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Analysis of Single Phase Induction Motor With Fuel Cell Based Multilevel DC-DC Boost

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Abstract: ***Now a day's single phase induction motors are play a vital role in different applications like home, industrials, est., In this paper presents a system model of fuel cell power with single phase induction motor via DC-DC boost converter with simple inverter. Non-isolated high step-up DC–DC converters are required widely in the industrial applications. Many of these conventional DC–DC converters have the disadvantages of operating at high duty-cycle, high switch voltage stress and high diode peak current. A three-level step-up converter is implemented to boost the fuel cell stack voltage of 90V to 340V. This high DC link voltage is fed to the voltage source inverter and interfaced with the load. Two feedback control loops are designed to make the system operate in stable conditions. This system configuration is suitable for low-power applications. The Performance of the developed system is analyzed in MATLAB/Simulink environment under different load torques for asynchronous machine.***

Keywords: Asynchronous Machine, DC-DC Converter, Fuel Cell

1. Introduction

The fuel cells are electrochemical devices that convert chemical energy directly into electrical energy by the reaction of hydrogen from fuel and oxygen from the air without regard to climate conditions, unlike hydro or wind turbines and photovoltaic array. Fuel cells are different from batteries in that they require a constant source of fuel and oxygen to run, but they can produce electricity continually for as long as these inputs are supplied. Thus, the fuel cells are among the most attractive DGs resources for power delivery. However, batteries need to be placed in parallel or in series with the fuel cells as a temporary energy storage element to support during startup or sudden load changes because fuel cells cannot immediately respond to such abrupt load changes.

Generally, fuel cells produce dc voltage outputs, and it keeps on varying with the load. So they are always connected to electric power networks through power conditioning units such as DC/DC and DC/AC to maintain the voltage constant or to stabilize the voltage [1]. A High DC link bus voltage of the order 340V is required to be fed to a PWM Voltage Source Inverter in order to obtain 230V RMS voltage from the inverter. An Alkaline Fuel Cell (AFC) of 2.5 kW, 48V DC is considered here for the simulation studies. Two such cells are connected in series to obtain an input voltage of 96 V at no-load.

Conventional DC-DC boost converter can boost only up to 220V. Therefore, Multilevel DC-DC Boost Converter is adopted to obtain a high dc link voltage. A High DC link voltage is advantageous as there will be a low average DC current. So it leads to low I^2R losses over the line. Multilevel converters have attracted interest in power conversion [2]; they already are a very important alternative in high power applications [2][3].

Some of the advantages of multilevel converters against traditional topologies are: (*i*) low harmonic distortion, (*ii*) low voltage stress, (*iii*) low EMI noise, (*iv*) low switching frequency, (*v*) high efficiency, and (*vi*) ability to operate without magnetic components [3]. All these advantages make multilevel converters one of the most important topics in power electronics, and industrial application research.

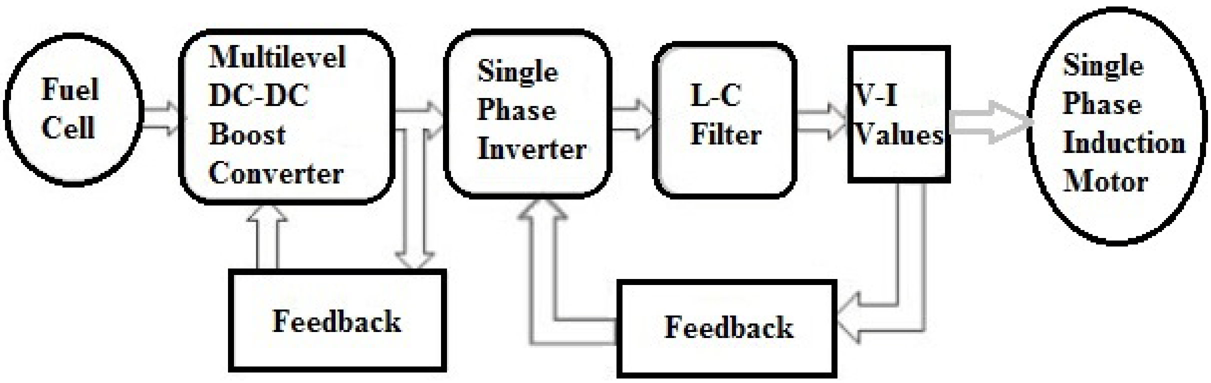

Figure 1: Block Diagram of Proposed System

Therefore, in this paper a three-level DC/DC boost converter and H-bridge DC/AC inverter combination fed single phase induction motor is considered for the study. The Proposed model is developed for a capacity of 5 kW in MATLAB/SIMULINK environment and the performance of the model is studied under steady state and transient conditions.

2. Three Level Boost Converter

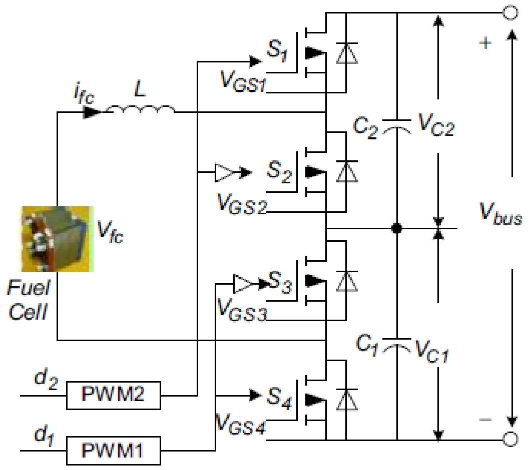

Figure 2: Three-level DC/DC boost converter

In conventional boost converter, the boost ratio is limited by the inductor's equivalent series resistance (ESR).The voltage gain of the boost converter is limited owing to the losses associated with the inductor filter, capacitor, main power switch and rectifier diode. In this converter, the boost factor is quasi-linear when the duty cycle is from [0-0.5] the boost factor becomes non-linear for high duty cycles [5]. This behavior complicates the boost converter control in renewable energy generation systems. The necessary boost factor for renewable generation systems is from 4-6. But the maximum boost factor obtained from this converter is around 2 when operated in linear region.

Therefore, three-level DC/DC boost converters are a well-adopted solution in applications with high input voltage and high switching frequency. The switches are stressed on half of the total dc bus voltage. This allows us to use lower-voltage-rated switches, having better switching and conduction performance compared to the switches rated on the full blocking voltage [6]. Therefore, the converter's overall performance, including cost and efficiency, can significantly be better compared to conventional converters, particularly when the switching frequency is above 20 kHz or metal–oxide–semiconductor field-effect transistors (MOSFETS) are used. In three-level boost converter, by cascading the output voltage *VC1* and the output voltage *VC2* high output voltage *Vbus* is easily obtained [4] as shown in Fig. 2. The output voltage obtained here is (N-1) times the voltage obtained from the conventional boost converter where N=3, the number of levels. A smaller size of the inductor is needed to achieve comparably low ripple. The inductor volume is one-fourth of that of the conventional one. In addition, it reduces the required semiconductor device voltage rating by a factor of two.

When multi-level boost converter is employed in open loop mode, it exhibits poor voltage regulation and unsatisfactory dynamic response, and hence, this converter is generally provided with closed loop control for output voltage regulation. In turn, the DC link bus voltage which is fed to the voltage source inverter should be almost constant. In order to maintain the DC link bus voltage constant, the control signals *d1* and *d2* have to be controlled. For different values of duty cycles, we get different values of DC link bus voltages. A feedback control loop is provided through comparator, gain block, PI controller. The output of the PI controller is nothing but the duty cycles *d1* and *d2* which varies the switching functions generated by the pulse width modulators PWM1 and PWM2. The DC link reference voltage is taken as 340V.

3. DC/AC inverter

A conventional H-bridge DC/AC inverter is used to convert the DC into AC supply. The closed loop control is implemented at the inverter output side to keep the load voltage constant irrespective of the load changes. Here PWM with bipolar voltage switching is employed for this inverter. The output voltage of a single-phase full bridge inverter is modulation index (*ma*) times DC input voltage.

$$V01 = maVd \ (ma < 1)$$

Here, the modulation index *ma* is the control variable and adjusted by the PI controller to maintain the inverter output voltage constant during load changes.

4. Induction Machine

Traditionally, DC motors were the work horses for the Adjustable Speed Drives (ASDs) due to their excellent speed and torque response. But, they have the inherent disadvantage of commutator and mechanical brushes, which undergo wear and tear with the passage of time [2]. In most cases, AC motors are preferred to DC motors, in particular, an induction motor due to its low cost, low maintenance, lower weight, higher efficiency, improved ruggedness and reliability. Where less than or equal 2HP rating requires, single phase induction machines are most suitable. The advancement in Power electronics and semiconductor technology has triggered the development of high power and high speed semiconductor devices in order to achieve a smooth, continuous and low total harmonics distortion (THD). In this paper single phase induction motor model of capacitor start and capacitor start-capacitor run machines are presented as a load to proposed inverter.

5. Simulation Results

The simulation of the circuit model is shown in Fig. 3. The Load voltage and the load current waveforms are shown in Figs. 4 & 5. These are the output waveforms after the LC Filter.

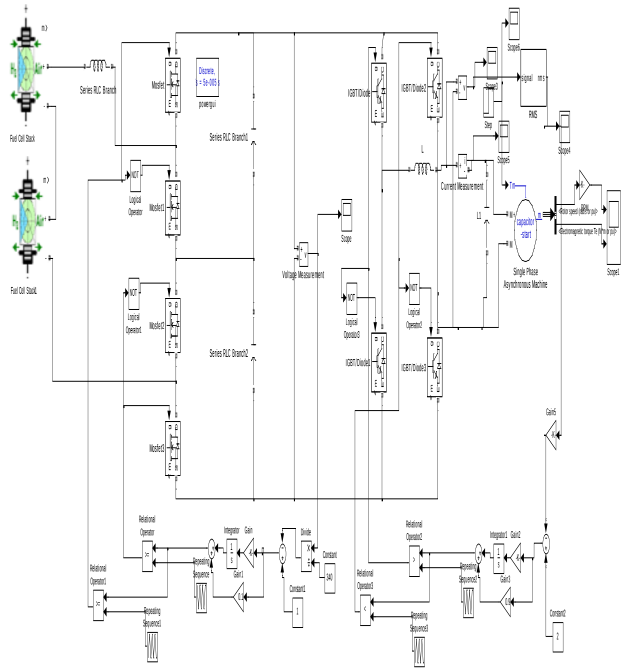

Figure 3: MATLAB/SIMULINK diagram of proposed concept.

The waveforms are almost close to a sine wave. It can be seen that the load voltage remains constant irrespective of the load changes as shown in figure4 (A) & (B), but the load current changes with respect to the load. The rms voltage remains constant at 250V for the entire simulation time as seen from the Fig. 5. The DC link bus voltage, *Vdc=VC1+VC2* is around 340 V. The FFT analysis of the load voltage for THD as shown in Figure 7. The total harmonic distortion is around 2.37% in steady state which is less than 5% as per the IEEE standards.

A single phase induction motor (capacitor run) type connected with variation of load torque, which gives transient and study state condition. with a step size of 0.2 sec and the system performance is tested for both R and RL Loads. A resistive load of 2.5 kW is connected in the time range of 0 to 0.2 sec. A RL load of 4.5 kVA is connected in the time range of 0.2 to 0.4 sec and a RL Load of 3.6 kVA is connected in the time range of 0.4 to 0.6 sec. The response of the system is analyzed in both steady state and transient conditions. It is observed that the developed PI controller gives better response and takes 3 to 5 cycles to reach a new steady state value during load changes from 50% to 90%.

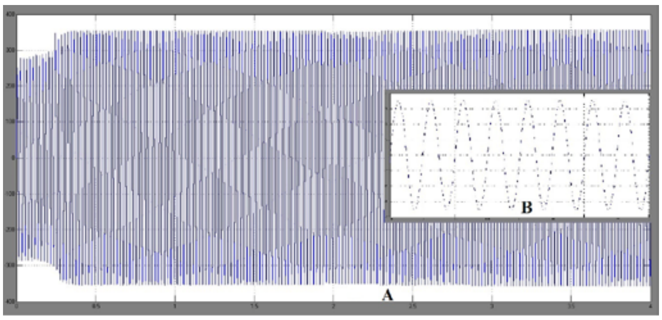

Figure 4: Load voltage A) During variation of motor torque B) X-axis zoom view of load voltage.

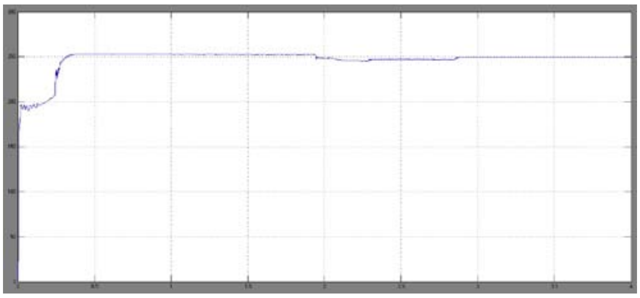

Figure 5: Inverter output voltage waveform during the load variation.

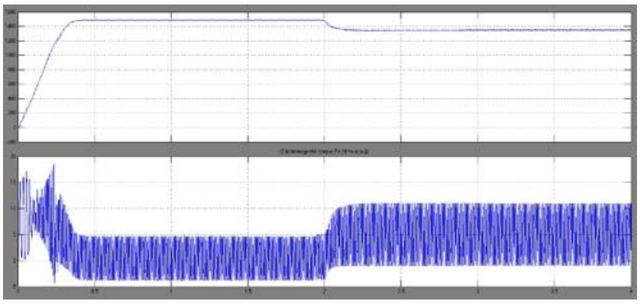

Figure 6: Speed and Electromagnetic Torque waveforms for variation of load motor.

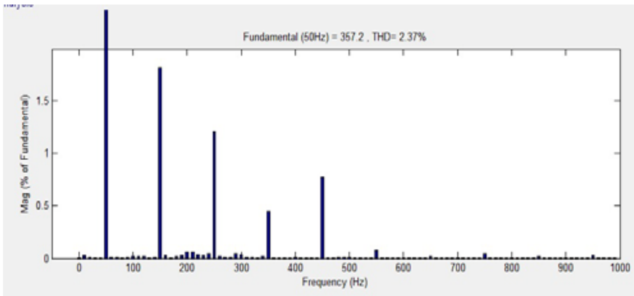

Figure 7: THD (%) of Load voltage.

6. Conclusion

A comprehensive state of the art of STATCOM for power quality improvement in the three-phase power system has been presented to explore the multilevel inverter topologies and control technique. The detailed classification, state of the art and comparison have been given for easy selection of a STATCOM for high power quality applications. The performances of topologies of STATCOMs selected from each category have been demonstrated to validate the designed STATCOM system. The compensation of reactive power for voltage regulation, harmonics elimination, load balancing, and THD (%) has been demonstrated for three-phase STATCOM. Finally, from the results Incremental -reduction cascade H-bridge topology best for STATCOM applications for low 3rd harmonic and low THD not only those, it also perform better as remaining topologies.

References

[1] L. Gyugyi, E. C. Strycula, “Active AC Power Filters”- in Proc. IEEE/IAS Annu. Meeting, Vol.19-c, pp 529-535, 1976

[2] Hirofumi Akagi, Yoshihira Kanazawa, Akira Nabae “Instantaneous Reactive Power Compensators

Comprising Switching Device s without Energy Storage Components"- IEEE Trans on Industry Appl, Vol.I1-20, No.3, pp.625-630, 1984

[3] E. H. Watanabe, R. M. Stephan, M. Aredes, "New Concepts of Instantaneous Active and Reactive Powers in Electrical Systems with Generic Loads"- IEEE Trans. Power Delivery, Vol.8, No.2, pp.697-703, 1993.

[4] Bhim Singh, Kamal Al-Haddad & Ambrish Chandra, "A New Control Approach to 3-phase Active Filter for Harmonics and Reactive Power Compensation"-IEEE Trans. on Power Systems, Vol. 46, NO. 5, pp.133 – 138, Oct-1999

[5] W. K. Chang, W. M. Grady, Austin, M. J. Samotyj "Meeting IEEE- 519 Harmonic Voltage and Voltage Distortion Constraints with an Active Power Line Conditioner"- IEEE Trans on Power Delivery, Vol.9, No.3, pp.1531-1537, 1994

[6] Hirofumi Akagi, "Trends in Active Power Line Conditioners"- IEEE Trans on Power Electronics, Vol.9, No.3, May-1994

[7] W.M.Grady, M.J.Samotyj, A.H.Noyola "Survey of Active Power Line Conditioning Methodologies" IEEE.Trans on Power Delivery, Vol.5, No.3, pp.1536-1542, July-1990

[8] Leszek S. Czarnecki "Instantaneous Reactive Power p-q Theory and Power Properties of Three-Phase Systems"- IEEE Trans on Power, VOL. 21, NO. 1, pp 362-367, 2006

[9] Karuppanan P and Kamala Kanta Mahapatra "Shunt Active Power Line Conditioners for Compensating Harmonics and Reactive Power"-Proceedings of the International Conference on Environment and Electrical Engineering (EEEIC), pp.277 – 280, May 2010

[10] Fang Zheng Peng & Jih-Sheng Lai, "Generalized Instantaneous Reactive Power Theory for Three-Phase Power Systems", IEEE Trans. on Inst. and Meast, Vol.45, No.1, pp.293-297, 1996

[11] Joao Afonso, Carlos Couto, Julio Martins "Active Filters with Control Based on the p-q Theory"- IEEE Industrial Elects Society Nletter-2000

[12] E. H. Watanabe, H. Akagi, M. Aredes "Instantaneous p-q Power Theory for Compensating Non sinusoidal Systems"- International School on Non sinlusoidal Currents and Compensation Lagow, Poland-2008.