

Optimum Step-Up Converter by Employing Active-Clamp in Fuel Cell Power Generation

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ABSTRACT:

In this paper to boost a 12-V dc voltage into a 220-V 50-Hz ac voltage A high-efficiency fuel-cell power-generation system with an active-clamp flyback–forward converter is presented. This system includes a flyback–forward converter and a full-bridge inverter which has high-efficiency high-step-up interleaved soft-switching. Two coupled inductors are presented in this system. Both of the inductors can operate in flyback mode and forward mode when the corresponding switch is in ON state and OFF state respectively by which magnetic core is used up to the maximum extent thereby improving power density .An LC lowpass filter is used at the load end to achieve low-total-harmonic-distortion at the ac load end.As a result maximum efficiency and density of power conversion can be expected for a wide input-voltage by implementing this system.

I.INTRODUCTION:

In search of solution to fossil-fuel energy shortage and to protect the protect the globe from pollutants which are released as byproducts from electric power generation Fuel Cell has been emerged which give solution to all these problems the major attributes of fuel cell are it is clean, high efficient renewable energy source, highly reliable. One of the most irreplaceable feature than compared to any other system is it can be placed anywhere in the power system for reinforcement of grid so that efficiency, reliability and integrity can be improved to a large extent. Boost dc/dc converters and a three-phase pulse width modulation inverter are used to interface fuel cell power plant with grid. Boost dc/dc converter and PWM inverter are used in present system. Fuel flow controller and dynamic model is not presented. In our present system reactive power control and management of active power is done by fuzzy control structure.

II. FUEL CELL:

An electrochemical device which produce electrical energy from chemical energy is called a fuel cell.In these conversion process fuel is not supposed to convert into thermal and mechanical energy.A fuel cell essentially consists of an electrolyte and two electrodes. The operation of a fuel cell resembles the operation of a Battery which also converts chemical energy to electrical energy except the fact that there is no mechanism to store reactants in the fuel cell instead they are supplied to fuel cells.Concept of Fuel cells first came into light in 1839,but the considerable technical aspects were not explained until the late 1950s. During the 1960s,NASA is the first to use fuel cell technology in spacecraft. Fig II.I shows the mode of operation of a simple fuel cell.Fuel(hydrogen-rich) and oxidant(typically air) are served separately as inputs which is quite opposite to ordinary combustion process.An electrode-electrolyte system which is present in the fuel cell separates the oxidant and fuel streams.Anode (negative electrode) is fed with fuel and cathode (positive electrode) is fed with air.At the electrodes to produce electric current Electrochemical oxidation and reduction reactions take place.water is the primary product of fuel cell reaction process.

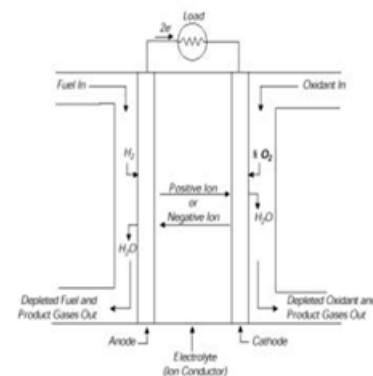


Fig.II.I Schematic of an Individual Fuel cell

III.DISTRIBUTED GENERATION:

The Electric Power Research Institute defines distributed generation as the “integrated or stand-alone use of small modular resources by utilities, utility customers, and third parties in applications that benefit the electric system, specific customers, or both.” Fuel cell power generation is similar to cogeneration and on-site generation. Distributed power market segment with fuel cell supply power in the range of 3 MW to 100 MW. This market is served by high temperature fuel cells and this market is comprised of unregulated subsidiaries, traditional utilities, energy service providers and municipal utilities. It is an assumption that fuel cells for distributed power market is integrated coal gasification. To compete in a deregulated market energy industry is changing. Distributed generation is extending its path because it can make use of new technologies, meet growing energy demand and stringent emission requirements. However many utilities to met the future demands showing attention on alternative generation technologies. If the operation of distributed power market technologies goes into real time the economy of the power system increases drastically there by reducing the cost of power when compared to centralized utilities. Some of the major advantages of distributed power market when compared to centralized utilities are

1. The major factor in any system is the economic factor it got reduced in this system
2. Provides a convenient path for cogeneration
3. We can supply power without any interruption.
4. Transmission and Distribution costs are reduced drastically.
5. Energy demand of the utilities can be met with lower costs
6. Remote areas with most economic customers where there is no Transmission and Distribution infrastructure could be served easily which will gain lot of advantage to system.

IV. ACTIVE CLAMP OPERATION:

Active Clamp circuit consists of two main switches Q1 and Q2 as shown in fig IV.I at to main switch Q1 is in ON state thereby applying voltage V across transformer primary secondary voltage across transformer secondary is $V_{in} \times (N_s/N_p)$.

During this point of time primary current is consists of one is reflected current from the output inductor and the other is current ramping up in the magnetizing inductance. At the this position switch Q2 is open and in this state clamp capacitor is previously charged. During this state power is transferred from the primry side to secondary side the power phase during this period is $T_s \times (V_{out}/V)$, where T_s is the switching period.

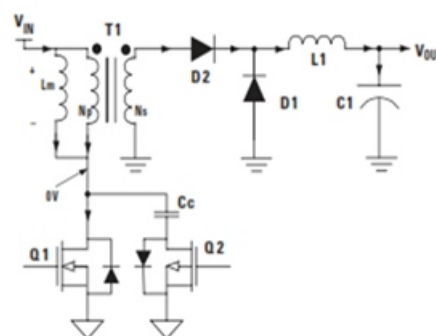


Fig. IV.I Operation at to

Fig IV.II shows the operation of active clamp circuit operation at t_1 at this position main switch Q2 is on and the main switch Q1 is in off. The at this point of operation magnetizing current flows through Q2 instead of Q1. Compared at to the voltage across the primary of transformer is reversed this is so because of the clamp capacitor voltage which is greater than V. As the magnetizing inductance polarity is reversed the energy is transferred to clamp capacitor from magnetizing inductance. During this period the clamp capacitor voltage increases slightly and reaches to peak value when magnetizing current is zero. Current in the magnetizing current is zero at t_2 and current starts to build in the opposite direction which is sourced from the clamp capacitor through reset switch Q2, magnetizing inductance and then back to the source.

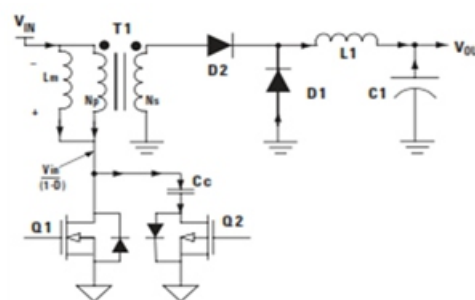


Fig. IV.II Operation at t_1

As the clamp capacitor dissipates the energy that is previously stored from the magnetizing inductance the current starts to build in the opposite direction. For the circuit to achieve steady state period magnetizing current should be equal to the current at the beginning of the reset and the clamp capacitor to the polarity to its polarity which is at the starting switching action gets completed by the end of time t_2 and is known as the controller oscillator period. Flow of current from the clamp capacitor is stopped by turning off the reset switch. Some important waveforms are shown in Fig IV.IV. Error signals and modulator ramp are shown in uppermost waveforms which determine the on time of main switch. Drain voltage of main switch is shown in center when the switch is in on state drain voltage is small and when the switch is in off state it raises up to the clamp capacitor potential. Current in the magnetizing inductance is represented in the lower waveform designated in red color and this current flows through clamp capacitor also which is designated in blue color when it is reset. At zero cross over point both the inductance current and clamp capacitor currents are balanced.

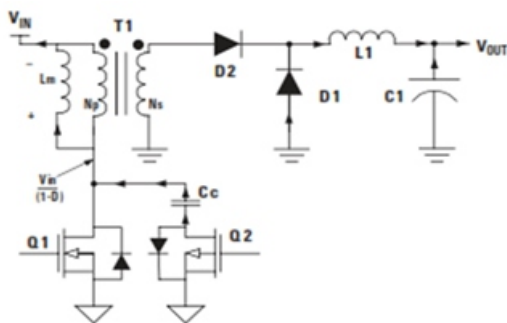


Fig.IV.III Operation at t_2

By resetting active clamp losses occurred by using several switches can be realized. Q1 can be made loss less by serving fast gate drive signals to Q1. To achieve this operation gate of Q1 is turned off well in advance before the drain voltage has a chance to rise. Due to the drain-source capacitance the rise of the drain voltage is delayed Q1 is turned off by a robust gate driver well in advance before the drain voltage increases. A high peak gate discharge current is provided to accomplish fast turnoff and reduced switching losses by using a compound gate driver which is made up of MOS and Bipolar devices. By selecting appropriate switch delays turn on losses can be minimized, allowing time for the drain voltage reduction prior to the initiation of the main switch.

For steady state operation, the net Voltage x Time product applied to the magnetizing inductance over a complete cycle must equal zero. When the main switch is on, the Volt x Time product is $V D T_s$, where D is the on-time duty cycle and T_s is the switching period. The off period is defined as $(1-D) T_s$. The voltage across the primary when the main switch is off is $V_{in} - V_c$, where V_c is the clamp capacitor voltage. In steady state operation, the Volt x Time products must be equal: $V_{in} \times D \times T_s = (V_c - V_{in}) \times (1-D) \times T_s$

Solving for clamp capacitor voltage yields:

$$V_c = V_{in} / (1-D)$$

Remember that the duty cycle (D) decreases as V_c increases. To maintain the quality of power clamp capacitor easily adopt the line voltage changing regularly. By this feature at all the operating conditions voltage across all the main switches is minimized thereby increasing overall efficiency of the system. Efficiency is improved to a great extent by using low rating MOSFET which in turn reduce the resistance and capacitance for lower gate charge. Energy which is stored in the leakage inductor is not dissipated rather it is recirculated which causes the duty cycle go over 50% which in result reduces voltage stress on converters there by reducing overall losses.

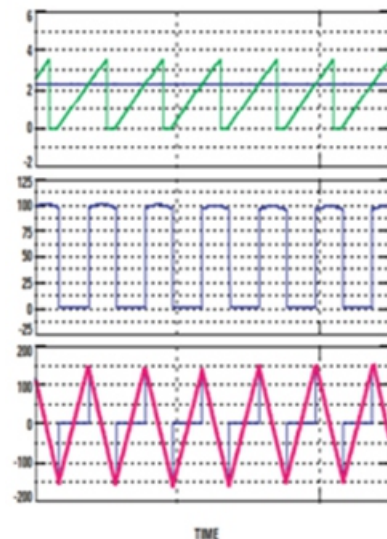


Fig.IV.IV.Active-clamp waveforms

V.PROPOSED SYSTEM STRUCTURE AND ANALYSIS:

The proposed system consists of an high step-up fly-back-forward converter and a full bridge inverter in single phase.

In proposed system main switches in circuit S1 and S2 operate in the interleaved mode to operate large input currents. With respect to main switches S1 and S2 the auxiliary switches in the active clamp circuit are handled complementarily i.e when main switch S1 is in on state then corresponding auxiliary switch Sc1 is in off state and if main switch S2 is on then corresponding auxiliary switch is in off state.

Clamp capacitors Cc1 and Cc2 are also incorporated in the active clamp circuit which are placed with an aim to recycle leakage energy produced in the system. L1 and L2 are the two coupled inductors placed in the system whose primary inductors L1a and L2a with n1 turns are coupled to secondary inductors L1b and L2b having n2 turns. In order to achieve boost type conversion secondary inductances are placed in series.

leakage inductances of two inductors L1 and L2 is designated by Llk and it is the summation of two inductors. Magnetizing inductors are designated by Lm1 and Lm2. turns ratio is designated by N. Cs1 and Cs2 are the parallel capacitors incorporated in order to implement ZVS soft-switching operation.

In secondary side of circuit voltage doubler configuration is employed for high step up conversion process which contains output capacitors C01, C02 and output diodes D01 and D02. Output bus voltage is shared equally by output capacitors C01 and C02. Single phase full bridge inverter is employed on the ac load side having switches S3, S4, S5 and S6 and the gate pulses to this switches are provided by a pulse width modulator.

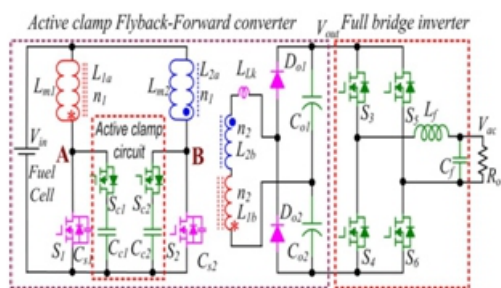


Fig.V.I. Proposed Fuel cell with High-step-up.

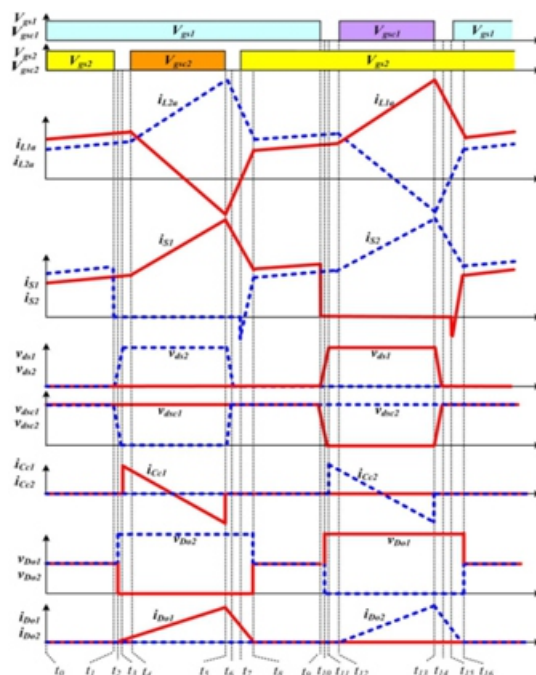


Fig. V.II. Operational waveforms of the proposed converter.

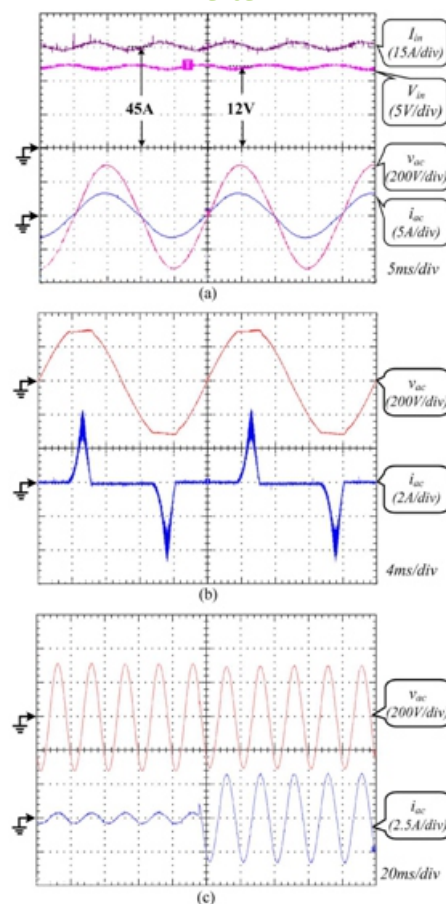


Fig. V.III Results across the output of inverter
a) Output waveforms for resistor load. b) Output waveforms for RCD load. c) Output for Dynamic Response

VI. CONCLUSION:

In this project fuel cell power generation is explained and analysed through an active clamp circuit operation in which the operation is done is by fuzzy controller and the economies of fuel cell power system are discussed and compared with traditional system. The voltage is stepped up to a high value by employing fly back-forward converter in addition to that the operation of primary switches is also discussed with ZVS soft-switching to minimize the switching losses. Ripples in input current is also very small because of the fact of interleaved operation and its configuration is current-fed-type. Performance of the circuit and its operation in steady state are discussed and its advantages are explored in fuel cell power generation system by using a fuzzy controller.

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