Modeling & Simulation of Novel Nine level Shunt Active Filter for High Power Drive System

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Abstract— Active filters provide a viable solution to mitigate harmonic related issues caused by diode or thyristor rectifier front-ends. Compared with the series and hybrid configurations, the shunt active filters do not need an additional coupling transformer and require much less protection and switchgear. To handle the large compensation currents and provide better thermal management, two or more parallel connected semiconductor switching devices can be used. Shunt active filter can improve the power quality issues. In this paper, a novel topology is proposed where two active filter inverters are connected with tapped reactors to share the compensation currents. The proposed active filter topology can also produce nine voltage levels, which significantly reduces the size of passive components. A current balancing algorithm is proposed to keep the reactor magnetizing current to a minimum. It is shown through simulation that the proposed active filter can achieve high overall system performance.

This paper presents a shunt active filter configuration that uses tapped reactors for harmonic current sharing. It also reduces voltage stress across the switches by utilizing a conventional three-level flying capacitor topology. Overall the configuration is capable of producing nine distinct voltage levels and thus reduces switching ripple in the compensating currents. Finally Matlab & Simulink based model is developed and simulation results are presented.

Keywords:- **Active filters, harmonic analysis, power conversion, power electronics**.

I. INTRODUCTION

Variable speed motor drives (VSDs) have found extensive application in a variety of high-power systems. One example is the electric propulsion system used in modern naval ships, the power ratings of which can be tens of megawatts [1-3]. Typically the front-ends of such ASDs employ a diode or thyristor rectifier. In spite of their simple control and robust operation, these devices can result in serious power quality issues. They can generate voltage and current harmonics that might affect the operation of other devices in the same ac system. Conventionally, passive *L-C filters are* used to mitigate harmonic related problems.

However, due to their large size and inflexibility, passive filters are gradually being replaced by active filters that utilize power electronic inverters to provide compensation for harmonics. Among various active filter configurations, the shunt active filter systems have a number of advantages and constitute the optimal harmonic filtering solution for VSD rectifier front-ends. Compared with the series and hybrid configurations, the shunt active filters do not need an additional coupling transformer and require much less protection and switchgear. They operate as three-phase controlled harmonic current sources and are not affected by harmonic distortions in supply voltages [4-9]. For high-power applications such as ship propulsion systems, the large compensation current often requires parallel operation of two or more switching devices or active filters. In recent years, multilevel converters have shown some significant advantages over traditional two-level converters, especially for high power and high voltage applications. In addition to their superior output voltage quality, they can also reduce voltage stress across switching devices. Since the output voltages have multiple levels, lower d*v/dt is achieved, which greatly alleviates electromagnetic* interference problems due to high frequency switching. Over the years most research work has focused on converters with three to five voltage levels, although topologies with very high number of voltage levels were also proposed. In general, the more voltage levels a converter has the less harmonic and better power quality it provides. However, the increase in converter complexity and number of switching devices is a major concern for multilevel converter. It has been shown that although more voltage levels generally mean lower total harmonic distortion (THD), the gain in THD is marginal for converters with more than seven levels.

This paper presents a shunt active filter configuration that uses tapped reactors for harmonic current sharing. It reduces current stress of the switching devices by distributing the compensation current between two parallel legs of a H-bridge topology. It also reduces voltage stress across the switches by utilizing a conventional three-level flying capacitor topology. Overall, the configuration is capable of producing 9 distinct voltage levels and thus greatly reduces switching ripple in the compensating currents.

II. PROPOSED CONVERTER

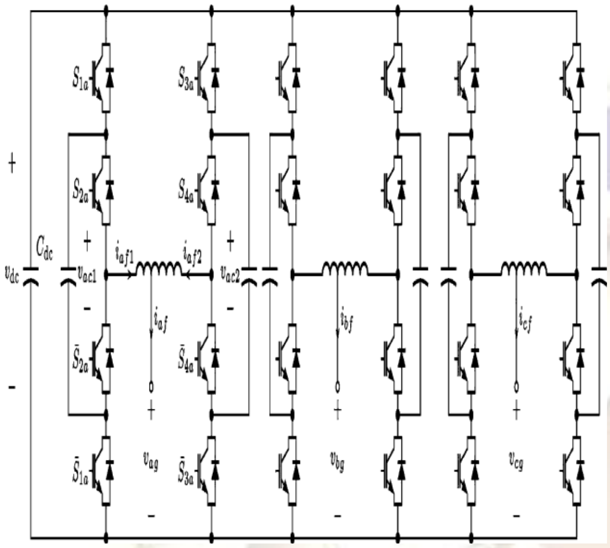

Fig. 1. Proposed 9 level filter

The proposed active filter topology is shown in Fig. 1. It consists of an H-bridge configuration made from three-level flying capacitor branches. Essentially, it is a voltage-source inverter (VSI) with capacitive energy storage (*C*dc) shared by all three phases. A total of eight switching devices are used in each phase. A tapped reactor is used to connect the two legs of the H bridge. Typically, the reactor is wound to be center tapped, making the output line-to ground voltages (*vag* for example) the average of the voltages from each side of the H-bridge. Then, the line-to-ground voltages will have five distinct voltage levels [9]–[11]. However, with this topology, the tap is set at 1/3 to get 7 voltage levels and tap is set to 1/4 to get nine voltage levels.

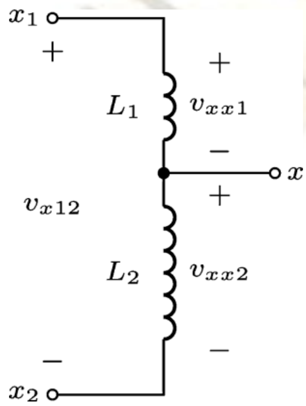

Fig. 2. Tapped Reactor Model

Unlike the center-tapped interphase reactor [9]–[12], the reactor in the proposed topology has a tap terminal at its K position, as shown in Fig. 2. For the convenience of analysis, the reactor can be divided into two parts. In Fig. 2, part one, denoted as *L*1 , consists of the portion from terminal *x*1 to the tap and has a number of turns *N*1 = *N*; part two, denoted as *L*2 , consists of the portion from the tap to terminal *x*2 and has a number of turns *N*2 = K*N*. Terminals *x*1 and *x*2 are defined as the input terminals while the tap terminal is defined as the output terminal *x*.

The voltage at the output terminal with respect to the common ground is

Vxg=K*Vx1+(1-K)*Vx2

Where K is tapping position of Inductor.

For K=1/3

Vxg= 1/3*Vx1+2/3*Vx2

The active power filter produces seven voltage levels. The switching sequence and output voltage levels are shown in Table I.

Table I

Vx1	Vx2	Vxg
0	0	0
0	Vdc/2	Vdc/6
Vdc/2	0	Vdc/3
Vdc/2	Vdc/2	Vdc/2
Vdc/2	Vdc	2Vdc/3
Vdc	Vdc/2	5Vdc/6
Vdc	Vdc	Vdc

For K=1/4

Vxg= 1/4*Vx1+3/4*Vx2

The active power filter produces nine voltage levels. The switching sequence and output voltage levels are shown in Table II.

Table II

Vx1	Vx2	Vxg
0	0	0
0	Vdc/2	Vdc/8
Vdc	0	2Vdc/8
Vdc/2	0	3Vdc/8
Vdc/2	Vdc/2	4Vdc/8
Vdc/2	Vdc	5Vdc/8
Vdc	0	6Vdc/8
Vdc	Vdc/2	7Vdc/8
Vdc	Vdc	Vdc

III. MATLAB MODELLING & SIMULATION RESULTS

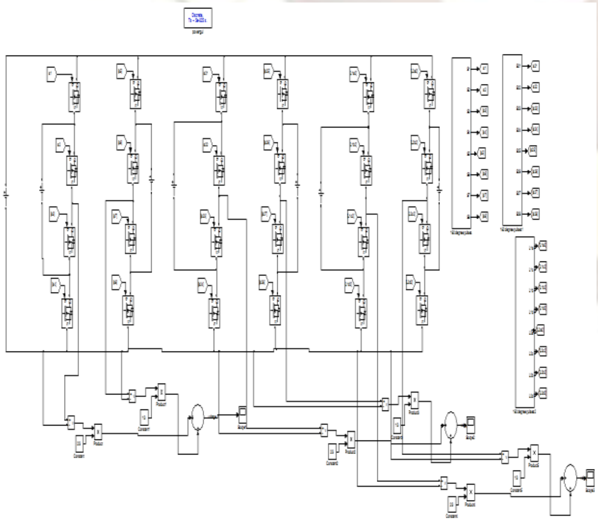

Fig.3 Matlab model of Multilevel APF

The Matlab/Simulink model of multilevel active power filter is shown in Fig.3. It consists of 3 H bridges configuration for three phase. Each H bridge consist of two arms connected by a tapped inductor

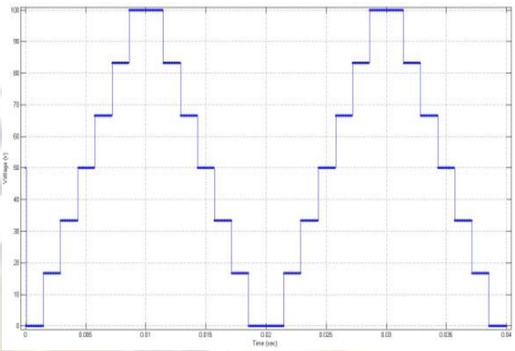

Fig.4 Seven level output

Fig.4 shows the seven level output. Here each voltage step is Vdc/6.

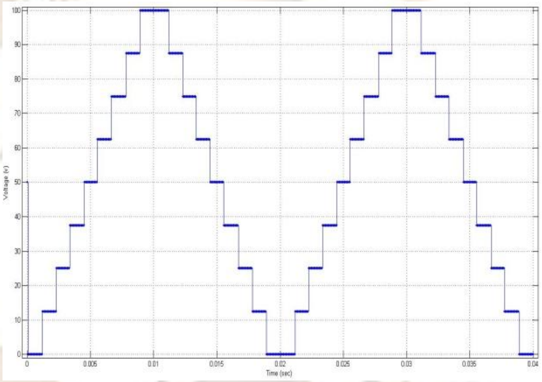

Fig.5 Nine level output

Fig.5 shows the nine level output. Here each voltage step is Vdc/8. It will reduce the voltage stress on tapped inductor.

IV. CONCLUSIONS

A new type of power converter has been introduced in this paper. The converter is based on parallel connection of phase legs through an inter phase reactor. However, the reactor has an off-center tap at one-third resulting in an increased number of voltage levels. Specifically, two three-level flying capacitor phase legs are paralleled in this way to form a nine power converter.

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