Fuel Cell Based Inverter Topologies

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Abstract—***Fuel cells are considered to be one of the most effective sources of energy because of their high efficiency, low environmental affect and scalability. Fuel cells have a low output voltage that varies with age and current. Fuel cells are limited in overload capabilities. Therefore, power converters are often necessary to enhance and regulate the voltage to provide a steady DC power source. Also the addition of an inverter allows for the conversion of DC power to AC. The method for a fuel-cell-based inverter system is presented here. This is followed by an assessment of the various topologies of inverters used for power conditioning of fuel cells. The utilization of fuel cells for distributed power generation requires the development of low-cost inverter that converts a fuel cell's variable dc output into useful ac. The inverter varies topologies are analyzed and discussed in this paper.***

Key words- fuel cell, inverter

I. Introduction

The demand of energy has increased considerably in recent years. Due to environmental Concerns, more attempts is now being put into the clean distributed power like geothermal, solar thermal, photovoltaic, and wind generation, as well as fuel cells that use hydrogen, natural gas, or other fuels to generate electricity without increasing pollution. Fuel cells are environmentally sound renewable energy sources which give higher efficiencies than traditional energy production methods. There are some difficulties in the application of fuel cells that is low output voltage that varies with age and current, slow response to a load step response, no overload capability and no acceptance of reverse current and many technical difficulties that must be minimized using power conditioning systems. In this paper, a discussion of the construction, types, application of fuel cell is presented. This is followed by an assessment of the various inverter topologies used for fuel cells output.

1.1 Construction of fuel cell

Fuel cells are similar to batteries except that in batteries the chemical energy is stored and need to be recharged. While in the fuel cells the fuel is constantly fed to the cell so that the consistent generation of electricity is ensured. A basic schematic diagram of a fuel cell is shown in Fig. 1.The hydrogen fuel is supplied to the anode electrode, while oxygen from air is supplied to the cathode. Where catalyst separates the hydrogen into electrons and positive hydrogen ions. The electrochemical reactions taking place at electrodes are as follows:

At cathode

$$2H_2 \rightarrow 4H^+ + 4e^-$$

At Anode

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

The overall reaction becomes

$$2H_2 + O_2 \rightarrow 2H_2O + \text{Electrical energy} + \text{heat}$$

As water is produced at the anode and electrical energy and heat are generated by fuel cell. Therefore fuel cell is an environmentally friendly source of energy.

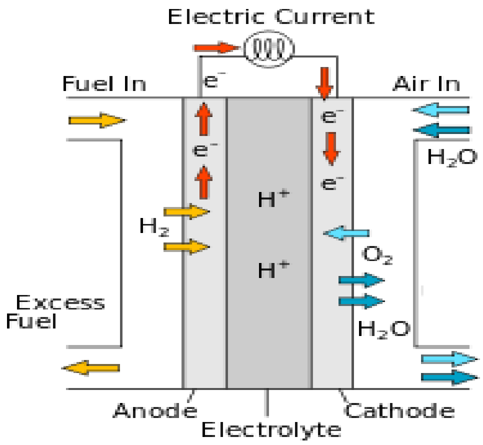

Fig. 1. A basic schematic diagram of a fuel cell

1.2 Types of fuel cells and their applications

Fuel cells can be classified on the basis of various parameters which include the nature and type of fuel used. However the most common classification of fuel cells is on the basis of electrolytes used in the fuel cell.

- Proton Exchange Membrane (polymer electrolyte) fuel cells (PEMFC).
- Direct Methanol Fuel Cell. (DMFC)
- Alkaline Fuel Cells (AFC).
- Phosphoric Acid Fuel Cells (PAFC).
- Molten Carbonate Fuel Cells (MCFC).
- Solid Oxide Fuel Cells (SOFC)

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II. TYPES OF FUEL CELLS

Sr. No.	Fuel cell type	PEMFC	AFC	PAFC	MCFC	SOFC
1.	Operating temperature in (K)	303-353	053-373	373-493	923-1123	973-1273
2.	Application	Electrical Utility, Portable power, Trans-portation	Military, Space, Residential plants	Electric Utility And trans-portation	Electric utility	Electric Utility

III. POWER ELECTRONICS INTERFACE REQUIREMENTS

Fuel cells are a solid state energy conversion device that can use a renewable fuel with no synchronized emissions and can be located in the utility area of a home much like other conventional appliances. Developing technologies to drive down production cost barriers in the power conditioning electronics associated with fuel cells is critical in deploying these distributed resources. The large number of applications in which fuel cells can be implemented necessitates that a power electronics interface be present. This interface should:

1. Control the fuel cell voltage
2. Convert the fuel cell output to the appropriate type and magnitude.
3. Deliver a high power factor (grid applications).
4. Provide little to no harmonics.
5. Operate efficiently under all conditions.
6. Add little to the cost of the overall system.

The power electronics interface for fuel cells often utilize DC–DC boost converters and inverters to boost the fuel cell voltage and convert the DC voltage to AC as seen in Fig. 2.

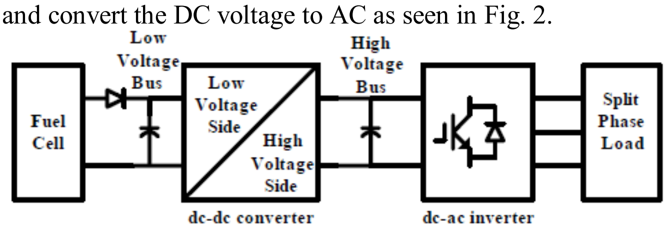

Fig. 2.Block diagram of the fuel cell inverter system

Single and dual-phase inverters are used for residential applications, while three-phase inverters are implemented in industrial applications and in centralized power generation. In this paper, discussion on the specific fuel cell restrictions and possible methods for power inverters to deal with these requirements.

IV. FUEL CELL RESTRICTIONS ON POWER ELECTRONICS

Power electronics are prone to high losses and failure under high temperature. Therefore, power electronics devices need to be thermally isolated from the fuel cell modules so that efficient and reliable operation can be guaranteed. The voltage gain is often limited and cannot function beyond a certain point.

V. INVERTERS

In almost every application, AC power is required demanding the utilization of an inverter in the power-conditioning system. The inverter converts high DC voltage from the booster to AC. The inverter therefore is an adjustable-frequency voltage Source. In this paper, the conventional inverter is studied, particularly single-phase, dual phase, and three-phase inverters. Inverters can be broadly classified into two types, voltage source and current source inverters.

A. SINGLE-PHASE INVERTER

A standard single-phase voltage or current source inverter can be classifying in the half-bridge or full-bridge configuration. The typical configurations of fuel cell power conditioning are full-bridge PWM inverter shown in Fig. 3. and half-bridge PWM inverters, shown in Fig. 4 Both designs are simple in nature and have low component count. However, compared with the half-bridge converter, the full-bridge inverter has two more switches adding to the cost while doubling the output voltage rating.

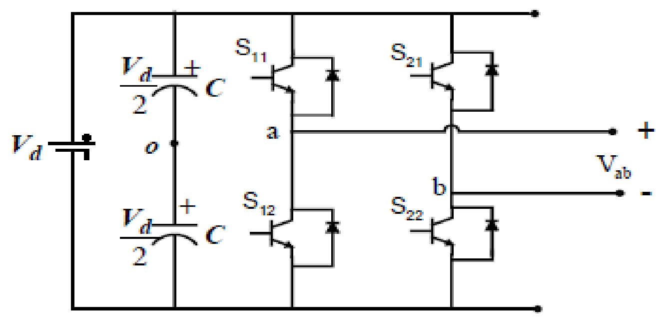

Fig. 3. Single Phase Full-Bridge Inverter.

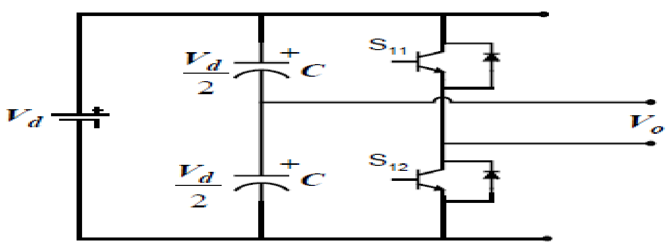

Fig. 4. diagram for Half-Bridge PWM inverter.

B. DUAL-PHASE INVERTERS

Four typical configurations of dual-phase inverters used for fuel cell power conditioning. The simplest configuration is that of topology A, shown in Fig.5. and consists of a single bus with two half-bridge inverters. This design is simple and low component count. The six-switch, single bus topology B in Fig.6.is modified version of topology A. The control method of the first and third legs is the same as the first and second legs of topology A. Conversely, the second leg is controlled to provide an output of Vd/2.Topology C is composed of two independent

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half-bridge converters, shown in Fig.7.Although this adds to the component count, the modularity of this design is much increased. Topology D is composed of a full-bridge inverter with the output attached to a transformer. The addition of a transformer adds to the cost and size of the inverter, shown in Fig.8.

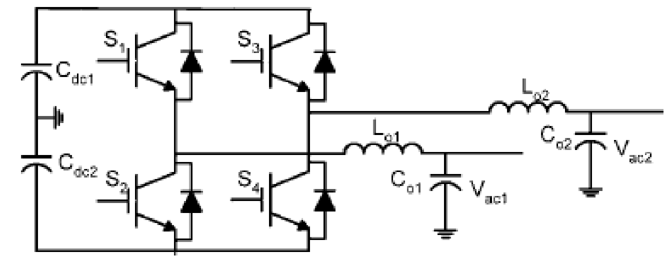

Fig.5. Topology A

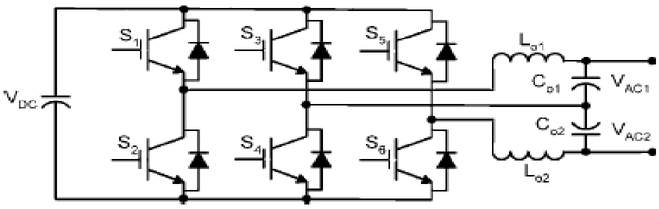

Fig.6.Topology B

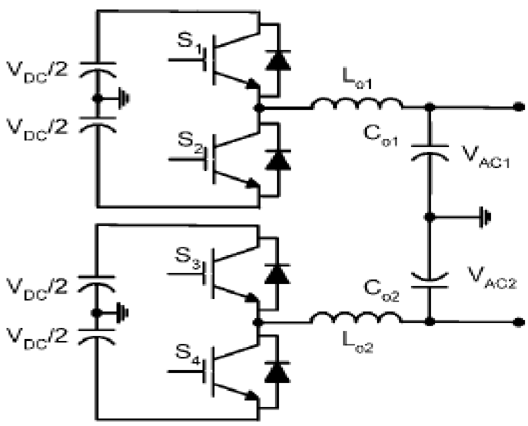

Fig.7.TopologyC

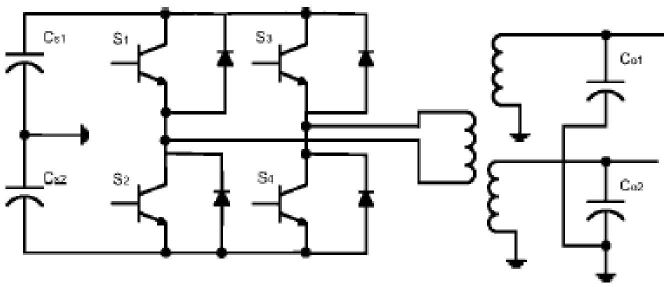

Fig.8.Topology D

C. THREE-PHASE INVERTERS

The conventional Three-phase inverter configuration of fuel cell power conditioning is a three-phase PWM inverter with an output LC filter, as shown in Fig.9 .This converter is simple in nature and the use of an inverter with an output *LC* filter allows for generation of output sinusoidal voltages with low harmonic distortion

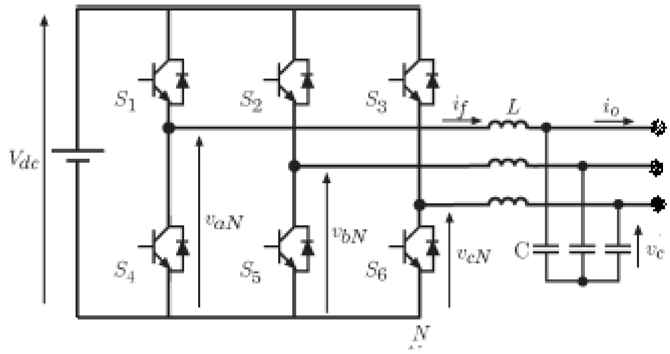

Fig.9. Three-phase PWM inverter with LC filter.

D. HIGH-FREQUENCY LINK INVERTER

High-frequency link inverter is frequently used in dc/ac power conversion in which compactness and light-weight are of important considerations. For this type of inverter, the high-frequency transformer is used. This inverter uses an AC–AC cycloconverter to first convert the DC to a high-frequency AC and then modifies this AC to the appropriate frequency and amplitude. A high-frequency link inverter for a fuel cell power-conditioning system is shown in Fig.10.

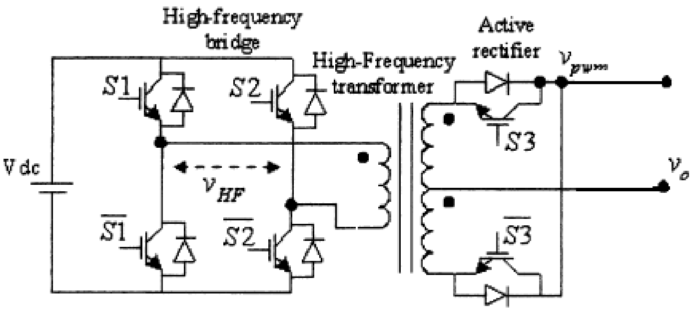

Fig.10. Block diagram of the inverter.

E. Z-SOURCE INVERTER

Z-source inverter for dc-ac power conversion needed for fuel-cell applications. **Fig.11.** shows the traditional two-stage power conversion for fuel-cell applications. Because the fuel cells usually produces a voltage that changes widely (2:1 ratio) depending on current drawn from the stacks. For fuel-cell vehicles and distributed power generation, a boost dc–dc converter is needed because the V-source inverter cannot produce an ac voltage that is greater than the dc voltage. **Fig.12** shows a Z-source inverter for such fuel cell applications, which can directly produce an ac voltage greater and less than the fuel

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cell voltage. Diode in series with the fuel cell, Shown in ***Fig.12.*** and ***Fig.13.*** is usually needed for preventing reverse current flow.

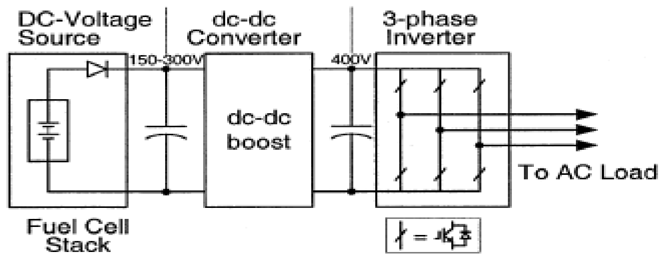

Fig.11. **Traditional two-stage power conversion for fuel-cell applications**

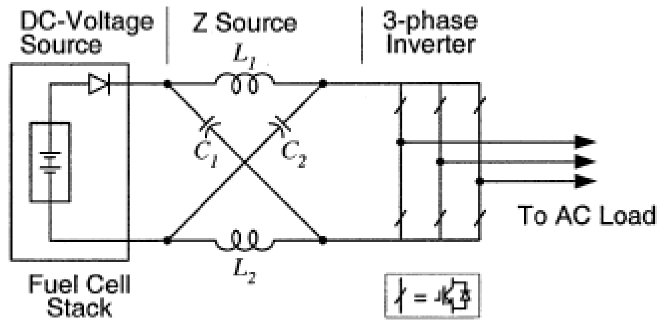

Fig.12. Z-source inverter for fuel-cell applications.

VI. SUMMARY

In this paper, multiple types of inverters topologies, there advantages and disadvantages are discussed. As with DC–DC converters, added benefits come at the cost of extra components which increase the cost and size of the inverter. As an example, The Z-source inverter can boost–buck voltage, minimize component count, increase efficiency, and reduce cost.

VII. CONCLUSIONS

Fuel cells are under consideration for almost every application including both residential and industrial power generation, as it is one of the most prominent sources of distributed energy in the future,. A power electronics interface must be inserted between the fuel cell and output to provide flexibility because fuel cells produce number of inherent restrictions such as low voltage, large voltage variation, low efficiency when ripple current is high, slow load step responsibility and no acceptance of reverse current. This paper first introduces construction of fuel cell, different types, the specific fuel cell restrictions and possible methods for power inverter. This is followed by a discussion of the various topologies of inverters used for fuel cells.

VIII. REFERENCES

[1] "2003 Fuel Cell Seminar Special Session on Fuel Cell Power Conditioning" Proceedings November 3, 2003.

[2] Peng, F.Z.: 'Z-source inverter', IEEE Trans. Ind. Appl., 2003, 39, ,pp. 504–510.

[3] Tuckey, A.M., and Krase, J.N.: 'A low-cost inverter for domestic fuel cell applications'. 33rd Annual IEEE Power Electronics Specialists Conf., 2002, vol. 1, pp. 339–346.

[4] Wai, R.-J., Duan, R.-Y., Lee, J.-D., and Liu, L.-W. 'High-efficiency fuel-cell power inverter with soft-switching resonant technique', IEEE Trans. Energy Conversion, 2005, 20,(2), pp. 485–492.

[5] Basharat Nizam"Z – Source Inverter for Fuel Cells" (IJETT) – Vol. 4 Issue 4- April 2013 pp.1060-1066.

[6] R. C. Dugan, T. E. McDermott, .Distributed generation,**"** *Industry Applications Magazine, IEEE, Volume: 8 Issue: 2, March-April 2002,* pp. 19 –25.

[7] B Viswanathan,M Aulice Scibioh,"Fuel Cells"Principles and Applications.Universities Press.

[8] C. D. M. Oates, R. W Crookes, S. H Pyke, and R. T. Leah, "Power conditioning for solid oxide fuel cells," International Conference on Power Electronics, Machines, and Drives, June 2002, pp. 12 – 17.

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