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Fuel Cell Energy Source Based Multilevel Inverter

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Abstract- This paper review analysis of the performance of a fuel cell energy source based Multi Level Inverter topology. Multi Level Inverter topologies are suitable in high power application due to their ability to synthesize waveforms with better harmonic spectrum. The Multilevel inverter circuit analysis and selection of proper references discussed based on the formulation switching patterns. A Single phase five level cascaded inverter is used to explain the methods. The method can be easily extended to an m-level inverter. The cascaded inverter is subjected to a new modulation scheme, which uses multiple modulating signals with a single carrier. In order to justify the merits of the proposed modulation scheme, harmonic analysis for and measured THD and output voltages are compared and discussed.

Index Terms- Multilevel inverter, Multicarrier Pulse width modulation, Total harmonic distortion, PV Cell, Switching frequency optimal PWM, Sub harmonic PWM modulation index.

I. INTRODUCTION

Fuel cell power generation is very desirable since it is renewable and does not contribute to pollution or Global climate change. FC is especially attractive for -applications in where sunshine is available for most of the time. This paper presents a FC array connected to Cascaded H-Bridge type multi-level inverter to achieve sinusoidal voltage waveform and output sinusoidal current to the utility grid with a simple and cost effective power electronic solution. The topologies of multilevel inverters are classified in to three types the Flying capacitor inverter, the Diode clamped inverter and the Cascaded bridge inverter [1][2]. The proposed scheme of multilevel inverter is the multi carrier sub-harmonic pulse width modulation (MC-SH PWM) [4][5].

II. LITERATURE REVIEW

In the year 2000, George A. O'Sullivan, presented “Fuel Cell Inverters for Utility Applications” in which he describes that Fuel cells are rapidly achieving economic viability, and they produce none of the air pollutants that harm human health. For utility applications, fuel cell dc must be economically converted without isolation transformers. A fault-tolerant design that safely dissipates fuel cell thermal energy when the utility fails is presented. A design of power converters for connecting fuel cells to utilities is described. The transformer less design consists of a boost converter followed by an inverter. While specifications are given for a 500 kW design at 60 Hz, other power levels and frequencies can be easily scaled. In the same year 2000, J.Padulles,G,W Aultand J.R McDonald, in their paper “An Approach to the dynamic modeling of fuel cell characteristics for distributed generation operation” describes an approach to the modeling of subsystems from the power systems point of view and main conclusions of modeling activity. This paper also suggests that fuel cell plants be designed to be capable of delivering ancillary services as well as power in order to facilitate their market entry with added value features. This paper also reports on modeling of the different plant subsystems in order to understand how such a plant will operate in future. In the year 2004, Jin Wang, Fang Z.Peng, Joel Anderson and Ryan Buffenbarger, in their paper “Low cost fuel cell inverter system for residential power generation” describes the low cost 10 kW inverter system to overcome the high installation cost of commercialization of sofc.In the same year 2004, Rajesh Gopinath, Sangsun Kim, Jae-Hong Hahn, Prasad N. Enjeti, Mark B. Yeary, , and Jo W. Howze, in their paper “Development of a Low Cost Fuel Cell Inverter System With DSP Control” describes the development of a low cost fuel cell inverter system in detail. The approach consists of a three-terminal push-pull dc–dc converter to boost the fuel cell voltage (48 V) to 200 VDC. A four switch [insulated gate bipolar transistor (IGBT)] inverter is employed to produce 120-V/240-V, 60-Hz ac outputs. High performance, easy manufacturability, lower component count, safety and cost are addressed. Protection and diagnostic features form an important part of the design. Another highlight of the proposed design is the control strategy, which allows the inverter to adapt to the requirements of the load as well as the power source (fuel cell). A unique aspect of the design is the use of the TMS320LF2407 DSP to control the inverter. Two sets of lead-acid batteries are provided on the high voltage dc bus to supply sudden load demands. Efficient and smooth control of the power drawn from the fuel cell and the high voltage battery is achieved by controlling the front end dc–dc converter in current mode. The paper details extensive experimental results of the proposed design on Department of Energy (DoE) National Energy Technology Laboratory (NETL) fuel cell. In the same year 2004, Dongmei Chen Huei Pengl in their paper “Modeling and Simulation of a PEM Fuel Cell Humidification System” describes that maintaining proper fuel cell membrane humidification is a key challenge in achieving optimal fuel cell performance. For automotive applications, the load and environment conditions are constantly changing. Therefore, the membrane humidity needs to be properly controlled during transient. A humidifier system using water vapor exchange membrane is modeled and analyzed in this paper. The 4-state humidifier model is integrated with a fuel cell stack. Feedback and feed-forward control algorithms are developed so that the fuel cell maintains its highest membrane water content under a wide range of operation conditions without flooding.

This paper presents the implementation of an efficient method for computing low order linear system models of Solid Oxide Fuel Cells (SOFCs) from time domain simulations. The method is the Box-Jenkins algorithm for calculating the transfer function of a linear system from samples of its input and output. In the year 2005[3], Hennann Wetzel, Norbert Frbhleke, Joachim Bicker, Peter Ide, Jiirgen Kunze in their paper "Fuel Cell Inverter System with Integrated Auxiliary Supply" describes an innovative, flexible modular concept for a fuel cell inverter system with optimized overall efficiency for a domestic heater and compared with conventional and frilly bidirectional solutions. Three types of bidirectional insulated DC/DC converters are discussed. The design should take into account the asymmetrical flow of power from the fuel cell to the mains and back to the fuel cell for the supply of the auxiliary equipment An integrated auxiliary power supply turned out to be best, which is fed during normal operation directly by the fuel cell, and, during start-up by the mains. A loss analysis for both operation modes has been carried out as support for the final design decision. A multilevel inverter is to determine the switching angles (times) so as to produce the fundamental voltage and not generate specific higher order harmonics. In this work, techniques are given that allow one to control a multilevel inverter in such a way that it is an efficient, low total harmonic distortion (THD) inverter that can be used to interface distributed dc energy sources to a main ac grid. A procedure to eliminate harmonics in a multilevel inverter has been given which exploits the properties of the transcendental equations that define the harmonic content of the converter output. Specifically, it was shown that one can transform the transcendental equations into symmetric polynomials which are then further transformed into another set of polynomials in terms of the elementary symmetric functions[1] In this paper, a power line conditioner using a cascade multilevel inverter is presented for voltage regulation, reactive power (VAr) compensation, and harmonic filtering. The cascade M-level inverter consists of (M-1)/2 H Bridges, in which each bridge has its own separate DC source. This new inverter can: (1) generate almost sinusoidal waveform voltage with only one time switching per line cycle; (2) eliminate transformers of multipulse inverters used in the conventional static VAr compensators; and (3) make possible direct connection to the 13.8 kV power distribution system in parallel and series without any transformer. In other words, the power line conditioner is much more efficient and more suitable to VAr compensation and harmonic filtering of distribution systems than traditional multipulse and pulse width modulation inverters. It has been shown that the new inverter is especially suited for VAr compensation. This paper focuses on feasibility and control schemes of the cascade inverter for voltage regulation and harmonic filtering in distribution systems. Analytical, simulated, and experimental results show the superiority of the new power line conditioner [14]. In This paper presents the development of a control scheme for a multilevel diode-clamped converter connected in a series-parallel fashion to the electrical system such that it can compensate for deviations in utility voltage (sag, surge, and unbalance) and act as a harmonic and/or reactive current source for a load. New carrier-based multilevel pulse width modulation techniques are identified to maximize switch utilization of the two back-to-back diode-clamped inverters that constitute the universal power conditioner. An experimental verification for a six-level power conditioner is given[15].In This paper is to present a new pulse-width modulation (PWM) technique for multilevel inverter/converter control, which provides more degrees of freedom for specifying the cost function than that for step modulation technique, for a given hardware. Therefore, the presented technique eliminates more specified low order harmonics without resorting to the increase of hardware. In comparison with the selective harmonic elimination PWM technique, for the same number of eliminated low order harmonics, the presented technique provides the advantages of both lower total harmonic distortion (THD) and less switching. Simulation and experimental results are presented to confirm the above-mentioned claims [16] In This paper presents transformer less multilevel power converters as an application for high-power and/or high-voltage electric motor drives. Multilevel converters: (1) can generate near-sinusoidal voltages with only fundamental frequency switching; (2) have almost no electromagnetic interference or common-mode voltage; and (3) are suitable for large volt-ampere-rated motor drives and high voltages. The cascade inverter is a natural fit for large automotive all-electric drives because it uses several levels of DC voltage sources, which would be available from batteries or fuel cells. The back-to-back diode-clamped converter is ideal where a source of AC voltage is available, such as in a hybrid electric vehicle. Simulation and experimental results show the superiority of these two converters over two-level pulse width-modulation-based drives [17].

III. MULTI LEVEL CONVERTER TOPOLOGIES

The general objective of the multi level converter is to synthesize a sinusoidal voltage form several levels of voltages by constructing a staircase kind of wave shape. Typically the different voltage levels are obtained from several capacitors connected in series across a DC bus the minimum number of levels of voltage in a multi level inverter is three. Basic multi level topologies have been categorized into the following three types (1) Diode clamped; (2) Flying capacitor; and (3) Cascaded inverter topologies.

*A. **Diode clamped multi level inverter (DCMI) [6]***

The DCMI uses capacitors in series to divide up the DC bus voltage into a set of voltage levels. To produce "m" levels of the phase voltage at the output, this inverter needs (m-1) capacitors on the DC bus. A 3 level DCMI are shown in fig 1a In the 3 level inverter as shown in fig 1 the DC bus consists of two capacitors. For a DC bus voltage Vdc, the voltage across each capacitor is Vdc/2; so the voltage stress across each device will be limited to Vdc/2, through clamping diodes. In the 3 level inverter, there are three switching combinations to generate three level voltages across the load. The diode clamped inverters require high voltage rating for the blocking diodes. Also the device ratings are not equal. The capacitor voltage is also not balanced[13].

When the number of levels is high enough in the DCMI harmonic content will be low enough to avoid the need for filters. These inverters have high efficiency because all the devices are switched at the fundamental frequency. The control method for this inverter is simple especially for back to back inter tie system.

However, this type of inverter suffers from the drawback of having to use a large number of clamping diodes when the number of levels is high. It is also difficult to control the flow of real power for the individual converter levels.

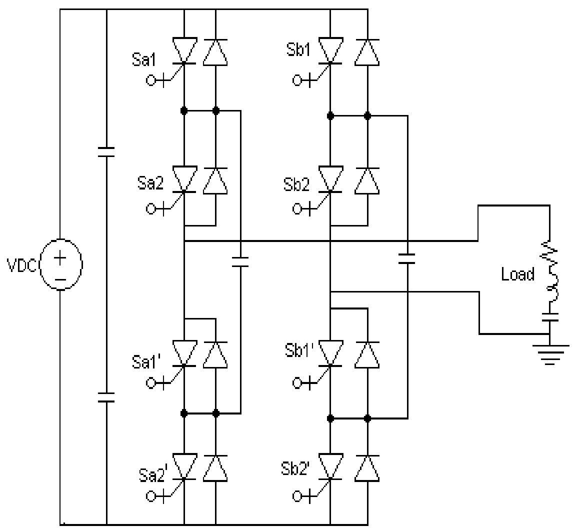

Figure.1 Circuit diagram of Diode-clamped multilevel converter

B. Flying capacitor multi level inverter (FCMI) [12]

In PCMI a ladder structure of DC side capacitors is used where the voltage on each capacitor differs from that of the next capacitor. To generate m level staircase output voltage, m – 1 capacitors in the DC bus are needed. The size of the voltage increment between two capacitors determines the size of the voltage levels in the output waveform. Figure 2a shows the 3-level configuration for a flying capacitor type inverter; if requires two bus capacitors and two more capacitors for maintaining the voltage levels .The major advantage of FCMI is that large amount of storage capacitors provide extra ride through capabilities during power storage. Both real and reactive power flow can be controlled, making this a possible voltage source converter candidate for high voltage direct current (HVDC) applications. The major disadvantage is that too many capacitors are used that makes the packaging difficult for this inverter. In addition switching losses are high especially due to real power transfer

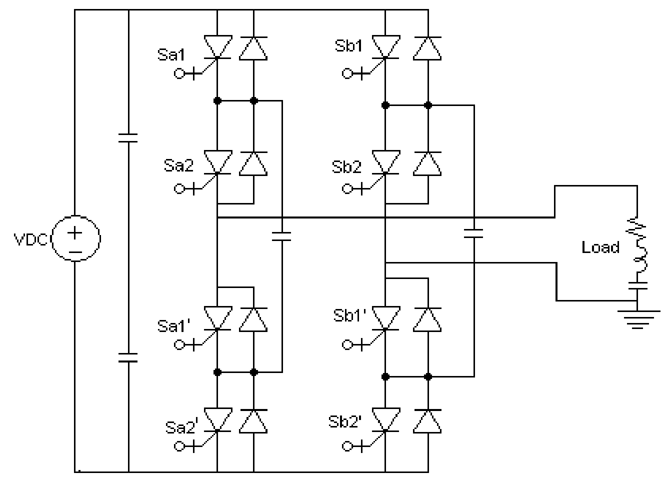

Figure.2 circuit diagram of multilevel converter using flying capacitor

C. Multilevel converter using cascaded-converter with separate DC sources[21]

The third structure introduced here is a multi level inverter, which uses cascaded inverters with separate DC sources (SDCSs). The general function of this multi level inverter is the same as that of the two previous inverters. The multi level inverter using cascaded inverter with SDCSs synthesizes a desired voltage from several independent sources of DC voltages, which may be obtained from batteries, fuel cells or solar cells. This configuration has become very popular recently in AC power supply and adjustable speed drive applications. This inverter can avoid extra clamping diodes or voltage balancing capacitors. A single phase 3 level configuration of such an inverter is shown in fig 3a. Each SDCS is associated with a single phase full bridge inverter. The AC terminal voltages of different level inverters are connected in series. By different combinations of the four switches Sa1- Sa4 each inverter can generate three different levels of voltage outputs + Vdc, -Vdc and zero. The AC outputs of each of these full bridge inverters are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. In this topology, the number of output phase voltage levels is defined by m = 2s + 1, where s is the number of DC sources. For a three phase system, the output voltage of the three cascaded inverters can be connected in either star or delta configuration. As this configuration uses separate DC sources, it is well suited for various renewable energy sources such as fuel cell, photovoltaic and biomass.

The major advantage of this configuration is that it requires the least number of components among all multi level inverters to achieve the same number of voltage levels.

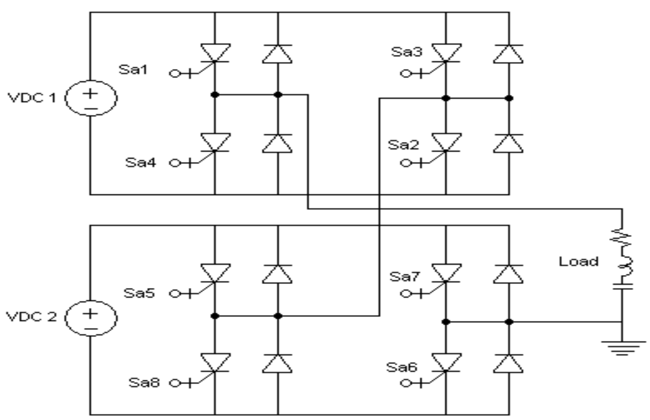

Figure.3 Circuit diagram of multilevel converter using cascaded-converter with separate DC sources

I. CONCLUSION

1. Those Fuel Cells are preferred which have high voltage ratings and low current profile. This is because at higher current the losses within the fuel cell will be more and hence the efficiency of the system, for which it is known, will deteriorate. But the main draw back of higher voltage fuel cells is that voltage level can be increased only by adding series stacks. This adds to the system cost.

2. In low power rating fuel cells, low voltage is an issue. Boost converter provides a solutions to raise the voltage level of the FC stack. Besides this bi-directional DC to DC converters are also used for boosting and isolation. This increases the bulkiness of the whole application.

3 "Multi Level Converter". After a brief overview of the background information, design considerations presented multilevel voltage source converters that synthesize the converter voltage by equally divided capacitor voltages. All these converters have been completely analyzed and simulated. Multilevel converters The application on which the multilevel voltage source converter may have the most impact is the adjustable speed drive. Using multilevel converters not only solves harmonics and EMI problems, but also avoids possible high frequency switching *dvldt* induced motor failures. With a balanced voltage stress in devices and utility compatible features, the multilevel converters have shed a light in the power electronics arena and are emerging as a new breed of power converters for high-voltage high-power applications.

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