Performance Analysis of Multilevel Converter Using Matlab

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Abstract- This paper deals with modern power electronic equipments related serious problems in recent years. High current harmonics, low power factor and non-sinusoidal line current are the drawbacks of the diode rectifiers and phase-controlled rectifiers. To increase the input power factor and decrease the total harmonic distortion, multilevel rectifiers and inverters have been proposed for high power and medium voltage applications because they can provide many advantages such as low voltage rating of power semiconductors and low voltage harmonics. This type of converter is suitable for high voltage and high power applications. This multilevel inverter has ability to synthesize waveforms with better harmonics spectrum.

Keywords: MATLAB Simulink, 3- level converter, Rectifier, PWM, Active power filter.

I. INTRODUCTION

Solid state control of ac power using diodes, thyristors and traics is widely used to feed controlled ac power to variety of electrical loads such as adjustable speed drives (ASD) and static power supplies. These electrical loads employing solid state controllers draw harmonic and Reactive power components of current along with active power component of current from ac mains and thus called non-linear loads. These injected harmonics and reactive power burden on ac source cause low efficiency, low power factor, poor utilization of distribution system, reduced life of other equipments, and disturbance to other consumers and interference to communication networks. Conventionally passive L-C filters were employed to reduce harmonics and capacitors were used to improve the power factor of the loads. But passive filters have the demerits of fixed compensation, large size and resonance [1].

Multilevel converters have emerged as a very important alternative in the area of high power medium-voltage applications. Voltage operation above classic semiconductor limits, lower common mode voltages, near sinusoidal outputs together with small 'dv/dt' are some of the characteristics that have made this power converters popular for industry and research [2].

Therefore for such reason multilevel converter are frequently used in substitution of traditional converter, employing higher breakdown voltage, lower switching device such as GTO/IGBT. Use of multilevel converter has following advantage.

(1) Substantially small filter as a consequence a cost reduction of the system in much application.

(2) No charge unbalance problem result when the converters are in either charge mode (rectification) or drive mode (inversion).

(3) Useful in reduction of line harmonics and near unity factor can be accomplished.

II. MULTILEVEL CONVERTER

Appeared in the early 70's in different of application, multilevel converter represent a high potential realization of high power controllable conversion systems such as rectifiers, inverters high power amplifiers etc. multilevel converters are based on the fact that a voltage sine wave (for inverter) or current sine wave (for rectifier) can be approximated to a stepped waveform having large number of steps

Multilevel converters have been developed to overcome the shortcoming in solid state switching device rating. So that large motor can be controlled by high power adjustable frequency drive. The most popular structure proposed as a transformer less converter is the diode clamped converter based on neutral point converter [3].

III. ACTIVE POWER FILTER USING MULTILEVEL CONVERTER

Harmonic mitigation in power system is a goal, which has occupied a great deal of research since 1960's. Harmonics are the by-product of the modern electronics. They are associated with large numbers of personal computer (single phase load), UPS, variable frequency drives (AC and DC) and any electronics device using a solid state power switching supplies to convert incoming AC to DC. Problem caused by harmonics are as follows:

- Elevated RMS current
- Circuit breaker trips
- Nuisance fuse operation
- Reduced equipment life(transformers, conductors, breakers, etc)
- Equipment malfunctioning
- High frequency current flow
- Reduced effective power factor, and Computer/telephone may experience interference or failures.

Passive filters are used for harmonics mitigation due to their advantages of simplicity, low cost and easy maintenance. However the disadvantages are

- The source impedance strongly affects filtering characteristics.
- As both the harmonics and fundamental current components flow into filter, the capacity of the filter must be rated by taking into account both currents.
- When the harmonics current increases the filter can be overloaded.
- The passive filter may fall into series resonance with the power system, so that the voltage distortion produces harmonic current flowing into the passive filter.
- Parallel resonance between the power system and the passive filters causes amplification of harmonics currents on the source side at a specific frequency.

Due to these resonances attention of researchers has been drawn to active power filter (APF). Correspondingly a pulse width modulated converter with 10 kHz of high switching frequency has been used for harmonic compensation and static VAR compensations. However the initial and running cost are hindering their practical use in power distribution system. In addition it is difficult for the PWM converters to comply with electromagnetic interfacing requirement. Due to power handling capabilities of actual semiconductor devices, these type of active power filter are connected through a coupling transformer to math with the sores voltage, thus increasing cost and complexity of the power topology [4].

A. CLASSIFICATION OF MULTILEVEL CONVERTER

Multilevel converters are classified in circuit topology as

- Diode clamped multilevel inverter
- Flying capacitor multilevel inverter
- Series H-bridge multilevel inverter

The Cascaded multilevel H-bridge inverter utilizing capacitor voltage sources is given. Active Harmonic elimination for Multilevel Inverters is given (Du et al., 2006). A survey of topologies, controls and applications of multilevel inverters is given reduced common mode modulation.
But in this inverter cascade multilevel inverter use all these topology [5].

B. A CONTROL SCHECE FOR MULTILEVEL CONVERTERS

Multilevel converters are suited for high voltage static power conversion. The series connection of multiples dc voltage sources in the dc bus allows the operation in medium voltage systems with lower voltage stresses across each semiconductor switch in both cases as a rectifier or as a multilevel inverter. Moreover the multi-step composition of the output voltage (for the inverter), or the input current (for the rectifier) presents lower THD factors as compared with the two levels converter, due to presence of multiple steps in the respective waveforms. The main application of this converter topology has been found in ac drives and also in reactive power compensators (i.e. active power filters) [2].

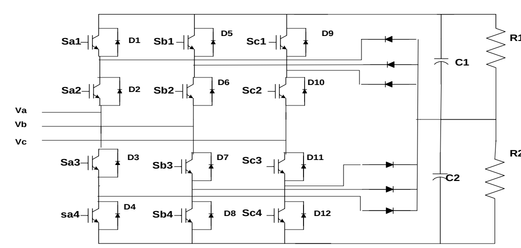


Fig.1 Power circuit for 3-phase multilevel converter

In this paper a generalized control scheme has been discussed that allows the operation of the multilevel converter in the four quadrant . The principal advantage of this characteristic is that it allows the converter to operate as a rectifier or as a active power filter or both at the same time. In the rectification mode the converter can operate as a frequency changer supplying active power from the DC bus to an output inverter while keeping the input current sinusoidal and with unity power factor [2].

As an active power filter, the three-level converter operates, as a controllable current source injecting the current harmonics required by non-linear loads. In this type of application the voltage across each capacitor remains constant and balance even under severe dynamic operating condition. The most important characteristic of the proposed control scheme is that which allows the operation of multilevel converter as a frequency changer (or rectifier), while it compensates for the current harmonics and reactive power required by distribution system. The Converter control scheme only senses the system current and voltage waveforms to generate the required reference signals, thus reducing the number of components and simplicity of the control topology [2,3].

IV. PRINCIPLE OF OPERATION OF CONTROL SCHEME

The proposed control scheme must perform two important duties. The first one is to keep the DC bus voltage constant, balanced and equal to a defined reference value, and the second one is to force the power distribution system current to be sinusoidal and in phase with the respect phase-to-neutral voltage, independently of the load value connected to the DC bus. For the above reasons the multilevel converter can operate as a rectifier (in the case it had load connected to DC bus), or as an active filter (in case no load connected to the DC bus). When the converter operates as a rectifier, it forces the system line current to be sinusoidal and in phase with the respective phase to neutral voltage, which means that it is also operating as an active power filter. The block diagram of the control scheme is shown in fig.2.

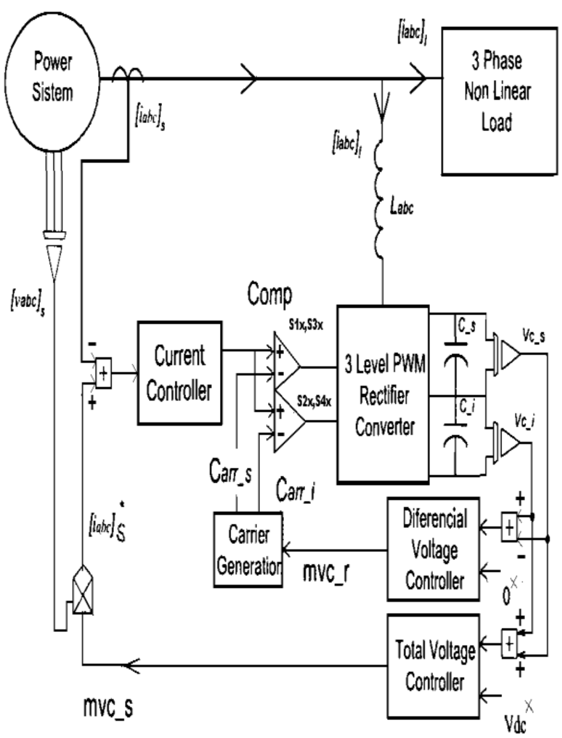


Fig.2 Blok Diagram of the control scheme

Fig.2. shows that the control scheme has basically two blocks. The first one keeps the DC bus voltage constant and balanced, while the second one is in charged of forcing the power distribution line current to be sinusoidal and with unity power factor.

The DC voltage control system must perform two functions simultaneously: the first one is to keep the DC bus voltage constant and equal to given reference value, and the second one is to maintain the voltage across each electrolytic capacitor constant and balanced. The voltage across each capacitor is equal to the DC bus Voltage divided by the number of capacitors.

The DC bus voltage is controlled by adjusting the amount of active power absorbed by the multilevel converter, while the balance across each capacitor is achieved by changing the amplitude of each triangular carrier waveforms. The gating signals of the converter are obtained by comparing the error current signal with two Carrier triangular waveforms with fixed frequency and variable amplitude.

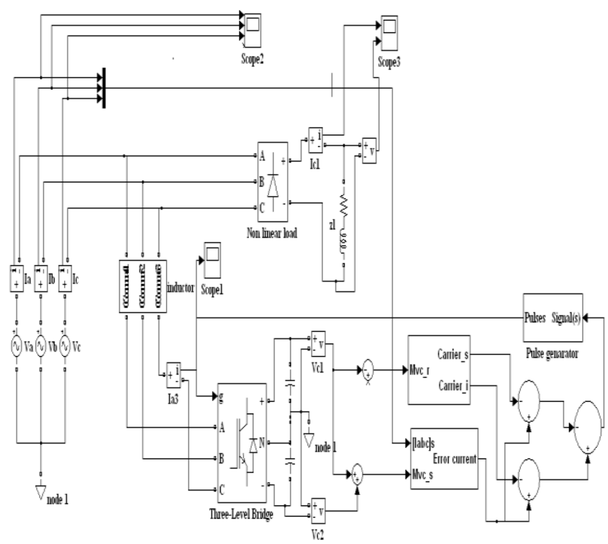


Fig.3 Simulation model of control scheme for multilevel converter

V. SIMULATION CIRCUIT OF CONTROL SCHEME FOR MULTILEVEL CONVERTER

The simulation of the control scheme of multilevel converters was carried out with the help of MATLAB (version 7.10). Simulink power system block sets were used for the simulation purpose is shown in fig.3.

Simulation of the control scheme as explained above was carried out which operates the multilevel converter as an active power filter and rectifier at the same time. As explained in control schemes must perform two important duties. The first- on is to keep the DC bus voltage constant balanced and equal to a defined reference value, and the second one is to force the power distribution system current to be sinusoidal and in phase with the respective phase-to-neutral voltage, independently of the load value connected to the DC bus. Hence two controller has been designed, one is the differential voltage controller which keeps the voltage across each capacitor constant, balanced and equal and the other is the total voltage controller which forces the input current to be sinusoidal and in phase with respective phase to neutral voltage.

The following waveforms for control scheme operating as active power filter and rectifier have been observed as follows.

- Input phase voltage
- Input line current
- Converter compensating current
- Load current
- Voltage across the two capacitors.

A. Multilevel converter act as active power filter

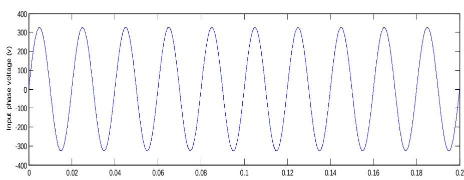


Fig.4 Reference phase voltage

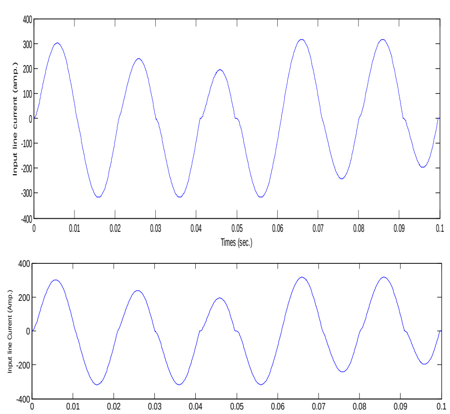


Fig.5 Input line Current

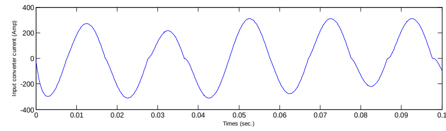


Fig.6 Converter input current

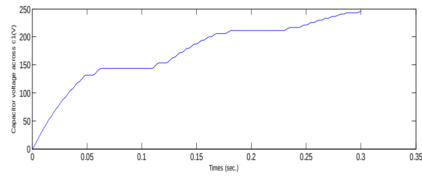


Fig.7 Capacitor voltage across c_1

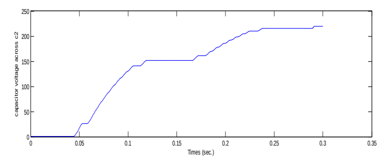
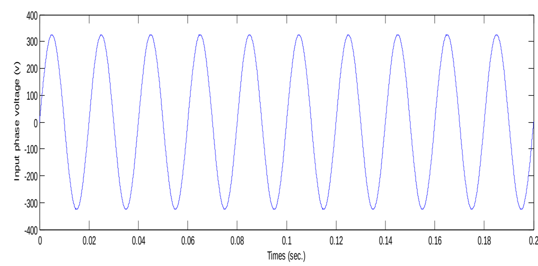


Fig.8 Capacitor voltage across c_2

B. Multilevel converter act as Rectifier



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ig.9 Reference phase voltage

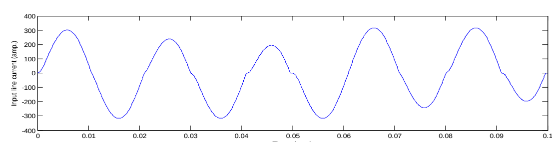

Fig.10 Input line Current

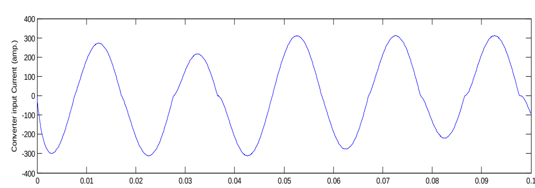

Fig.11 Converter input current

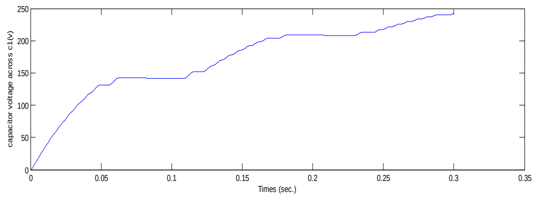

Fig.12 Capacitor voltage across c_1

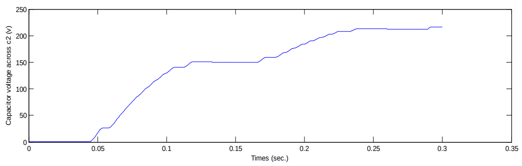

Fig.13 Capacitor voltage across c_2

VI. RESULTS AND DISCUSSION

A generalized control scheme that allows the operation as an active filter and/or frequency changer in active front-end multilevel converters is proposed and analyzed in this paper. The basics characteristics of the proposed control scheme is that permits the operation of the converter in four quadrants, giving full control on the active and reactive power and current harmonics absorbed by the converter. The control scheme is designed for the application in multilevel converters. The objective of this paper is as follows:

- Simulation of the control scheme of multilevel converter (three-level converter) as an active filter and rectifier or both same times.
- Make conclusion from the above analysis.

REFERENCES

[1] S. J. Finney, A. M. Massoud, and B. W. Williams, "A comparison of Three-level converters versus two-level converter for low voltage drives, traction and utility application", in 11th International Conference on harmonics and power Quality, 2004

[2] Sun-kyoung Lim, Jun-Ha Kim and Kwanghee Nam, "A DC link voltage balancing algorithm for 3-level converter using zero sequence current", IEEE 0-7803-5421, April 1999

[3] Sui-Hui, Zou-Ji-Yan, Li Wei-dong, "A novel Active power filter using Multilevel converter with self voltage balancing," IEEE proceed Electrical power appl., Vol. 151, No. 4, July 2004, pp 460-467

[4] Sleven Kincic et. al., "Power Factor Correction of single phase and three-phase unbalanced loads using multilevel inverter", IEEE Conf. Proc. 2001, pp 131-138

[5] Bor-Ren Lin, Hsin-Hung Lu, and Shuh-Chuan Tsayin, "Control Technique for high power factor Multilevel Rectifier", In IEEE Transactions on aerospace and electronics system, Vol. 37, No-1, January 2001

[6] J. S. Lai and F. Z. Peng, "Multilevel Converters A New Breed of Power Converters," in IEEE Trans. Ind. Application., vol. IA-32, No 3, May/June 1996, pp.509-5 17.

[7] Franco Hernandez C, Luis Moran T. Jose Espinoza C, Juan Dixon R, "A Generalized control Scheme for active Front End Multilevel converters," in IEEE 27 annual conference 2001,pp915-921.

[8] Luis. A. Moran Juan. W. Dixon and Rogel. R. Wallace, "A Three phase active power filter with fixed switching frequency for reactive power and current Harmonic compensation", in IEEE, 1992

[9] M. Basu, S. P. Das and G. K. Dubey, "Parallel converter scheme for high-power active power filters," IEEE Proceed Electrical power appl., Vol.151,No.4,July 2004