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Control strategy for hybrid power filter to compensate unbalanced and non-linear, three-phase loads

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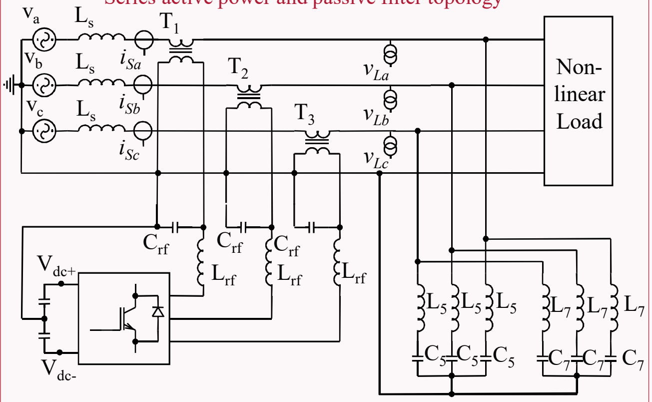
ABSTRACT. A control algorithm is proposed for a three-phase hybrid power filter constituted by a series active filter and a shunt passive filter. The control strategy is based on the dual formulation of the vectorial theory of electrical power, so that the voltage waveform injected by the active filter is able to compensate the reactive power, to eliminate harmonics of the load current and to balance asymmetrical loads. An experimental prototype was developed and experimental results presented.

Experimental Prototype

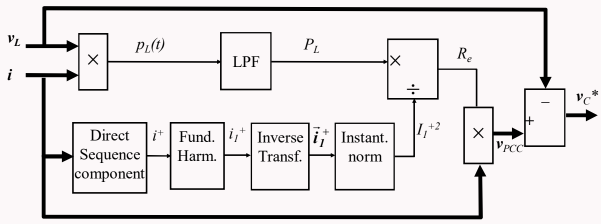
Series active power and passive filter topology



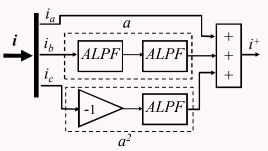
Control strategy

$$\text{Resistive behavior} \Rightarrow \boldsymbol{v}_{PCC} = R_e\, \boldsymbol{i} = \frac{P_L}{I_1^{+2}}\, \boldsymbol{i} \quad \Rightarrow \quad \boldsymbol{v}_C^* = \frac{P_L}{I_1^{+2}}\, \boldsymbol{i} - \boldsymbol{v}_L$$

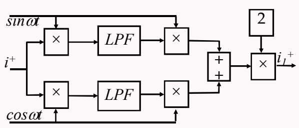
Reference voltage calculation



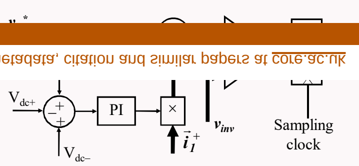
Direct sequence component calculation



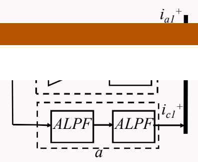
Fundamental component calculation



Control DC-link and PWM generator scheme

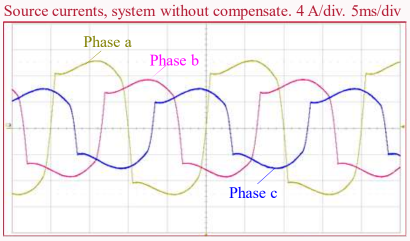


Fortescue inverse transformation

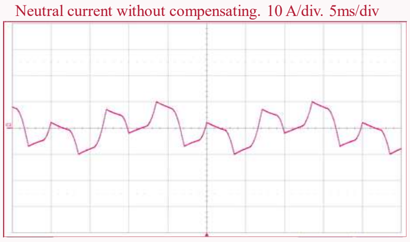


Experimental Results

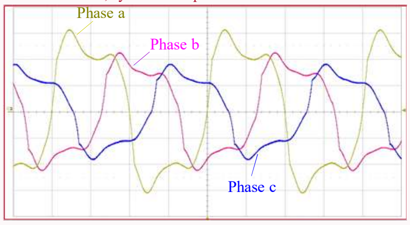
Source currents, system without compensate. 4 A/div. 5ms/div



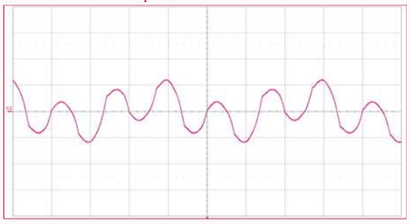
Neutral current without compensating. 10 A/div. 5ms/div



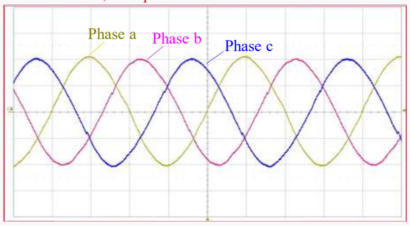
Source currents, system with passive filter. 4 A/div. 5ms/div



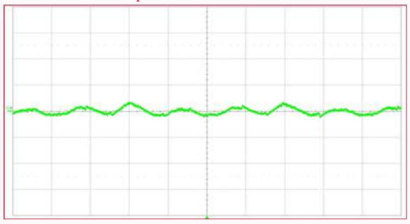
Neutral current with passive filter. 10 A/div. 5ms/div



Source currents, with passive and active filter. 4 A/div. 5ms/div



Neutral current with passive and active filter. 4 A/div. 5ms/div



Measured value before and after the compensation

			THD(%)	RMS	Fund.	H3	H5	H7	H9	P(kW)	Q(kvar)	S(kVA)	PF
Without compensation	Phase a	V	12.4	96	95.8	6.7	5.8	4.8	3.8	0.76	0.23 (ind)	0.79	0.91
		I	28.5	8.7	8.3	2	1.1	0.6	0.4				
	Phase b	V	9.1	97.1	96.7	4.4	3.9	3.6	3.1	0.54	0.17 (ind)	0.57	0.91
		I	27.6	6.1	5.9	1.3	0.7	0.5	0.3				
	Phase c	V	7.2	98.2	97.9	3.1	3.0	2.7	2.5	0.45	0.13 (ind)	0.47	0.92
		I	25.9	5.0	4.8	1.0	0.6	0.4	0.3				
	Neutral	I		5.4	3.3	4.1	0.5	0.4	0.9	-	-	-	-
With passive filter	Phase a	V	11.3	97.8	97.1	9.4	3.3	1.2	2.3	0.79	0.05 (ind)	0.79	0.93
		I	34.9	8.6	8.2	2.8	0.6	0.2	0.2				
	Phase b	V	7.6	98.9	98.6	6.1	2	0.6	1.6	0.57	0.02 (cap)	0.57	0.94
		I	32.4	6.1	5.8	1.8	0.4	0.1	0.2				
	Phase c	V	5.6	100	99.8	4.2	1.3	0.5	1.3	0.47	0.07 (cap)	0.78	0.94
		I	28.9	5.0	4.8	1.3	0.2	0.1	0.1				
	Neutral	I	[illegible]	[illegible]	[illegible]	[illegible]	0.3	0.1	0.5	-	-	-	-
With active and passive filter	Phase a	V	[illegible]	[illegible]	[illegible]	[illegible]	0.2	0.1	0.1	0.56	0.01	0.56	1
		I	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0				
	Phase b	V	1.0	98.5	98.4	0.5	0.1	0.2	0.1	0.54	0.01	0.54	1
		I	2.6	5.5	5.5	0.1	0.0	0.0	0.0				
	Phase c	V	1.2	98.8	98.8	0.5	0.1	0.1	0.2	0.56	0.01	0.56	1
		I	2.9	5.7	5.7	0.1	0.0	0.0	0.0				
	Neutral	I		0.5	0.3	0.4	0.0	0.0	0.0	-	-	-	-

CONCLUSIONS. A control algorithm for a hybrid power filter constituted by a series active filter and a passive filter connected in parallel with the load is proposed. The control strategy is based on the dual vectorial theory of electric power. The new control approach achieves the following targets:

- The compensation characteristics of the hybrid compensator do not depend on the system impedance.
- The hybrid filter and load set are resistive behavior. This fact eliminates the risk of overload due to the current harmonics of non-linear loads close to the compensated system.
- This compensator can be applied to loads with random power variation as it is not affected by changes in the tuning frequency of the passive filter. Furthermore, the reactive power variation is compensated by the active filter.
- Series and/or parallel resonances with the rest of the system are avoided because compensation equipment and load are resistive behavior.
- The active filter improves the harmonic compensation features of the passive filter and compensates the reactive power, achieving unit power factor.
- The proposed control algorithm allows balancing asymmetrical loads.

Experimental results are presented. This allows the verification of the developed theoretical analysis

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