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Design of current source hybrid power filter for harmonic current compensation

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ABSTRACT

This paper presents the development of a three phase current source hybrid power filter (CSHPF) which is designed to compensate the source current harmonic distortion of nonlinear power converters. It is an alternate power filter circuit to voltage source inverter (VSI) based hybrid power filter for harmonic current compensation. CSHPF overcomes the limitations of standalone passive power filters, voltage source based active power filters and the classical PI controllers of active power filter. The control method involves the concepts of the *P–Q* theory and fuzzy logic based intelligent control to compute the reference compensating currents. This paper considers fuzzy logic control method for DC link current regulation in CSHPF. Current source hybrid power filter is suitable for compensating inter harmonic components produced by saturated machines and arcing devices. The proposed CSHPF and the control technique have been implemented in simulation environment using Matlab Simulink and experimental setup using FPGA controller to illustrate its performance in harmonic current compensation.

1. Introduction

Most of the variable speed drives are fed from the power controllers which have nonlinear characteristics. The front end rectifiers of the power controllers draw/inject harmonic currents into the utility through the point of common coupling (PCC) and cause power quality problems [1,2]. The harmonic current causes a number of undesirable effects like heating, torque pulsation in motors, equipment damage in the utility system and electromagnetic interference. The simplest method to mitigate the harmonic current and reactive power compensation is by using passive LC filters. The passive filters have some limitations even though it is a simple approach [3,4].

Active power filters (APF) are employed to compensate voltage harmonics (series APF) or current harmonics (shunt APF) with reactive power compensation required by nonlinear load [5,6]. This paper emphasises on elimination of current harmonics and reactive power compensation; hence shunt APF topology has been considered.

Based on the literature survey, it is identified that there are some limitations and scope for improvements in the design and control of the power filters for harmonic current compensation as given below.

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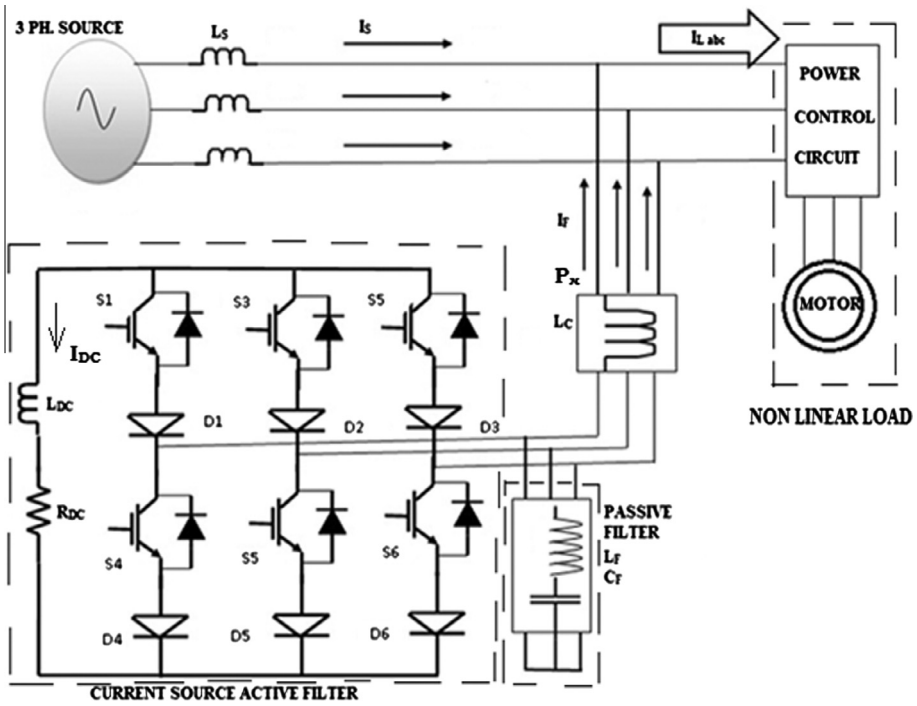

Fig. 1. Circuit configuration of CSHPF.

- Although passive filters are simple and cheap, their fixed compensation characteristics and resonance with system impedance are considered as their major drawbacks and they could not perform minimising total harmonic distortion and controlling reactive power.
- Active filter power rating and cost are high when they are operating alone. The power rating of the APF would be ranging up to eighty percent of the load power rating. The losses in the APF circuit are considerably high.
- PI controller and the time domain or frequency based classical algorithms used for the control of APF are complex and time consuming. They require exact mathematical model of the system and high performance computing tools for effective online operation.
- Most of the conventional control methods assume the ideal supply conditions and steady loads. But, practically there could be variation in the input supply conditions, imbalance and distortions in the mains voltage. When the load is a dynamic device, the load parameters are also varying with time. Then the performance of the APF would be affected [7,8].
- Proper selection of the passive elements and active filter is essential in a particular application. To avoid the errors due to dynamic conditions and variation of the system parameters intelligent control methods can be incorporated.
- In the VSI based APF circuit, there is a possibility for shoot through fault. To avoid this problem CSI based APF could be designed for current harmonic compensation. It can also compensate inter harmonics produced by the arcing devices.

To overcome the above limitations, CSHPF has been designed for harmonic current mitigation in the source current of the power converters. The reliability and protection of CSHPF have a great advantage over voltage source hybrid power filter (VSHPF) [9,10]. There no chance of shoot through fault in CSHPF circuit.

The shunt active power filters are generally constructed using voltage source inverters but the proposed CSHPF structure is using a current source inverter. To reduce the rating of the CSAPF, LC passive filter is used in parallel which is designed for the compensation of dominating fifth order harmonic current component. VSI based APFs have DC link capacitors whereas an inductor is used for the DC link in CSI based APF. The inductor of DC link connected in CSI maintains link current and stores the energy and delivers as required by the system.

The reference current computation and DC link current regulation are performed through modified version of instantaneous reactive power theory [11]. APF has to respond dynamically and act with high control accuracy in current tracking. Many advanced control and signal-processing techniques have been applied, such as hysteresis band current control (HBCC), pulse width modulation (PWM), fuzzy-logic control, neural-network theory, sliding-mode control, and adaptive signal processing [12–16]. The majority of shunt active power filter control methods which have been presented require a complex mathematical model, especially for the tuning of the PI controllers [17]. The proposed current source hybrid power filter (CSAPF) is designed using two modulation techniques, PI and Hysteresis carrier less Modulation and a fuzzy logic based carrier less hysteresis modulation [18–24].The HBCC technique has good current tracking accuracy and easy implementation.