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HYBRID ACTIVE FILTER FOR REDUCTION OF CURRENT HARMONICS IN THREE PHASE SYSTEM USING SYNCHRONOUS REFERENCE FRAME THEORY

Jainish R. Rana[1], Vinesh N.Kapadia[2]

Assistant Professor, EC Department., S.N.P.I.T & R.C, Umrakh, Bardoli, Gujarat, India[1]

Associate Professor & HOD EC Department., S.N.P.I.T & R.C, Umrakh, Bardoli, Gujarat, India[2]

Abstract— This paper presents a new control scheme for a parallel hybrid active filter system intended for current harmonic compensation of large nonlinear loads. The control scheme is based on the concept of a synchronous reference frame (SRF) control. The adopted hybrid active filter consists of one active filter and one passive filter connected in series. By controlling the equivalent output voltage of active filter, the harmonic currents generated by the nonlinear load are blocked and flowed into the passive filter. The power rating of the converter is reduced compared with the pure active filters to filter the harmonic currents. This approach reduces the reactive power. The effectiveness of the adopted topology and control scheme has been verified by the computer simulation.

Keywords — **Hybrid active filter (HAF), current harmonic elimination, IEEE 519 harmonic standard, parallel hybrid active filter system, THD, synchronous reference frame.**

I. INTRODUCTION

Recently power harmonic pollution due to nonlinear loads used in industry products, AC/DC converters for ac traction system and high voltage dc transmission has been serious in the power quality of transmission or distribution system. The harmonic currents result in degrading the power quality in distribution system. Many circuit configurations of filters have been proposed to limit the line current distortion. Passive filters with low impedances at the dominant harmonic frequencies were used to reduce the harmonics for the consideration of hardware cost. However, these circuit configurations have several drawbacks. The passive filter offers series resonance with line impedance, parallel resonance with power factor correction capacitor and design become bulky. The passive filters with fixed compensation characteristics are ineffective to filter the current harmonics. The series or parallel resonance is happen between the system impedance and passive filters. The developments and applications of active filters have been researched because of the increasing concern the power quality at the consumer or distribution side. Active filters overcome the drawbacks of passive filters by using the switching mode power converter to perform the harmonic current elimination. Shunt active filters are developed to suppress the harmonic currents and compensate reactive power simultaneously. The shunt active filters are operated as a current source parallel with the nonlinear load. The power converter of active filter is

controlled to generate a compensation current which is equal-but-opposite to the harmonic and reactive currents generated from the nonlinear load. In this situation, the mains current is sinusoidal and in phase with mains voltage. However, the construction cost of active filters in a practical industry is too high. The power rating (utility voltage and harmonic currents) of power converter in active filters is very large. Theses limit the applications of active filters used in the power system. Hybrid active filter topologies have been developed to solve the problems of harmonic currents and reactive power effectively. Using low cost passive filters in the hybrid active filter, the power rating of active converter is reduced compared with that of pure active filters. Hybrid active filters retain the advantages of active filters and have not the drawbacks of passive and active filters. The hybrid active filters are cost-effective and become more practical in industry applications.

II. PARALLEL HYBRID ACTIVE FILTER SYSTEM IMPLEMENTATION

With a suitable closed-loop control, the active filter is made to inject an identical harmonic current drawn by the load, but in opposite phase. The active filter is implemented by a three phase PWM voltage source inverter (VSI) connected in series with the passive filter branch. The passive filter capacitor supports the fundamental line voltage and enables a small harmonic voltage requirement of the active filter. For six-pulse thyristor rectifier front-ends with inductive load, the lower order fifth and seventh current harmonics predominantly contribute to supply current THD and inevitably require harmonic filtering to meet IEEE 519 harmonic standard. The parallel hybrid active filter topology consists of fifth and seventh L–C tuned passive filter branches with corresponding active filters connected in series. Alternatively, there can be one active filter connected in series with the entire passive filter system such as fifth, seventh harmonic. However, the active filter inverter has to implement by a high frequency PWM inverter.

III. SRF THEORY

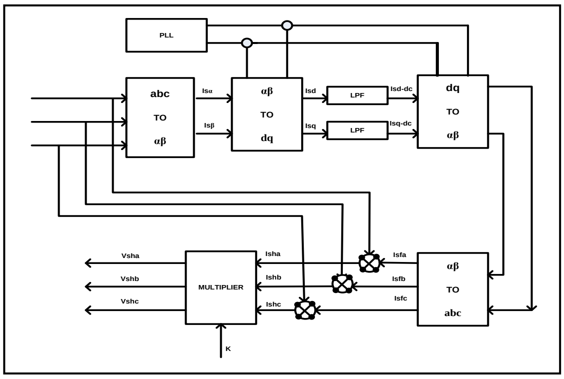

Figure 1. Block diagram of SRF theory

The block diagram for synchronous reference frame theory is mentioned in figure 1.

This conversion can be obtained by dq transformation theory. At the output we obtain two components d and q, one dc component and second oscillatory component respectively. The dc components related to fundamental frequency (d component) and oscillatory component related to harmonic frequency (q component) of the system. This signal is passed through well designed low pass filter so only dc component passed through it and oscillatory components are rejected. Resultant dc is used to get fundamental component by inverse dq transformation. This fundamental component is subtracted from harmonics + fundamental component that is our polluted input signal. It results harmonic component of voltage or current. This signal is used to get control PWM signal for inverter, our active filter. The equations used to derive all this conversation and extraction are mentioned below. Equation (1) and (2) converts abc to αβ parameter where Va, Vb and Vc are input phase voltages. This equation can be implemented by hardware using simple operational amplifier circuit as shown in figure 2.

$$V\alpha = 0.473Va - 0.407Vb - 0.407Vc \quad (1)$$

$$V\beta = 0Va - 0.7Vb + 0.7Vc \quad (2)$$

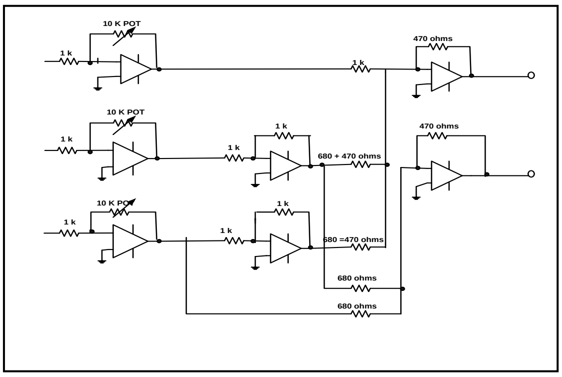

Figure 2. abc to αβ transformation circuit

Equation (3) and (4) are used for conversion from αβ to dq transformation.

$$Vd = \cos\omega t * V\alpha - \sin\omega t * V\beta \quad (3)$$

$$Vq = \sin\omega t * V\alpha + \cos\omega t * V\beta \quad (4)$$

The following equations (5) and (6) are used to find αβ to abc parameter and equations (7), (8), (9) are used to find αβ to abc parameter where Vsf α and Vsf β are related to fundamental components.

$$Vsf\,\alpha = \cos\omega t * Vsdc\,d + \sin\omega t * Vsdc\,q \quad (5)$$

$$Vsf\,\beta = -\sin\omega t * Vsdc\,d + \cos\omega t * Vsdc\,q \quad (6)$$

$$Vfa = 0.471\,Vf\alpha \quad (7)$$

$$Vfb = -0.235\,Vf\alpha - 0.408\,Vf\beta \quad (8)$$

$$Vfc = -0.235\,Vf\alpha + 0.408\,Vf\beta \quad (9)$$

These equations can be implemented using simply rated amplified and addition – subtraction circuit using operational amplifier circuit as shown in figure 3. Figure 4 shows how PWM controlled pulse are generated for active filter related to harmonic components from fundamental plus harmonic (that is out input) to fundamental component (that is output of inverse αβ transformation).

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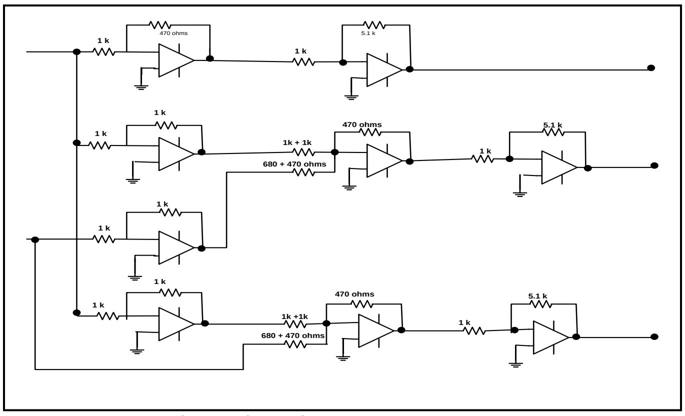

Figure 3. αβ to abc conversion circuit

Figure 3. αβ to abc transformation circuit

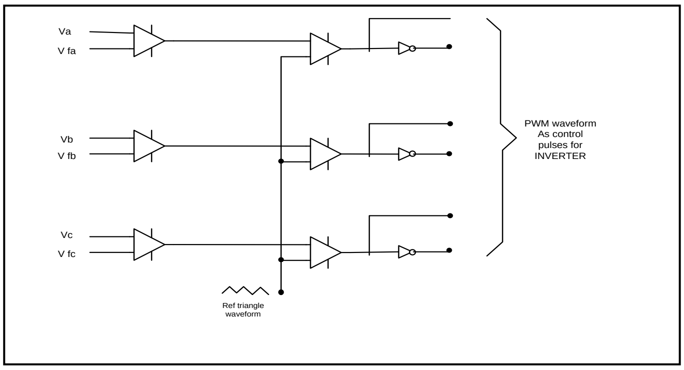

Figure 4. PWM controlled pulse generator for active filter

IV. SIMULATION AND EXPERIMENT RESULT

Digital computer simulation is implemented to confirm the validity and practicability of the proposed hybrid active filter using MATLAB software. The various results for total harmonic distortion without filter, with passive filter only and with hybrid active filter at firing angle of 60˚ are mentioned in figure 5, 6 and 7 respectively. The result are tubulised in tableII which clearly shows that without filter the total harmonics distortion is 30.89%, which is considered very high as per international slandered, is reduced to 4.67% by suitable passive filter and further reduce to 1.39% by hybrid active filter with this design. The result mentioned in table I and table III gives effect in THD with firing angle change and effect in THD with source impedance change respectively.

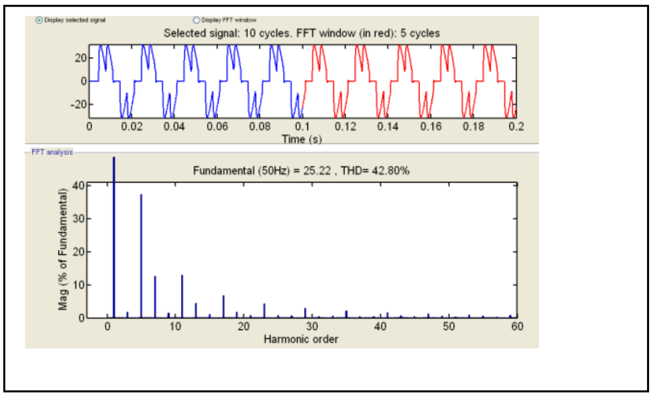

Figure 5. THD measurement for without filter

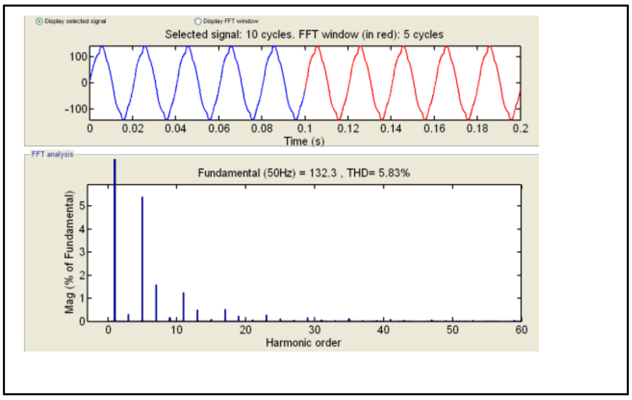

Figure 6. THD measurement with passive filter

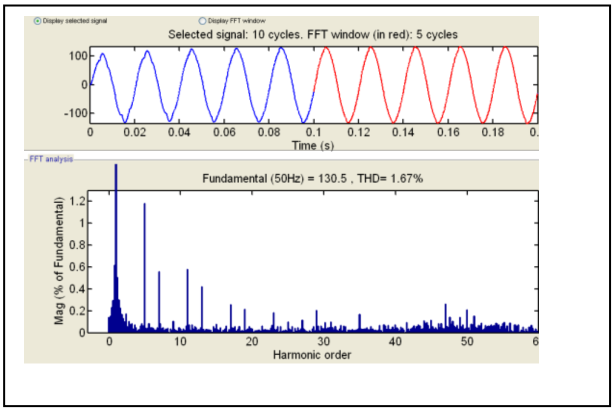

Figure 7. THD measurement with hybrid active filter

TABLE I. result of thd for various firing angle

Firing angle	**THD Vs1(%)**	**THD Is1(%)**	**Magnitude of current harmonic component**		
			Fifth(%)	**Seventh(%)**	**Eleventh(%)**
10°	5.01	2.81	1.21	0.71	0.72
30°	7.71	2.85	1.39	0.71	0.67
45°	7.52	3.03	1.22	0.48	0.59

TABLE II. Result of THD for various case

Case	**Firing angle**	**THD Vs1 (%)**	**THD Is1 (%)**	**Magnitude of current harmonic component**	
				Fifth(%)	**Seventh(%)**
WITHOUT FILTER	60°	4.47	42.18	20.99	12.98
	30°	10.94	30.89	22.57	11.38
WITH PASSIVE FILTER ONLY	60°	3.62	6.11	4.53	2.80
	30°	6.38	5.93	4.67	2.37
WITH HAF	60°	5.01	1.61	1.21	0.71
	30°	7.71	2.85	1.39	0.71

TABLE III. The effect of source impedance in THD

Firing angle	THD Is1 (%)		
	Ls	Ls *0 .1	Ls* 0.01
30˚	2.85	3.87	8.12

V. CONCLUSIONS

The complete study of 6 pulse rectifier is done with RL load. The effect with different firing angle is observed. It creates very high THD without filter compared to demand IS standard. It increases with firing angle increase. The value of THD must be controlled by suitable filter.

A passive filter is designed to reduce the harmonics. It is tuned for fifth harmonic elimination i.e. for 250 Hz. The value obtained for Cf=0.47 µF, Lf= 0.8623 µH and Rf = 2 ohms. With passive filter only the performance of the system is analysed and made a comparison of parameter THD with and without filter. It shows that without filter THD= 25.19 % and with filter THD=1.66 %. The THD increases with increase in firing angle.

Than using SRF technique, complete simulation is done for hybrid active filter which shows the parameter THD further reduced to 1.44 %. The effect of change in source impedance is also observed. It gives batter result for good range of source impedance compared to without filter. The results are tabulated in table I, II and III.

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