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Comparison of Multilevel Inverter Topologies for STATCOM Applications

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ABSTRACT
In this paper is to present an comparison of four different STATCOM multilevel inverter topologies which are suitable to be connected to the un-linear loads and unbalancing loads. The majority of power consumption has been drawn in reactive loads. These loads are drawn in low power factor and therefore give rise to reactive power burden in the power system. So that STATCOM controller is used to compensate reactive power, correction of power factor and elimination of current harmonics. This paper mainly focuses the analysis issues of the Cascade H-bridge, Incremental cascade H-bridge, Incremental cascade I–bridge and Incremental – reduction cascade H-bridge multilevel topologies with PWM technique for STATCOM applications; Inverter operation play a vital in STATCOM, presenting a methods for best suitable in the point of low THD, better output, cost and efficiency. MATLAB/SIMULINK results are present in this paper of multilevel inverter four topologies for STATCOM applications with Instantaneous p – q theory controller implemented.

I. INTRODUCTION

A Static compensator (STATCOM) is basically one of the shunt-type FACTS controllers, and DSTATCOMs are the distribution network STATCOMs. There are some variations of the STATCOM, but their composition is basically the same. One STATCOM is composed of one inverter with energy storing capacitors on its dc side, inductance and a control system, and it is connected in parallel with the power grid, as shown in Fig. 1.

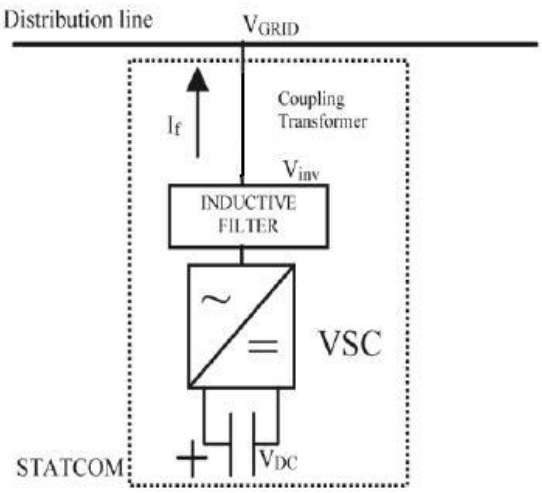

Fig.1 Basic Structure of STATCOM

The STATCOM controls the reactive-power flow in the electric line, injecting or absorbing it. This reactive-power output of the converter is controlled by varying the amplitude of the output voltage [7]-[10].

The evolution of existing power semiconductor switches (GTO, IGBT) and the appearance of new ones (IGCT, IEGT, etc.), combined with the utilization of new inverter topologies, have allowed the increase of power and voltage ratings of electronic converters. This means that, in some cases, even the coupling transformer is not necessary, and the inverter could directly be connected to medium voltage levels [3]. Therefore, in this kind of application, the Cascade H-bridge, Incremental cascade H-bridge, Incremental cascade I–bridge and Incremental – reduction cascade H-bridge multilevel topologies as shown in following figures. Multilevel inverters have become very popular in the last few years, due to their capability to generate cleaner voltage waves and lower switching losses [1]-[4]. If the cascaded H-bridge topology scaled in powers of three is utilized, the number of sources and semiconductors is minimized [5]. With this topology, each H -bridge operates at a lower frequency, decreasing switching losses and permitting the use of slower semiconductors. This paper shows that lower frequency operation of the asymmetrical converter has permitted the adaptation of industrial controllers for filtering purposes. Using theses topologies are implemented in STATCOM with PWM techniques by Instantaneous p–q Theory.

II. MULTILEVEL INVERTER TOPOLOGIES

The basic features of various cascade multilevel topologies are summarized in this section. These four topologies are implemented for STATCOM and analyses.

A. *Cascade H-bridge multilevel inverter*

Fig. 2 shows the block diagram of a single phase leg of the cascade H-bridge multilevel inverter. The output waveform levels consist of $S \times V_{DC}$ where S is the number of the separated dc sources or the number of the cells. The number of levels in the output waveform is equal to 2S+1.

Fig. 2 illustrates the output waveform and the harmonic chart of a cascade H-bridge multilevel inverter using S=2. The 5 levels of the output are $\pm 1V_{DC}$, $\pm 2V_{DC}$ and 0. Note that the dc source has the voltage value of 10v.

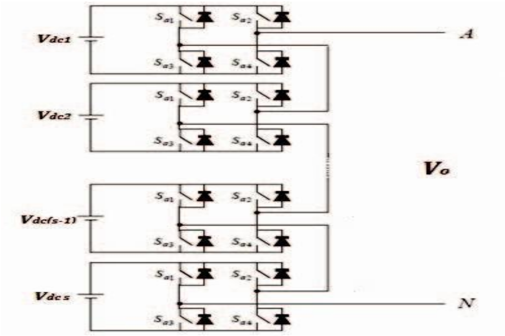

Fig.2 Cascade H-bridge multilevel inverter

B. *Incremental cascade H-bridge*

This section introduces a topology based on the cascade H-bridge named incremental cascade H-bridge (Fig. 3). It increases the number of output waveform levels thereby considerably reduces the low order harmonics and also THD.

The number of output levels is 2^{S+1} where S is the number of the separated dc sources or the number of the cells. In Fig. 4 the incremental cascade H-bridge multilevel inverter output and its harmonic chart, for S=2 are shown.

The output waveform has 7 levels: $\pm 3V_{DC,}$ $\pm 2V_{DC,}$ $\pm 1V_{DC}$ and 0.

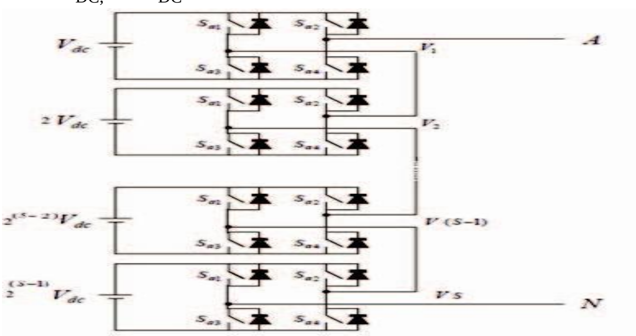

Fig.3 Incremental cascade H-bridge.

C. *Incremental cascade I-bridge*

Fig. 4 shows the block diagram of a single phase leg for the incremental cascade I-bridge. In this topology one leg of H-bridge is canceled by using special method.

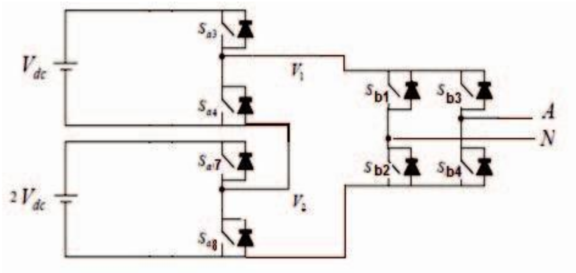

Fig.4 Incremental cascade I-bridge

Special switching method can be selected to put switches in permanent status which causes some of them be removed. The number of switches in this topology is less than H-bridge topology:

$b = (S \times 4)$ For H-bridge topology (1)

$b = (S \times 2) + 4$ For I-bridge topology (2)

D. *Incremental - reduction cascade H-bridge*

The block diagram of a single phase leg for the incremental-reduction cascade H-bridge is shown in Fig. 5. The inverter consists of H-bridge while the DC-link voltage among the cells is 1V, 3V, 9V.

In this topology the original output is the summation of all cells output. Each cell can produce positive or negative polarities. The output waveform for S=2 is illustrated. The output waveform has 9 levels (3^S): $\pm 4V_{DC}$, $\pm 3V_{DC}$, $\pm 2V_{DC}$, $\pm 1V_{DC}$ and 0.

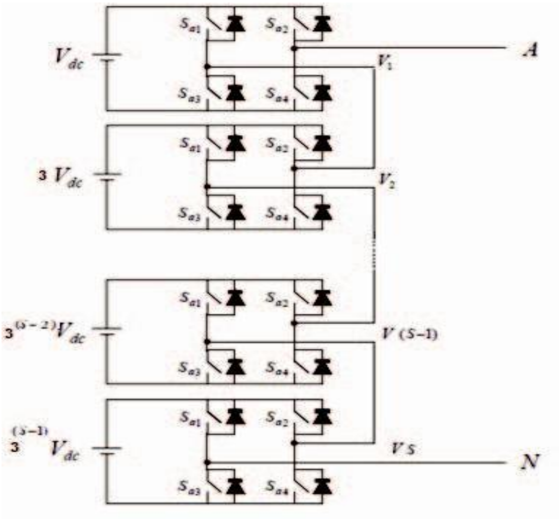

Fig.5 Incremental-reduction cascade H-bridge

III. PROPOSED CONCEPT

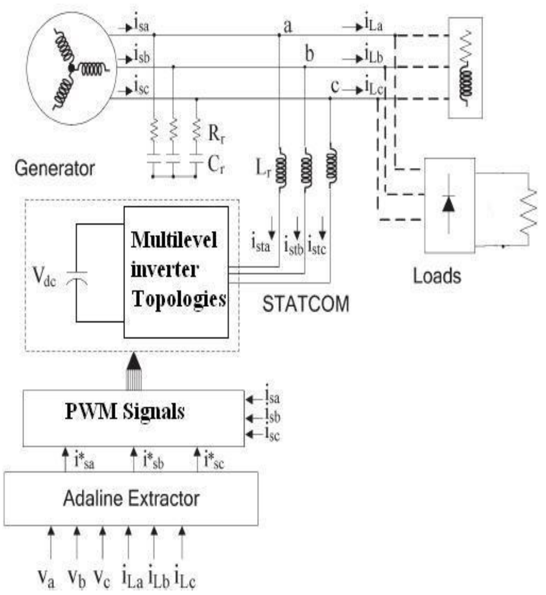

Fig.6 Proposed STATCOM diagram

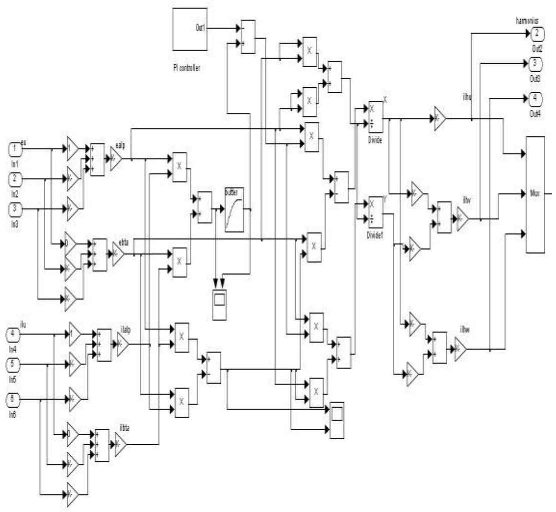

Fig.7 Diagram of Instantaneous p–q Theory

A. *Instantaneous p–q Theory:*

The control of STATCOM is implemented on the basis of instantaneous reactive power theory (or $p-q$ theory) to calculate the desired compensation current. The block diagram for the control using IRPT is shown in Fig. 7(a). In this method, the sensed three-phase PCC voltages and load currents are trans-formed into $\alpha-\beta-o$ axis using Clark's transformation. In addition, the source must deliver no zero-sequence active power (so that the zero-sequence component of the voltage at the PCC does not contribute to the source power). The reference source currents in the $\alpha-\beta-o$ reference frame are converted to the abc frame using the reverse Clark's transformation.

IV. SIMULINK RESULTS

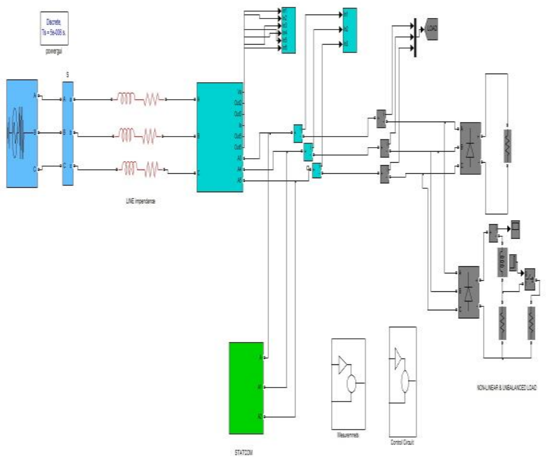

Fig.8 MATLAB/SIMULINK diagram of Multilevel inverter topologies STATCOM.

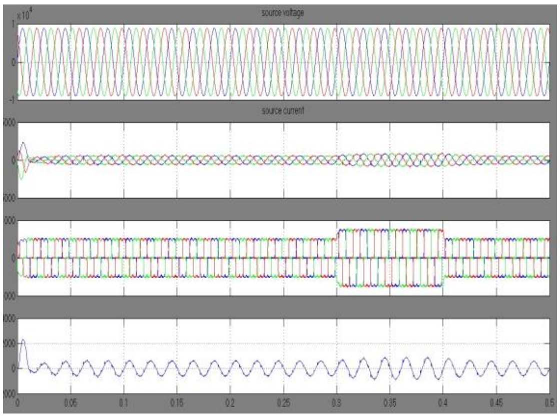

Fig.9 compensated results under cascaded H-bridge 5-inverter STATCOM

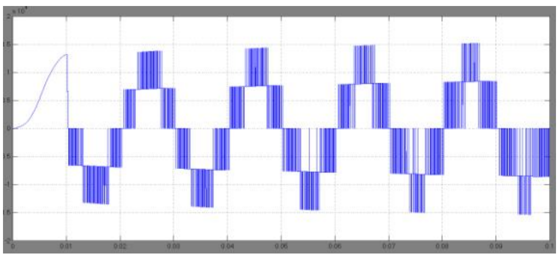

Fig.10 Inverter voltage

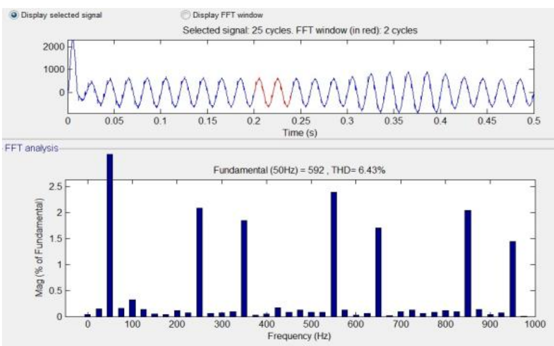

Fig.11 Source current THD

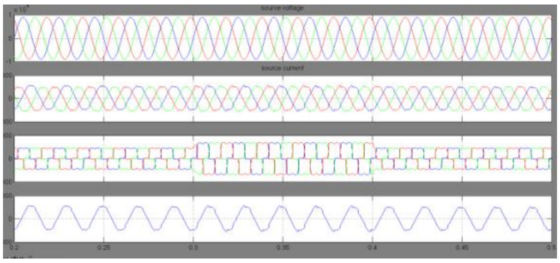

Fig.12 compensated results under incremental cascaded H-bridge,

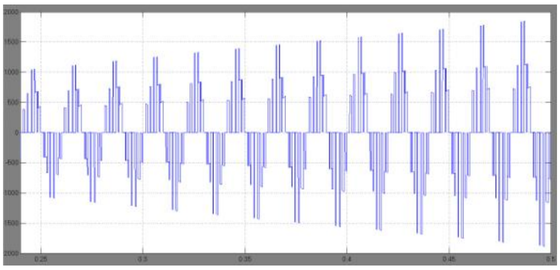
Fig.13 7-level incremental cascaded H-bridge inverter voltage

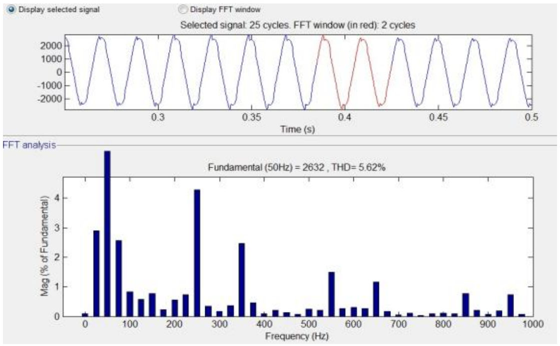

Fig.14 source current THD under incremental cascaded H-bridge.

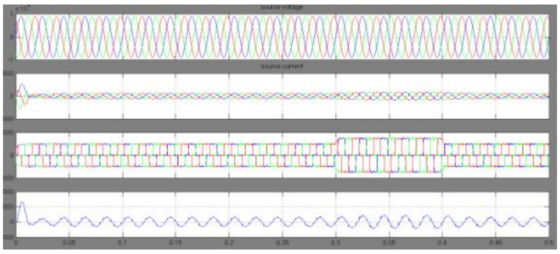

Fig.15 compensated results under incremental cascaded I-bridge.

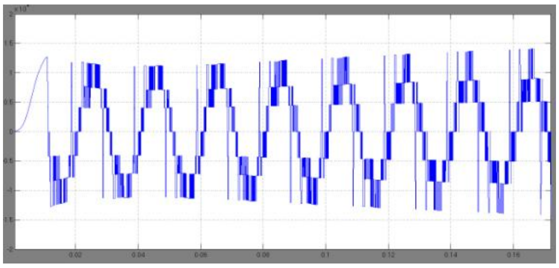
Fig.16 7-level inverters voltage under incremental cascaded I-bridge.

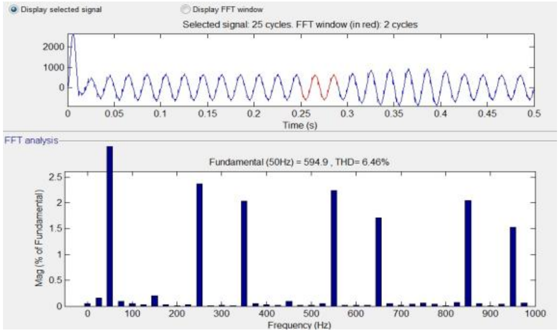

Fig.17 source current THD under incremental cascaded I-bridge.

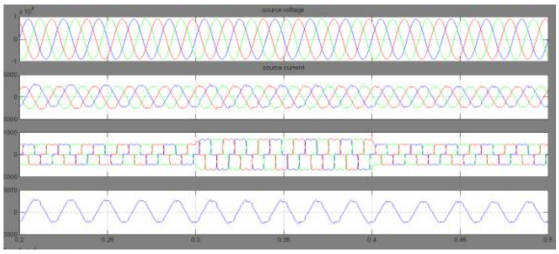

Fig.18 compensated results under Incremental - reduction cascade H-bridge.

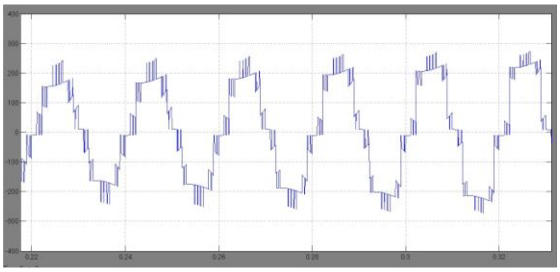
Fig.19 9-level inverter voltage under Incremental - reduction cascade H-bridge.

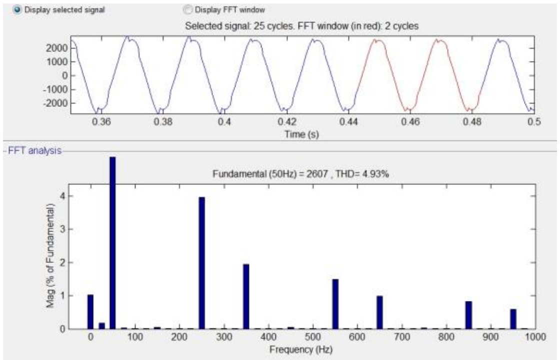

Fig.20 Source current THD under Incremental - reduction cascade H-bridge.

Table.1 Comparison of THD and 3rd Harmonic in Source Current

Type of multilevel inverter topologies	Output Levels	THD (%)	3rd Harmonics
Cascaded	5-level	6.43	0.06%

multilevel inverter			
Incremental cascade H-bridge	7-level	6.83	0.25%
Incremental cascade I-bridge	7-level	5.62	0.78%
Incremental - reduction cascade H-bridge	9-level	4.93	0.04%

V. 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