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# Power Converter Topologies for Fuel Cell- Based Hybrid Power Systems

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***Abstract*— Power electronics is one of the key factors enabling sustainable energy technologies. Various power circuits have recently been investigated in an attempt to explore reliable, highly efficient, high power density, and low-cost power processing systems for alternative energy generation. This paper presented the different types of power converters suitable for use in fuel cell and battery hybrid power source for electric vehicle application. Various types of hybrid power system configurations and associated control methods are explored. The converter topologies reported in the literature can be broadly classified into unidirectional and bidirectional converters. For interfacing storage devices bidirectional converters are needed, whereas for interfacing primary source fuel cell, unidirectional converter topologies should be investigated. The feasibility of proposed converter for hybrid source has been simulated using MATLAB.***
***Keywords*— Power Converter, Fuel cell, Battery, IGBT**

## I. Introduction

Fuel cells are an environmentally friendly renewable energy source that can be used in a wide range of applications and it is more suitable for use in transportation system. Fuel cells have the potential to provide clean power for variety of uses including substitution for gasoline and diesel powered propulsion system. The application is extremely sensitive to size, weight, and cost, so a proton exchange membrane fuel cell (PEMFC) using hydrogen stored in a metal hydride is the best choice [1]. Fuel cell power generation is expected to play a big part due to its several advantages, such as high efficiency, low environmental pollution, fuel diversity, reusability of exhaust heat and modularity [2]-[6].

## II. Power Converter topologies

The possibilities of using auxiliary sources like battery bank or super capacitor have been presented in many literatures for electric vehicle application [7]. Different power converter topologies can be used for power electronic interface between the FC and the utility dc bus. Basically low voltage high current structures are needed because of electrical characteristics of FC. A classical boost converter shown in Fig.1 is often selected as "FC converter" [6] because it can be operated in the current control mode in continuous conduction mode. Based on the load condition, the boost converter can be commanded to draw a specific amount of current from the FC with a ripple that is well defined by the frequency, size of the inductor, and the duty cycle. In many applications, the use of an isolated transformer can provide an increase in the input/output voltage conversion ratio as required and a full bridge converter can be used. However, there are applications where transformer-less energy converter systems could potentially offer significant advantages, including simplicity, cost, and converter size reduction, particularly in high-power applications. That way, the use of paralleling power converters with an interleaved technique may offer some better performances.

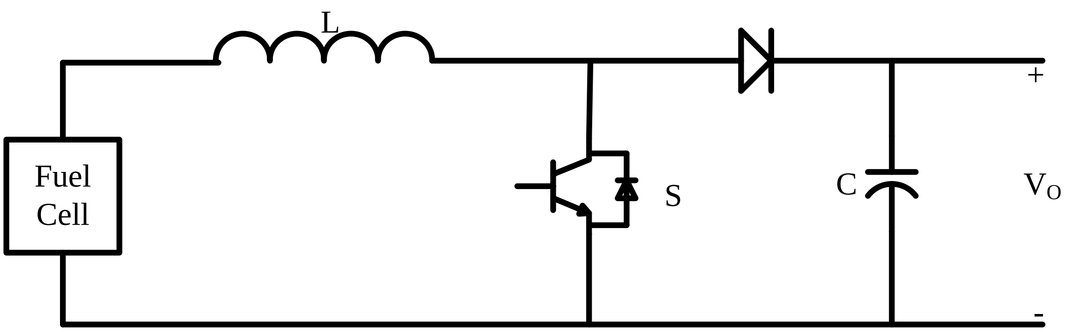


Fig.1 A Classical Boost Converter.

A dual converter topology has been proposed for fuel cell and battery hybrid power system used for UPS application in [7] and the same is shown in Fig 2. It has four legs with MOSFET as switching device. One phase leg is used as FC converter, which forms a unidirectional boost converter. Battery is connected to other phase leg to form a bidirectional buck boost converter. Output of the two converters is connected to support the dc link. Other half of the circuit forms a single phase inverter.

Power conditioning is an important and essential process necessary for converting the DC electrical power generated by a fuel cell into usable DC or AC power for automotive application, stationary loads and interfaces with electric utilities. The electrical characteristics of a fuel cell are presented in, showing that they are not an ideal electric power source. A typical fuel cell stack has a DC output voltage that varies widely (2:1) with the load current and age of the fuel cell, and has a limited overload capability. Therefore, a DC-DC converter stage is often required to increase and regulate the fuel cell voltage to higher voltage levels for further processing into AC via a DC-AC inverter stage. In this section, several DC-DC converter topologies are examined that can be engaged in fuel cell systems. These topologies have different performance and complexity and it is very important to select the right converter in order to achieve the maximum utilization of the fuel cell energy and to minimize loses.

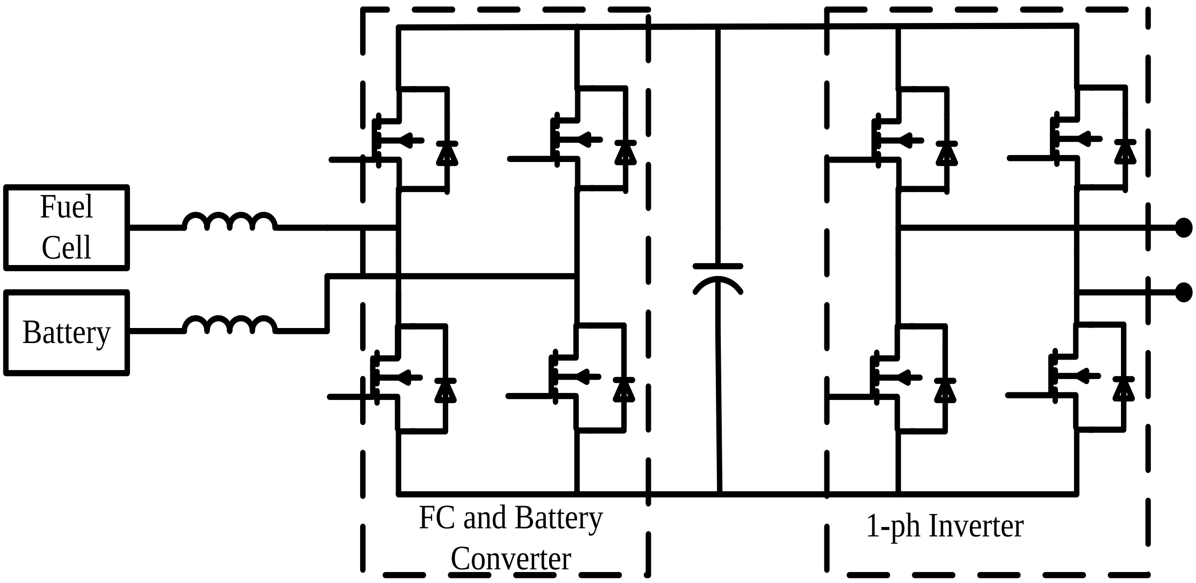


Fig.2 Converter topology for Fuel Cell Unit.

The full-bridge (FB) converter is a popular topology and is widely used in FC power systems. However, as the FC has a wide voltage range, the turns ratio of the primary to secondary windings of the transformer should be reduced to obtain the required voltage for the inverter, resulting in high voltage stress for the rectifier diodes and in low efficiency. The hybrid FB three-level (H-FB TL) LLC converter is used as the UDC because it integrates the advantages of the H-FB TL converter and the LLC resonant converter. If the voltage difference between the dc bus and the battery is low, non isolated bidirectional converters are always employed for their simple structure and control scheme. A traditional two level buck/boost converter is widely used as the BDC in many industrial applications. However, if the range of the input voltage is wide, the inductance will be larger, which results in a low dynamic performance.

A three-level (TL) converter can significantly reduce the size of inductor, which leads to a faster dynamic response than two-level converters. Therefore, the TL buck boost converter has been chosen as the bidirectional converter. Furthermore, the voltage stress on the switches is just half of the dc bus voltage bus. The design of the converter is detailed in. Both configurations need a unidirectional dc/dc converter as an interface between the fuel cell and the rest of the system. Therefore, a unidirectional power converter can satisfy the requirement as power can only flow from the fuel cell to the system. The load is also isolated from the battery and fuel cell through a unidirectional dc/dc converter. When sudden changes occur in the load power, the fuel cell still works at its nominal power, and the battery provides the difference. If the power of load increases, the battery supplies the load. On the other hand, when the load decreases, additional power charges the battery.

In another topology called, the power train topology a simple unidirectional boost converter connects the FC to the load and the battery is connected directly to the high voltage dc bus. A bidirectional dc-dc converter for battery was considered for FC, battery and ultra capacitor vehicle. A typical FC based propulsion system shows the use of a bidirectional dc-dc converter which connects the battery to the dc bus and a boost converter for FC.

A plug-in FCHV topology, the FC is interfaced by a boost converter with the dc link, which boosts the FC voltage to a higher level. Batteries are connected to the dc link via a bidirectional converter to supply and absorb regenerative energy.

A fuel cell converter system which consists of an isolated boost converter and an inverter for residential power supply has been reported. For isolation and high boost ratio, forward, push-pull as shown in Fig.3, half bridge and full bridge can be considered as topology candidates.

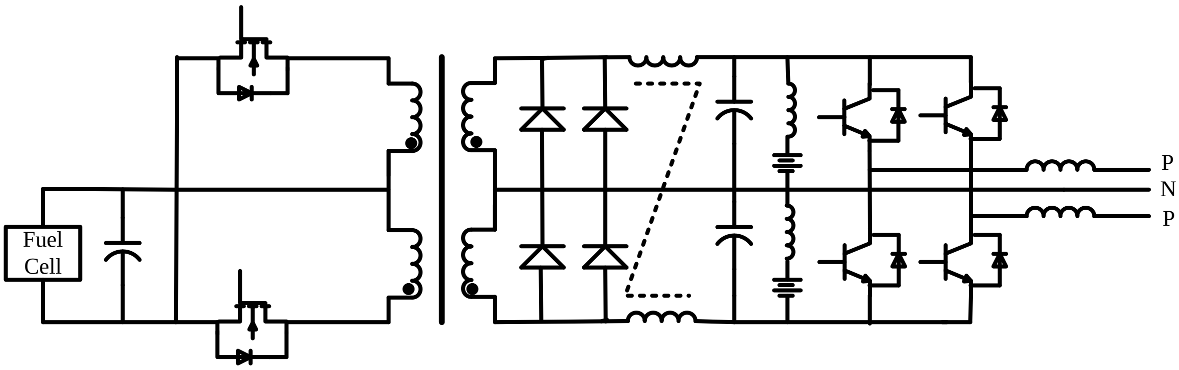


Fig.3 Voltage Fed Push-Pull Converter for a fuel Cell System.

## III. Proposed Topology and Results

The proposed converter topology is shown in Fig.4. Simulation results in MATLAB platform are presented in fig 5 and 6 which shows the FC voltage and current also the battery voltage, current and battery SOC. The switching frequency of PWM signal is 10kHz.

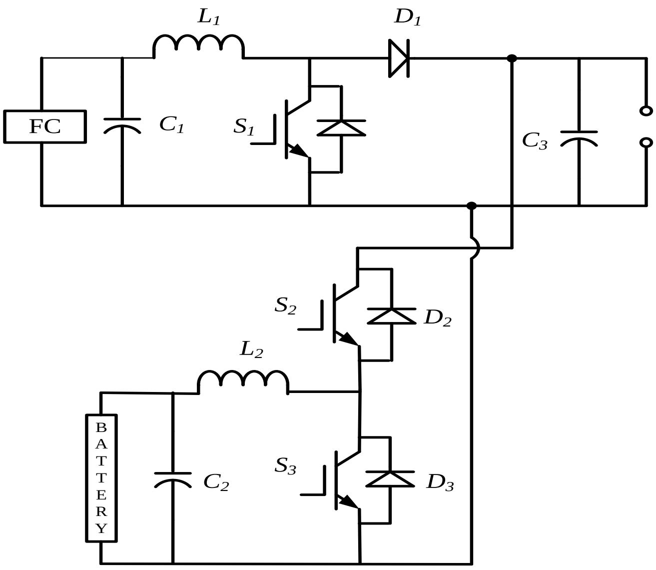


Fig.4 Converter configuration for FC based Hybrid System.

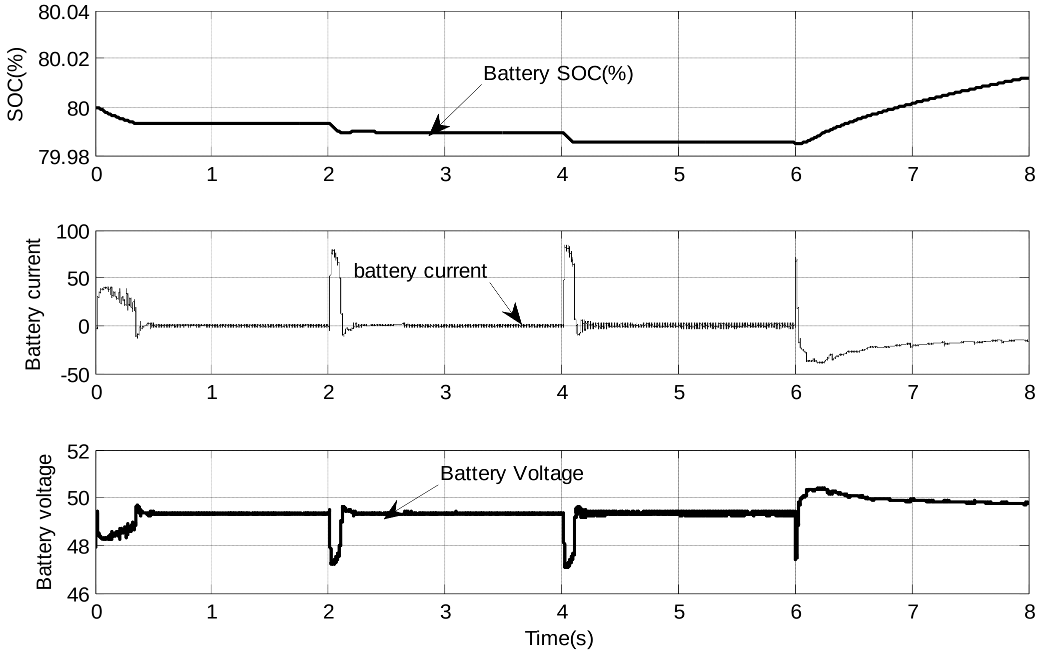


Fig.5 Battery SOC, current and voltage.

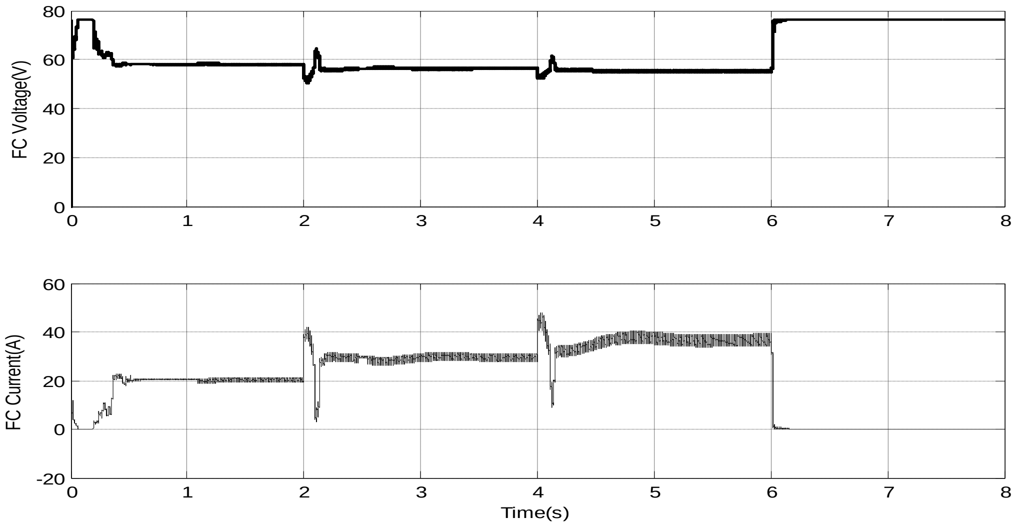


Fig.6 FC voltage and current.

## IV. CONCLUSIONS

This paper presents the suitable converter topologies for use in FC-battery fed hybrid power system. Appropriate converter structure can be chosen based on application. Many factors are required to be analyzed before selecting a converter topology such as overall cost of the converter design, required control strategy, efficiency of the converter and environmental condition. The proposed converter consists of different power converters connected to different voltages of fuel cell and battery respectively. The converter performance was verified through simulation and results are presented for a motor load

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