by combining points 1) to 5), is maintained under the FC wide input voltage range and 0%–100% loading conditions.

II. DC-DC CONVERTER

Modern electronic systems require high-quality, small, lightweight, reliable, and efficient power supplies. Linear power regulators, whose principle of operation is based on a voltage or current divider, are inefficient. This is because they are limited to output voltages smaller than the input voltage, and also their power density is low because they require low frequency line transformers and filters. The higher the operating frequency, the smaller and lighter the transformers, filter inductors, and capacitors. In addition, the dynamic characteristics of converters improve with increasing operating frequencies. High-frequency electronic power processors are used in dc-dc power conversion. The functions of dc-dc converters are:

1. To convert a dc input voltage V_S into a dc output voltage V_O.
2. To regulate the dc output voltage against load and line variations.
3. To reduce the ac voltage ripple on the dc output voltage below the required level.
4. To provide isolation between the input source and the load.

5. To protect the supplied system and the input source from electromagnetic interference.

A. Boost converter

A boost converter is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching mode power supply containing at least two semiconductors switches and at least one energy storage element. Filters made of capacitors normally added to the output of the converter to reduce output voltage ripple.

When a boost converter operates in continuous mode, the current through the inductor (I_L) never falls to zero. During the On-state, the switch S is closed, which makes the input voltage (V_i) appear across the inductor, which causes a change in current (I_L) flowing through the inductor during a time period (t) by the formula:

$$\frac{dI_L}{dt} = \frac{V_i}{L}$$

At the end of the On-state, the increase of I_L is therefore:

$$\Delta I_{Lon} = \int_0^{DT} dI_L = \int_0^{DT} \frac{V_i}{L} dt = \frac{V_i DT}{L}$$

If we consider zero voltage drops in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of I_L is:

$$V_i - V_o = L\frac{dI_L}{dt}$$

As the inductor current at the beginning of the cycle is zero, its maximum value $I_{L_{Max}}$ (at $t = DT$) is

$$I_{L_{MAX}} = \frac{V_i DT}{L}$$

A. Proposed circuit diagram

Proposed circuit of soft-switching techniques for efficiency gains in Half-bridge fuel cell power conversion is shown in Fig..1. A fixed DC is converted into AC by inverter. It is boosted by using a step-up transformer then this boosted ac voltage is passed through a rectifier to convert it as DC voltage.

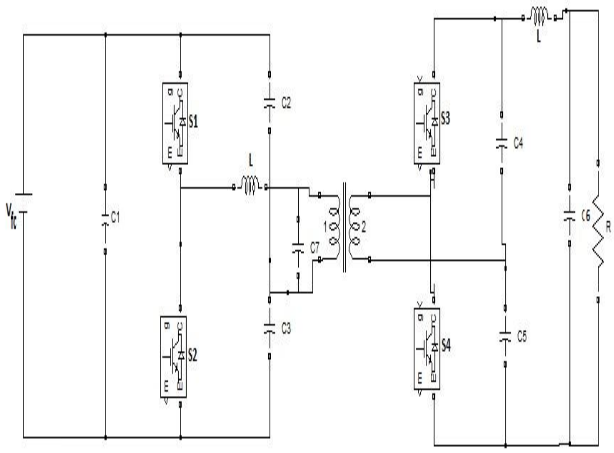

Fig.1- Proposed circuit Diagram

Fig. 1 shows the half bridge dc-dc converter. It contains five parts including a dc input circuit, a primary side circuit, a secondary side circuits a filter circuit and a dc output circuit. The major symbol representation is summarized as follows; V_{in} and L_{dc} are the input circuit parameters. They are input voltage and input inductor. Primary circuit has switches S_1, S_2, C_2, C_3 and C_7. Secondary circuit has S_3 and S_4switches C_4 and C_5 Filter circuit are L_f filter inductor and C_1 are filter capacitor. C_0 and V_0 are output capacitor and output voltage. The operation allows a resonant discharge of the lossless snubber capacitance of the switching devices and each devices anti parallel diode is conducted before the conduction of switching devices. There are two modes

Mode: 1 Energy storing mode
Mode: 2 Energy transferring mode

Energy storing mode

In the input side supply voltage is applied within the range of 35-48v with internal resistance of 1Ω. Energy is stored in the Inductor. Stored energy is released after some time interval. Time period is depend upon the switching frequency.

Energy transferring Mode

To transfer the energy from Inductor to the entire circuit.

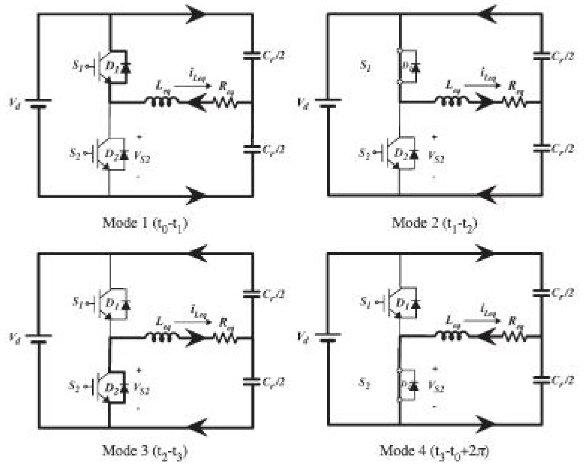

Fig.1(a) Operation modes of the Half bridge inverter

III. MATHEMATICAL ANALYSIS OF CIRCUITS

The section deals with calculation of DC – DC converter of ZVS-PWM. The calculation used to find out the output voltage control region of converters. The formula is utilized to be calculated the output voltage Losses:

1. The conduction losses in the rectifier are the same for conventional PWM and ZVS PWM.

$$P_{rect} = 4\ (I_{out} / 2\ V_f) \text{ -------(1)}$$

2. The conduction losses on the primary bridge diodes are.

$$P_D = V_{diode}\ I_{av} \text{ -------(2)}$$

Vdiode is the forward voltage drop on the diodes and Iav is the average current.

3. The conduction losses due to channel resistance of the switches can be calculated as

$$P_Q = R_{on}\ I_{rms} \text{ -------(3)}$$

To find parameters.

1. $I_o = V_o / R$ -------(4)
2. $P_o = V_o^2 / R$ -------(5)
3. $E1 = 4.44\ N1\ \Phi f$ -------(6)
4. $E2 = 4.44\ N2\ \Phi f$ -------(7)

IV. SIMULATION RESULT

Proposed circuit of soft-switching techniques for efficiency gains in Half-bridge fuel cell power conversion is shown in Fig.2. A fixed DC is converted into AC by inverter. It is boosted by using a high frequency transformer then this boosted ac voltage is passed through a rectifier to convert it as DC voltage. The DC input voltage waveforms are shown in Fig.2(a)

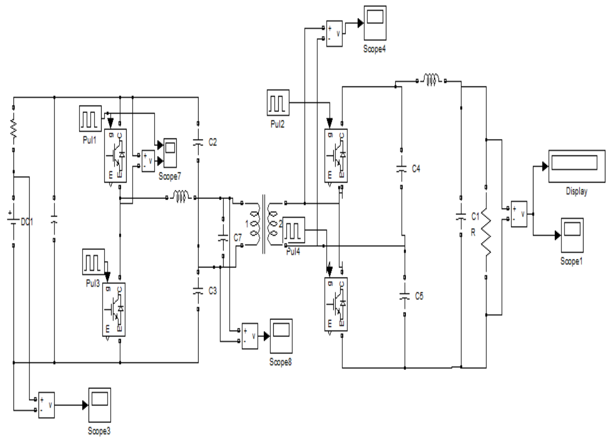

Fig.2(a) Simulation circuit of proposed circuit

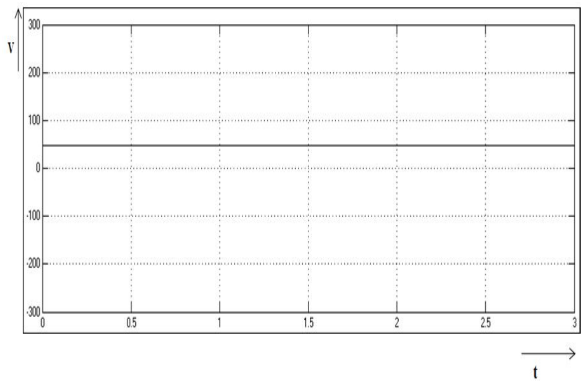

Fig.2(b) Input Voltage

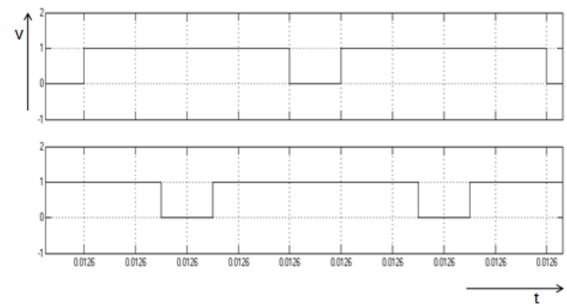

Fig.2(c) Switching pulses of S1 & S2

The output voltage is 220V**.** The output voltage waveform of the circuit is shown in Fig.2(c).

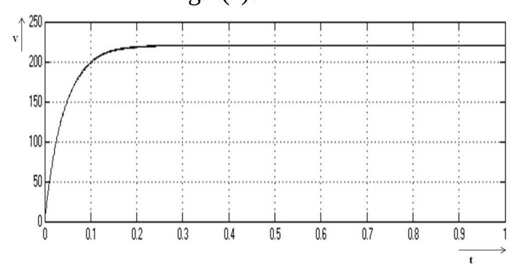

Fig.2(c) Output Voltage

A. Open loop with disturbance

Open loop with disturbance at an time sec at 1.5sec and given error voltage of 6v that is voltage input to primary winding 48v and secondary winding 220V and output voltage is purely dc voltage 220V. so, this error is given to open loop are shown in fig.3

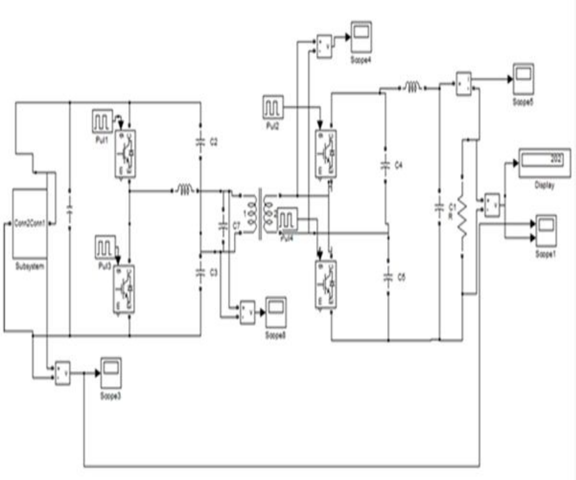

Fig.3 Simulation Circuit For Open Loop With Disturbance

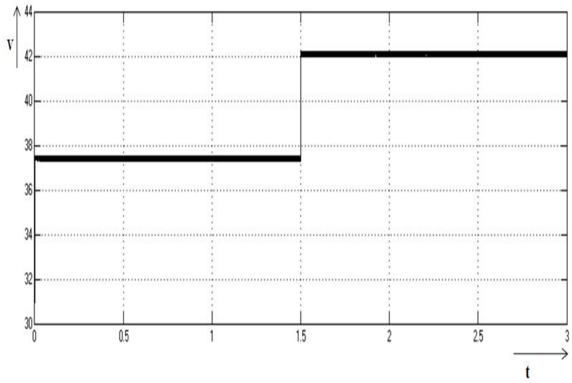

Fig.3(a) Fuel Cell Input Voltage Wave Form

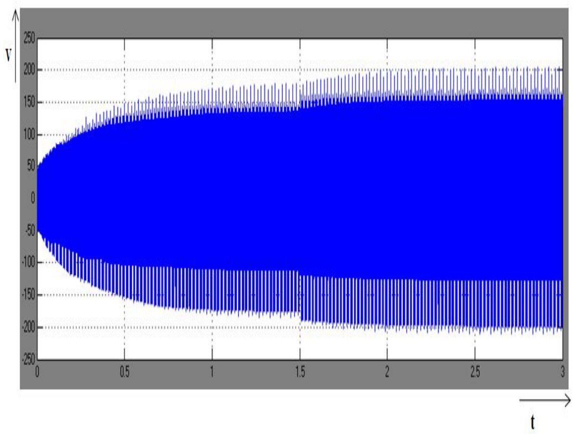

Fig.3(b) Transformer Secondary Voltage Wave Form

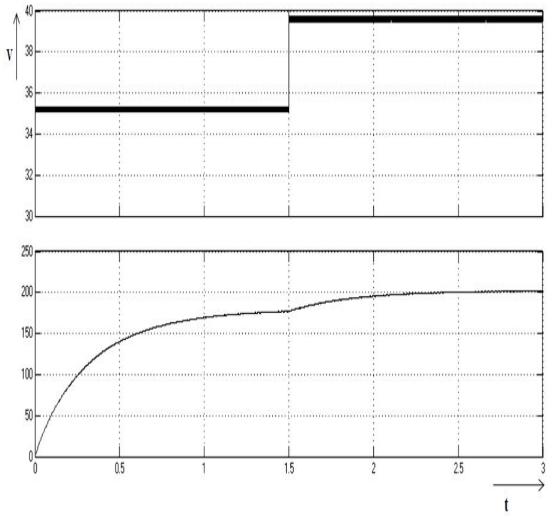

Fig.3(c) Fuel Cell output voltage and final output voltage wave form

A.Closed loop with disturbance

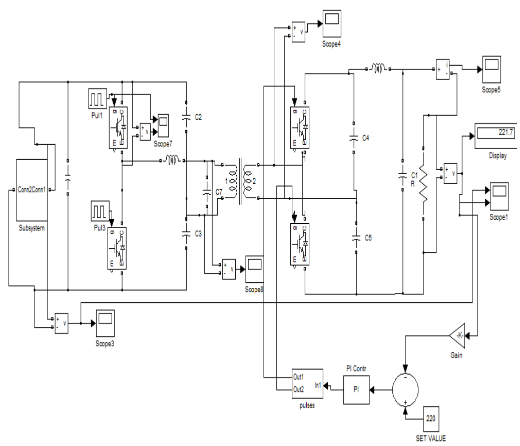

Fig.4 Simulation circuit for closed loop with disturbance

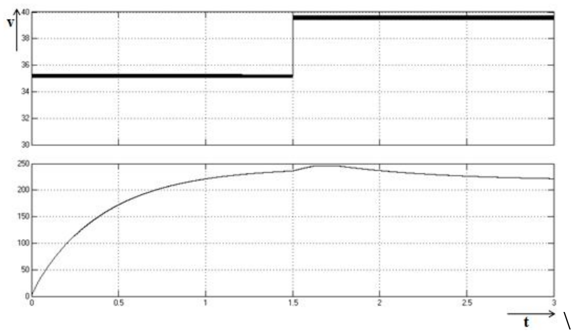

Fig.4(a) Fuel Cell Output Voltage And Final Output Voltage Wave Form

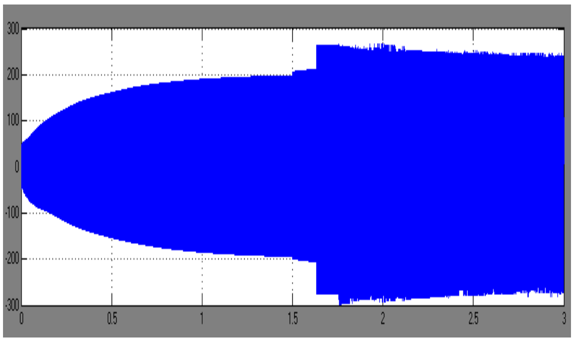

Fig.4(a) Transformer Secondary Voltage WaveForm

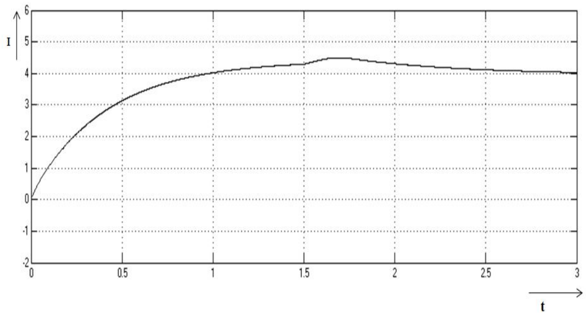

Fig.4(b) Output Current Wave Form

V. CONCLUSION

The DC to DC converter using Half-bridge inverter is simulated using mat lab simulink the proposed circuits are simulated. As a result, the proposed combined techniques successfully reduce conduction losses, minimize reverse-recovery losses in the output rectifiers, minimize transformer ringing, and ensure low stress in all the switches. The high efficiency is maintained in the entire range of loading conditions while taking into consideration remarkable challenges associated with FC power conversion: high current, low voltage and wide range of loading conditions.

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