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COMPARISON OF VARIOUS TOPOLOGIES OF SHUNT ACTIVE POWER FILTER APPLIED TO FOUR-WIRE SYSTEM

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Abstract:

This paper presents a complete comparative study about the six most common configurations of shunt active power filter applied to four-wire distribution systems**.** Now-a-days use of non-linear loads in industries has been increased tremendously which are the source of harmonic currents to by injected in supply system. These harmonics cause a problem with power quality. Active filtering of electric power has now become a mature technology for harmonic current compensation in four-wire system. In this paper P-Q theory is used which is widely used control algorithm of shunt active power filter. Modeling of this technique is implemented in MATLAB/Simulink.

Index Terms: Shunt Active Power Filter (SAPF), P-Q Theory, MATLAB/Simulink, Current Harmonic Compensation.

1. Introduction:

In recent years, many harmonic disturbances in power lines have occurred, mostly as a result of nonlinear loads such as electrical machines, static power converters, rectifiers, computer power systems, power electronics loads, variable-speed drives, etc. Now-a-days the usage of power electronic devices for human comfort has also expanded significantly. Although these powerful electronic devices make our lives easier, they add a lot of harmonic current to the power supply system and its impact on power factor [1].

Three-phase AC mains with a neutral conductor can supply a large number of single-phase loads. They create excessive neutral current, harmonics, reactive power, and unbalanced currents, resulting in neutral conductor overheating and equipment damage. Unbalance between single-phase loads and single-phase non-linear loads causes neutral current [2]. The equipment which carries a non-linear load gives a lot of problem in the system quality. The power quality is mainly important factor of the system which carries the power factor, efficiency, stability, sustainability, noise etc [3]. The presence of harmonics in the power lines results in greater power losses in distribution, interference problems in communication systems and, sometimes, in operation failures of electronic equipment, which are more and more sensitive since they include microelectronic control systems, which work with very low energy levels.

Current harmonics and unbalances may cause large amount of financial loss in distribution systems. Total harmonic distortion (THD) is taken in to the consideration to measure harmonics. This gives the difference between a periodic waveform containing harmonics waves and pure sine wave[4]. Generally, the injected harmonic currents deteriorate power quality by increasing total harmonic distortion (THD) of a power system [5]. Four-wire SAPF (shunt active power filter) has been utilized in four-wire distribution systems to alleviate these issues [4].

In this proposed work, we design the control system for shunt active power filter to ensure sinusoidal currents at grid side, with total compensation of reactive and harmonic contents. The topologies are evaluated under two load conditions. They will analyze by source current compensation. From this analysis, it is possible to choose of better topology depends on the type of load to be compensated.

2. Control System:

Instantaneous reactive power theory is also known as P-Q theory or α-β theory. This theory is based on a set of instantaneous power defined in time-domain control algorithm. This theory first converts voltages and currents from the *abc to αβ0* coordinates, and then defines instantaneous powers on these coordinates. By using instantaneous powers and *αβ* voltages reference current in *αβ* coordinates generated. Then by using reverse Clark's transformation reference current in *abc* coordinates generated. The P-Q theory uses *αβ0* transformation, also known as Clark's transformation. Fig. 1 shows Control Algorithm of SAPF using Instantaneous reactive power theory.

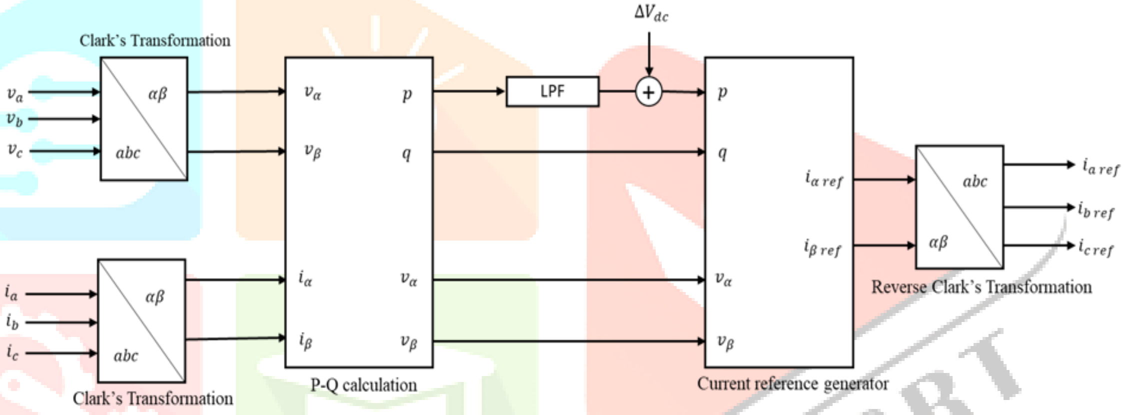


Fig. 1 Block diagram of control algorithm of SAPF

3. Topologies of Shunt Active Power Filter:

Different topologies based on SAPF performing in four-wire systems have been studied in the literature. Fig. 2 shows the circuit diagram of 3Leg-3Inductor shunt active power filter applied to four wire system. Same values of series inductance (L_f) is connected to each phase of VSC based shunt active power filter and capacitor mid-point is connected to neutral wire. The 3legs contains two pairs of IGBT with anti-parallel diodes T_i (i = 1 to 6). Split capacitors are employed in this topology. The neutral return path of the split capacitor will be used, and the whole neutral current will flow from the DC bus capacitor.

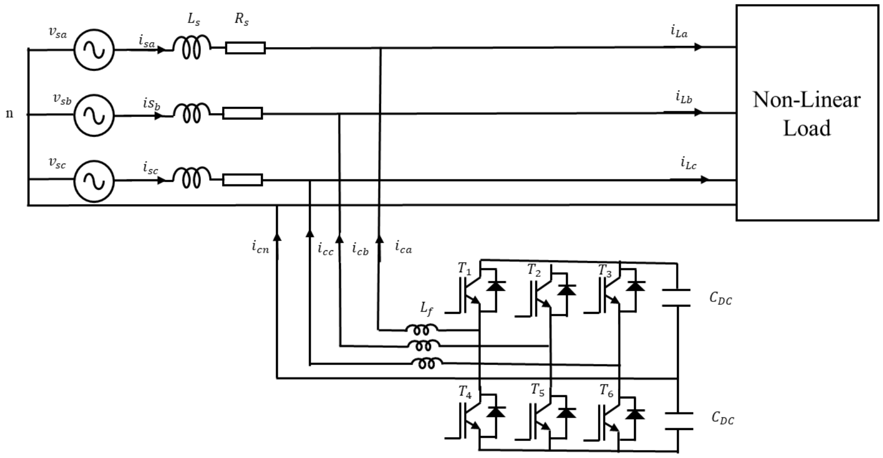


Fig. 2 Circuit diagram of 3Leg-3Inductor SAPF applied to 4-wire system

Fig. 3 shows the circuit diagram of 3Leg-4Inductor shunt active power filter applied to four wire system. This architecture differs from the 3Leg-3Inductor topology in that an extra inductor is connected between the split capacitor's mid-point and the neutral wire.

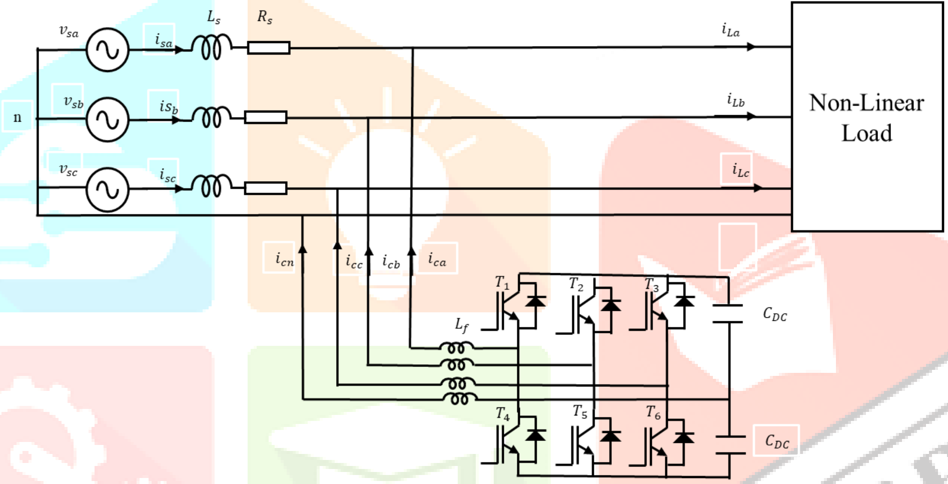


Fig. 3 Circuit diagram of 3Leg-4Inductor SAPF applied to 4-wire system

Fig. 4 shows the circuit diagram of 4Leg-3Inductor shunt active power filter applied to four wire system. Same values of series inductance (L_f) is connected to each phase of VSC based shunt active power filter and 4th leg is connected to neutral wire. The 4legs contains two pairs of IGBT with anti-parallel diodes T_i (i = 1 to 8). This inverter is fed by the DC capacitors.

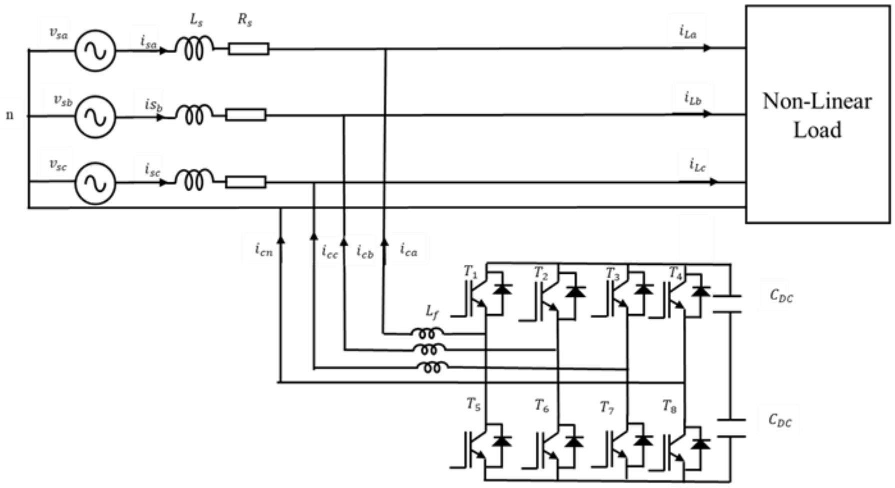


Fig. 4 Circuit diagram of 4Leg-3Inductor SAPF applied to 4-wire system

Circuit diagram of 4Leg-4Inductor shunt active power filter applied to four wire system shown in fig. 5. This architecture differs from the 4Leg-3Inductor topology in that an extra inductor is connected between the 4th leg and the neutral wire.

Fig. 6 shows the circuit diagram of 3Leg voltage source converter based DSTATCOM applied to four wire system. This architecture same as the 3Leg-3Inductor topology. In this A RC filter is connected to the system in parallel with the load and the compensator to reduce the switching ripples in the PCC voltage injected by the fast switching of DSTATCOM.

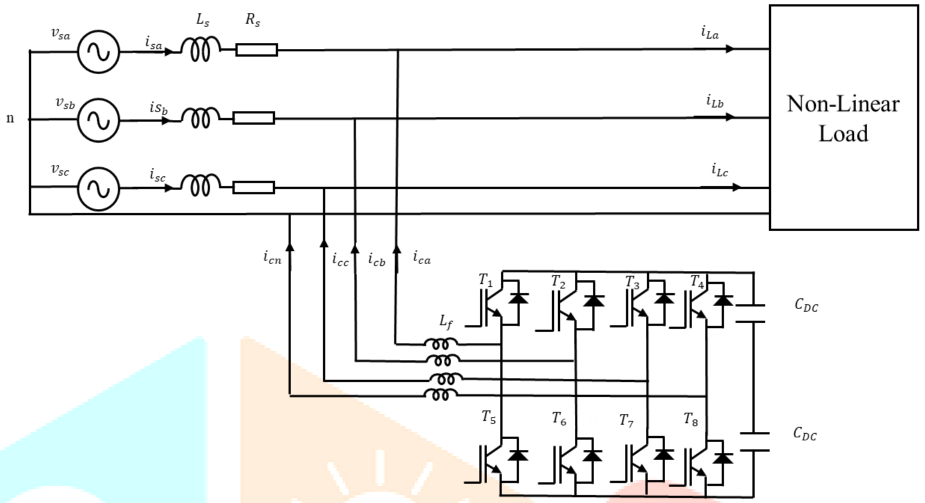


Fig. 5 Circuit diagram of 4Leg-4Inductor SAPF applied to 4-wire system

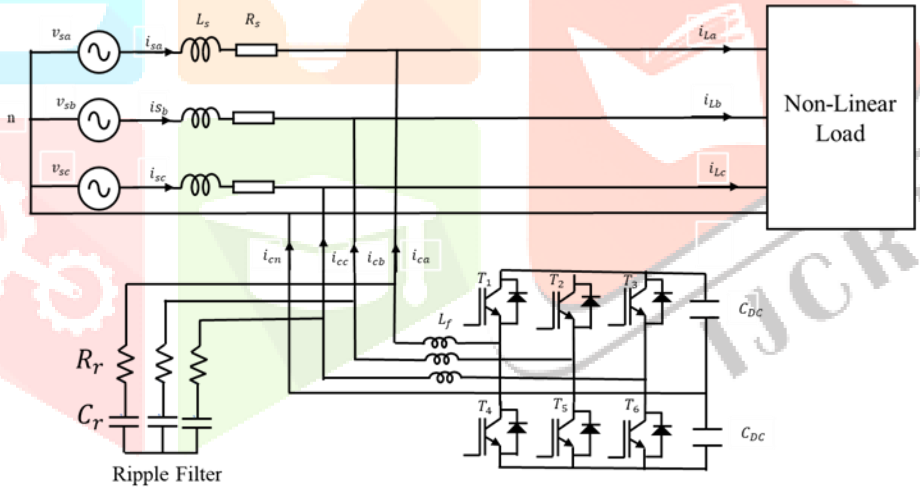


Fig. 6 Circuit diagram of 3Leg DSTATCOM applied to 4-wire system

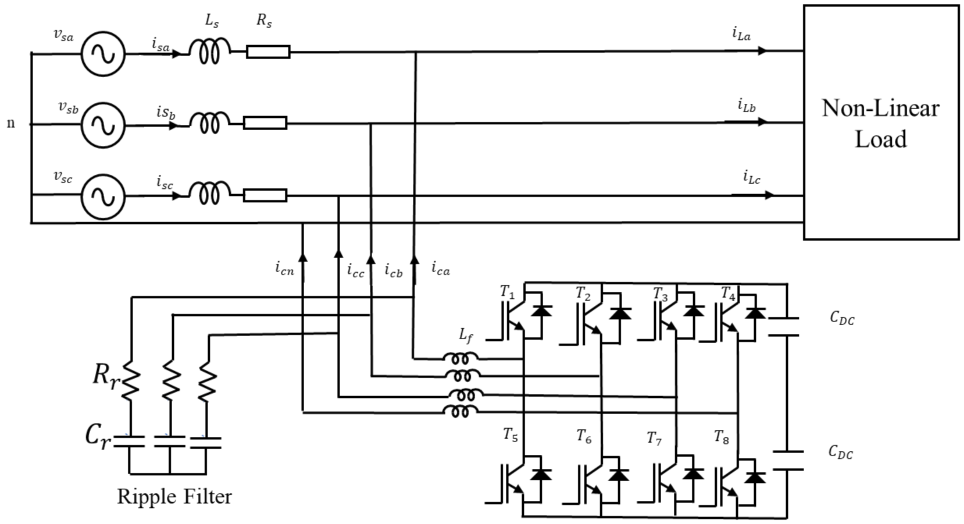


Fig. 7 Circuit diagram of 4Leg DSTATCOM applied to 4-wire system

Fig. 7 shows the circuit diagram of 4Leg voltage source converter based DSTATCOM applied to four wire system. This architecture same as the 4Leg-4Inductor topology. In this A RC filter is connected to the system in parallel with the load and the compensator to reduce the switching ripples in the PCC voltage injected by the fast switching of DSTATCOM.

4. Results:

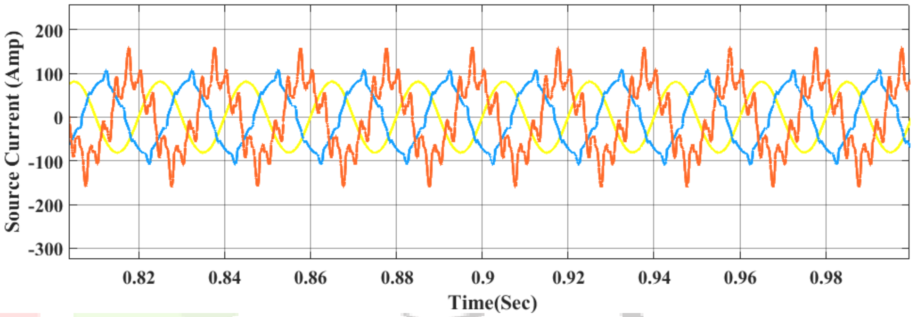


Fig. 8 Source Current of 3Leg-3Inductor SAPF

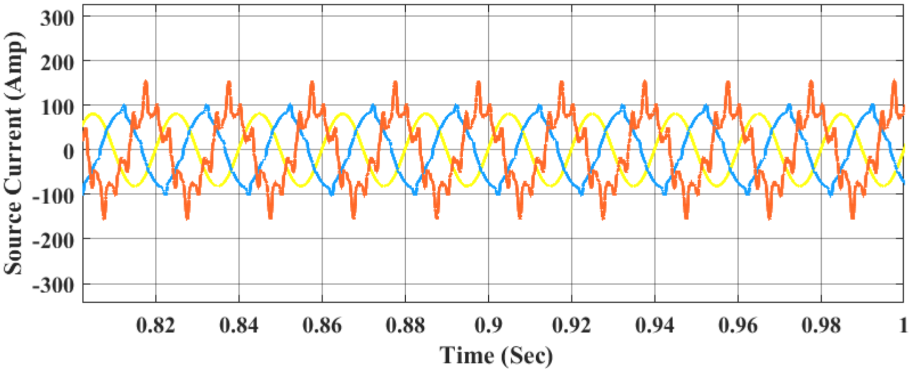


Fig. 9 Source Current of 3Leg-4Inductor SAPF

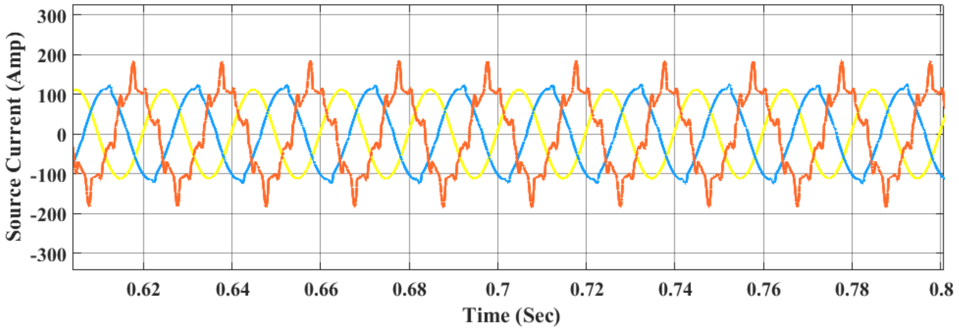


Fig. 10 Source Current of 3Leg DSTATCOM

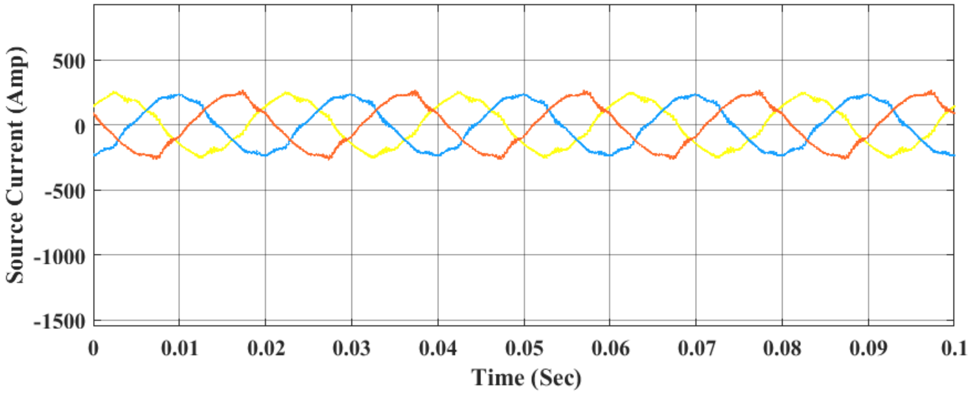


Fig. 11 Source Current of 4Leg-3Inductor SAPF

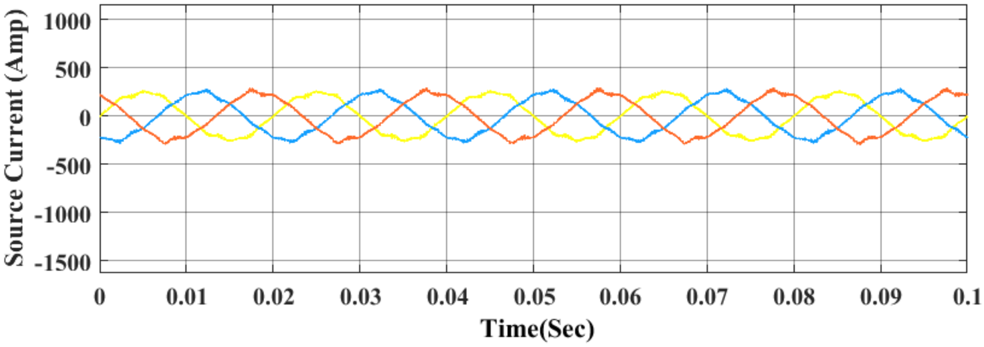


Fig. 12 Source Current of 4Leg-4Inductor SAPF

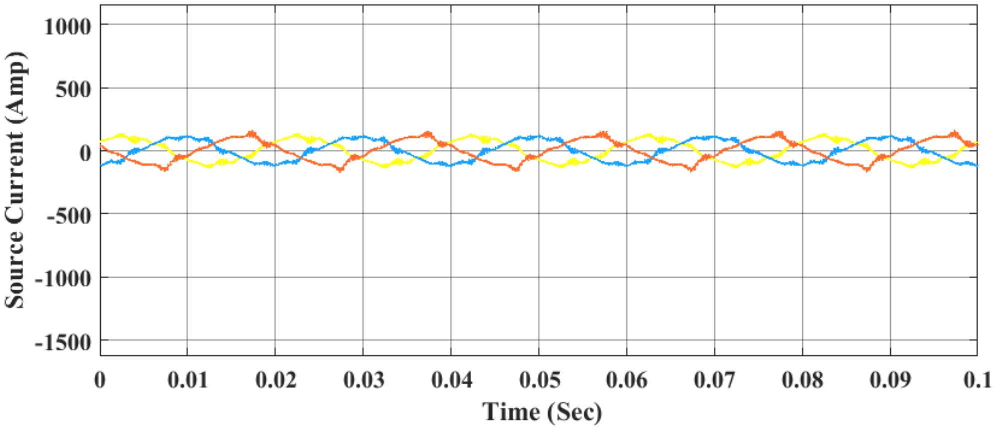
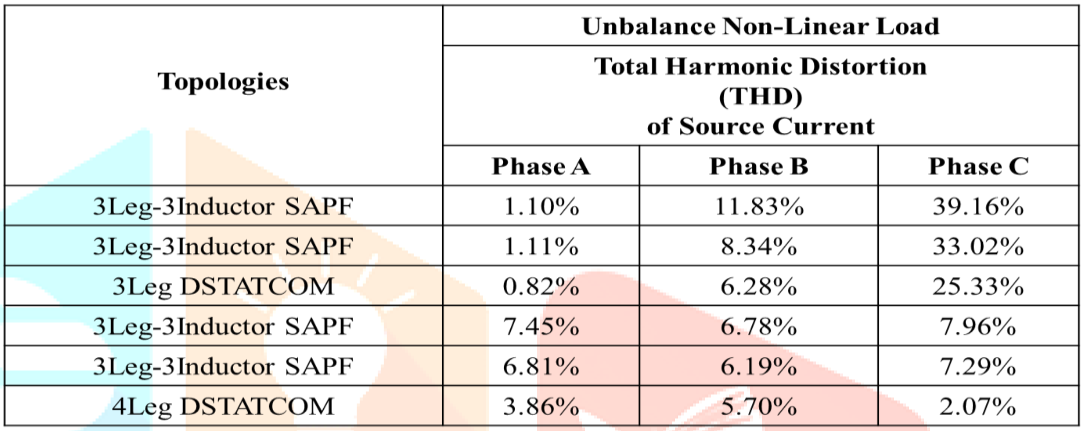


Fig. 13 Source Current of 4Leg DSTATCOM

Table No.1 THD of Source Current without Compensation

Unbalance Non-Linear Load		
Total Harmonic Distortion (THD) of Source Current		
Phase A	**Phase B**	**Phase C**
98.44%	**129.17%**	**130.73%**

Table No.2 THD of Source Current with Compensation



Topologies	Unbalance Non-Linear Load		
	Total Harmonic Distortion (THD) of Source Current		
	Phase A	Phase B	Phase C
3Leg-3Inductor SAPF	1.10%	11.83%	39.16%
3Leg-3Inductor SAPF	1.11%	8.34%	33.02%
3Leg DSTATCOM	0.82%	6.28%	25.33%
3Leg-3Inductor SAPF	7.45%	6.78%	7.96%
3Leg-3Inductor SAPF	6.81%	6.19%	7.29%
4Leg DSTATCOM	3.86%	5.70%	2.07%

Conclusion:

The six topologies-based shunt active power filter applied to four-wire systems have been studied in this paper. These topologies were analyzed in terms of source current compensation. From analysis, it is possible to conclude that the choice of better topology depends on the load to be compensated. As the number of inductors increased the THD of source current get reduced.

The topology 4Leg DSTATCOM is the most efficient topology among all studied structures, mainly due to lowest THD of source current. Table no.1 shows the value of total harmonic distortion of source current without compensation. Table no. 2 shows the values of total harmonic distortion of source current with compensation of all the topologies. THD of phase A is 98.44%, phase B is 129.17% and phase C is 130.17% for the without compensation system. This THD is reduced up to for phase A is 3.86%, phase B is 5.70% and phase C is 2.07% with 4Leg DSTATCOM topology. In this way, it is possible to make the right decision about which topology should be chosen for any industrial plant.

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