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Three Phase Auto-tuned Shunt Hybrid Filter for Harmonic and Reactive Power Compensation

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Abstract

Hybrid filters are highly recommended for harmonic and reactive compensation in existing installations. Since current harmonic compensation can limit voltage harmonics also to a great extent, shunt hybrid filters are preferred. The traditional shunt hybrid filter consists of shunt passive and shunt active filter. Here, shunt passive filter provides fixed compensation at all load conditions. Therefore, probably at low load conditions, shunt passive filter acts as major consumer. This embarrassing situation can be avoided by replacing traditional shunt passive filter with the shunt auto-tuned passive filter. The shunt auto-tuned passive filter uses an ANN based controller to select passive filter components to provide adequate harmonic and reactive compensation under all load conditions. Remaining harmonic and reactive power compensation are provided by ANN based active filter. The performance of the proposed hybrid filter was tested by simulation and laboratory experiments under various source/load conditions and the results show that the proposed shunt hybrid filter is adaptive to varying source/load conditions.

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1. Introduction

Non-linear loads such as adjustable speed drives, UPS, inverters, and similar power electronic equipment generate distortions in current and voltage in power distribution systems. These devices also cause power quality issues such as reactive power burden, excessive neutral currents, unbalanced currents and low efficiency. To limit the problems created by harmonics, IEEE 519 guidelines are recommended.

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Hence to meet IEEE standards, many harmonic mitigation techniques are developed. Initially, various configurations of passive filters were developed to provide low or high impedance to harmonics such as shunt, or series or their combinations. They are less expensive, but are not desirable in industries due to their shortcomings such as resonance, fixed compensation, bulky size etc. [1-2]. To avoid these problems with passive filters, active filters are developed. Active filters are switch mode power electronic converters to inject harmonic currents in equal and opposite in phase at point of common coupling(PCC) so that utility need to supply only the distortion free currents[3-6]. However, the VA rating of the power electronic converter used as the active filter becomes very large. Hence, the applications of active filters are limited.

Hybrid filters combine both passive and active filters retaining their advantages, i.e. the VA rating of the active converter is reduced as much as possible in order to reduce the overall cost, electromagnetic interference and losses. Different configurations of hybrid filters were developed. In this work, the shunt hybrid filter is a combination of shunt auto-tuned passive filter and shunt active filter. The traditional shunt passive filter elements are designed to compensate for the reactive power under rated load conditions. But as the load on the system varies, reactive power demand varies, whereas traditional filter provides fixed compensation always. Many different types of harmonic filters were reported [7-14]. Hence ANN based auto-tuned shunt hybrid filter was suggested by the authors which can supply variable reactive power compensation. The performance of this shunt hybrid filter was analyzed under various source/load conditions in a test system.

2. Auto-tuned Shunt Hybrid Filter

The auto-tuned passive filter is the filter made tunable by automatically switching the capacitance or by varying the inductance. An ANN based controller [1] senses the source voltages and load currents and accordingly selects suitable capacitors (TSC) and tap positions of inductors (TSR) for the passive filters. The ANN controller predicts switching status of Thyristor switched Capacitors and Tapping positions of Thyristor controlled reactors used for fifth and seventh harmonic compensation. To improve power quality, the auto-tuned filter components are selected such that they can provide maximum reactive power demand of the load (7000 VAR). The 5^{th} and 7^{th} harmonic passive filters can provide 50% (3500 VAR each).The capacitors in TSC units are designed such that the capacitor units provide reactive power requirement by the load at fundamental frequency. The corresponding inductive reactance of TSR unit in 5^{th} harmonic filter is calculated on the concept that TSC-TSR filter provides the minimum impedance path at 5^{th} harmonic frequency (ie. $X_L=X_C$).The capacitor values in 5^{th} harmonic filter are selected as 30μF(500 VAR), 60μF(1000 VAR) and 120μF(2000 VAR) respectively. The various settings possible in TSC-TSR filter and the corresponding reactive power supplied are shown in Table I.

Table 1. Auto-tuned Shunt Hybrid Filter

C_1 30μF	C_2 60μF	C_3 120μF	5^{th} harmonic Inductor TCR(mH)	7^{th} harmonic Inductor TCR(mH)	Tap setting	
ON	OFF	OFF	13.48	6.87	1	500VAR
OFF	ON	OFF	6.73	3.44	2	1000 VAR
ON	ON	OFF	4.49	2.29	3	1500 VAR
OFF	OFF	ON	3.37	1.72	4	2000 VAR
ON	OFF	ON	2.70	1.38	5	2500 VAR
OFF	ON	ON	2.25	1.15	6	3000 VAR
ON	ON	ON	1.92	0.981	7	3500 VAR