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Implementation of Modular Multilevel Converter based Active Power Filter

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Abstract

This paper presents a shunt active filter based on modular multilevel converter (MMC).The main objective is to eliminate the current harmonics for enriching the power quality. Low output current total harmonic distortion (THD), high modularity, low power device stress etc. can be achieved using MMC. The current controller of shunt active filter is based on DQ reference theory and make use of PWM technique for switching strategy.
Keyword- Modular Multilevel Converter, Shunt Active Power Filter

I. INTRODUCTION

Presently, with an increasing demand for electricity in various industries and as a result of more electrical loads with different power requirements, more power electronic converters are adopted. The introduction of power electronic based systems will lead to harmonic pollutions and degrade the power quality of the system. In order to improve the power quality, these harmonics should to be eliminated.

Several methods have been developed to deal with this issue. Different topologies of passive filter can be used to mitigate the effects caused by the distorted currents. Despite of it is technical simple and low cost solution, the performance of the passive filters is strongly depended on the network impedance and system frequency. Passive power filters are bulky, inflexible and have low compensation ratings which limit their applications for compensation.

Shunt active power filters (APF) are static power converters controlled to synthesize the current harmonics drained by non-linear loads. They also can be used to compensate reactive power and imbalances at load terminals. Two-level APFs are not suitable for medium or high voltage applications that required large compensation capacity. At present, there are four multilevel converter circuit for active power filter, i.e. cascaded H-bridge converter, neutral point clamped converter, flying capacitor converter and modular multilevel converter [3].

Among these, the APF based on MMC has several advantages. The modular multilevel converter (MMC) is a interesting converter to be applied in medium/high voltage networks. Conceptually, the MMC does not have the drawbacks of the multilevel converters. The MMC has modular structure so like cascaded H bridge topology, this has the advantage of synthesizing large voltage using devices of low voltage rating, simple power circuit layout and high reliability due to modular structure. Unlike cascaded H Bridge, MMC does not require isolated DC sources, so there is no need of isolation transformer, this reduces the overall size and cost of the verter drastically.

The main objective of this paper is to present an initial study of a shunt active filter based on MMC topology to compensate the non-sinusoidal currents drained by a non-linear loads.

II. MODULAR MULTILEVEL CONVERTER

Figure 1 shows the single-phase modular multilevel converter. Two IGBTs, two anti-parallel diodes and a DC capacitor compose each SM of MMC. Figure 2 shows the detail of one SM. Depending on the state of the self-commutated switch, the SM is said active or inactive (bypassed).

The switching strategy used to control the MMC assumes that the number of active SM per phase should be always equals to n. As a consequence, it is possible to synthesize a terminal voltage with (n + 1) different levels. The two switches of submodules are controlled with complementary signals and produce two active switching states that can connect or bypass its respective capacitor to the total array of capacitors of the converter leg, generating, in this way, the multilevel waveform.

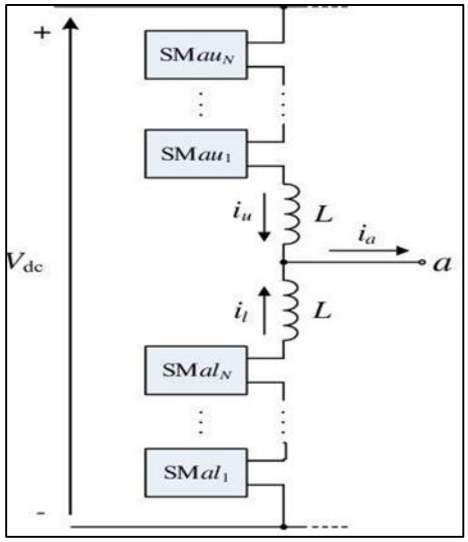

Fig. 1: Single phase MMC

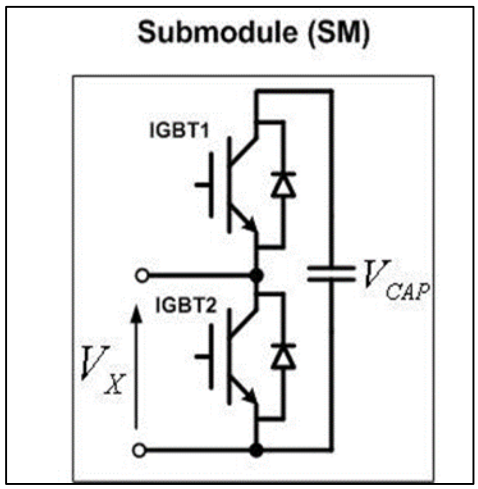

Fig. 2: Submodule

III. SHUNT APF SYSTEM DESCRIPTION

Figure 3 shows a block diagram of an electric system having MMC- shunt active filter connected between the source and the load terminals [4]. Passive filters are used to connect the MMC to the PCC to eliminate high frequency harmonics generated by the PWM switching strategy. Despite of the fact the active filter operates as a controlled current source compensating the harmonic currents at the load terminals. It also drains the fundamental frequency current, iF,1, from the electric source in such a way to regulated the voltage of the MMC dc bus.

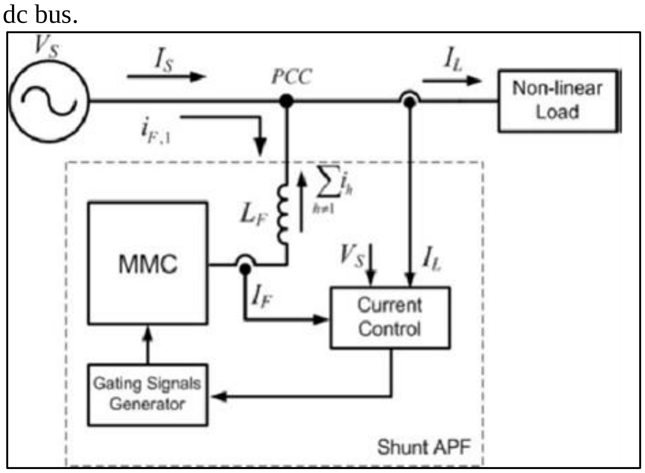

Fig. 3: Shunt active power filter scheme

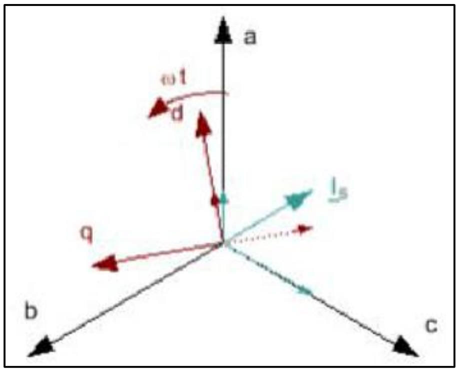

Fig. 4: The current phase or projections on the rotating synchronous dq referential axis

IV. CONTROL SCHEME

The synchronous fundamental dq frame theory is used in the proposed system [2].According to this theory, the Park transform is used to make the transition from the three-phase coordinate system of the current obtained from the current transducers, to a two-phase orthogonal coordinate system rotating at an imposed speed. Following this transformation, the current projections on the two axes will be : - a DC component due to the current harmonic with the angular frequency equal to the dq frame rotating speed; - an AC component, due to the current harmonics of angular frequencies different from the dq frame rotating speed.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta - \frac{4\pi}{3}\right) \\ -\sin\theta & -\sin\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta - \frac{4\pi}{3}\right) \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

For the extraction of the DC component, low-pass filters are commonly used, and for the extraction of the AC components, high-pass filters are used. One disadvantage of this method is the necessity to obtain the dq frame angular position (angle), which involves the use of a PLL for determining the mains voltage phase [2].

V. SWITCHING METHOD

PSPWM (Phase-shifted pulse width modulation) technique has been proposed [1] for modular multilevel converters in this paper. The method is widely used in different industrial applications. The method is based on conventional pulse width modulation method where the intersection between reference waveform and carrier waveform determines the switching instants. This method assigns an speci c triangular carrier waveform to each individual cell, while each carrier is phase shifted by 2π/N in which N is the number of cells per arm. Additionally, the generated arm reference is distributed among all cells in one arm. The individual cell switching pulse is generated locally at cell level. The switching frequency is determined by carrier frequency and consequently is similar for all cells. There is a minimum limit on the carrier frequency and generally this method is not suitable for low switching frequency applications.

VI. RESULT AND DISCUSSION

This paper presents a three level MMC based shunt active power filter whose main objective is harmonic compensation. It eliminates harmonics by injecting compensating current to the system and make the source current sinusoidal. The paper proposes DQ control for reference current generation and PWM based switching method. Harmonics due to nonlinear loads is expected to be eliminated after implementation of the proposed system.

VII. CONCLUSION

Shunt active power filter is mainly used to resolve the supply current harmonics compensating for the reactive power in the distribution system caused by nonlinear loads. The components of load harmonic currents are cancelled by the usage of the active filter and the source current remain sinusoidal and in phase with the respective phase to neutral voltage. This paper presents an MMC based SAPF which again has many advantages over other multilevel topologies.

The MMC has several advantages -(i) passive component reduction, (ii) continuity of operation even under failure of any submodule, (iii) possibility of operation with low switching frequency, (iv) ease of maintenance and (v) lower conduction losses(vi)and high reliability due to its modular structure.

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