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Control of Series Active Power Filter by State Feedback

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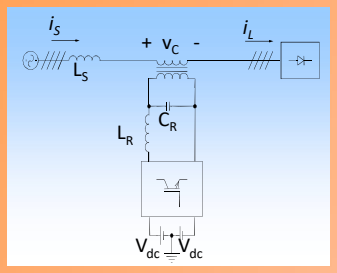
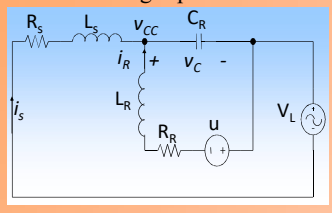
ABSTRACT: The active power filters in series connection or series APF, are static compensation systems based on an electronic converter PWM (Pulse Width Modulation). The systematic use of series APFs in the power systems allows the elimination of the harmonics caused by specific loads named voltage source harmonic loads. To obtain this compensation objective, several strategies have been proposed up now. Nevertheless, each strategy development has been based on the equivalent electrical circuit and on the results obtained in simulation and/or experimental tests. Generally, the control structure formal analysis is not carried out. In this work, the whole system state model has been obtained. Besides, the system behavior has been analyzed from the state equations for each compensation strategy. As a consequence, the analysis has allowed the establishment of design rules respect to the resultant control strategy. Finally, a practical case is presented, whose results illustrate the proposed method.

Connection diagram of a series active filter

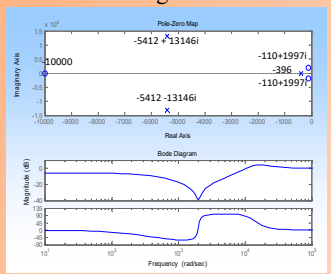


Circuit single-phase model

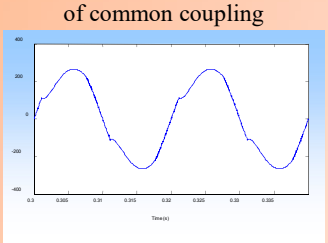


Without series filter

Poles and zeros map and Bode diagram



Voltage waveform in the point of common coupling

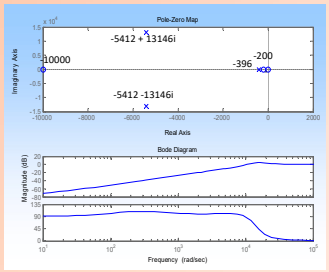


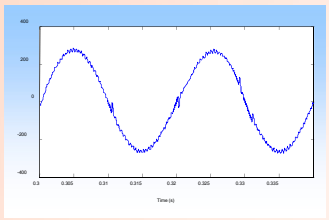
THD=10,7%

Control strategies

1. Detection of the load voltage

$$v_{CH} = -k_v\, v_{LH}$$
$$\dot{\mathbf{x}} = \mathbf{A}\,\mathbf{x} + \left(\mathbf{B}_2 - \mathbf{B}_1\right)\mathbf{v}_L$$

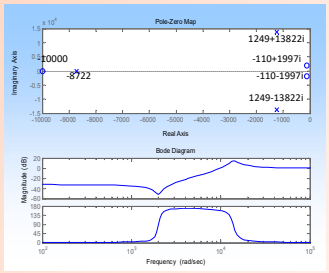


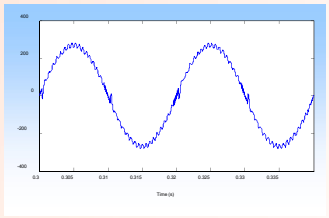


THD=3,83%

2. Detection of the source current

$$v_{CH} = k\, i_{SH}$$
$$\dot{\mathbf{x}} = \left(\mathbf{A} + \mathbf{B}_1\,\mathbf{K}\right)\mathbf{x} + \mathbf{B}_2\,\mathbf{v}_L$$

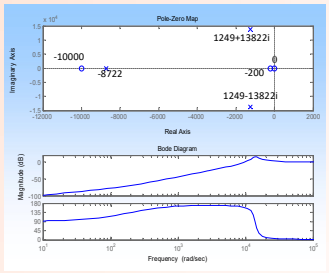


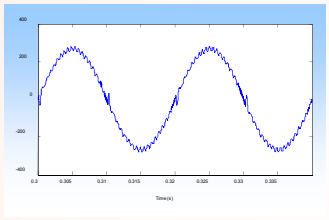


THD=1,82%

3. Hybrid strategy

$$v_{CH} = k\, i_{SH} - k_v\, v_{LH}$$
$$\dot{\mathbf{x}} = \left(\mathbf{A} + \mathbf{B}_1\,\mathbf{K}\right)\mathbf{x} + \left(\mathbf{B}_2 - \mathbf{B}_1\right)\mathbf{v}_L$$





THD=1,67%

Poles and zeros map and Bode diagram

Voltage waveform in the point of common coupling

CONCLUSIONS. The harmonics generated by the non-linear loads named voltage-source type of harmonic sources can be compensated by series active power filter. However, their operation characteristics depend decisively on the type of compensation approach adopted to generate the compensation voltage references. In this paper, three compensation strategies have been initially analyzed, from the point of view of the equivalent electrical circuit: the detection of the voltage load, the detection of the source current and a hybrid control.
The electrical analysis demonstrated the superiority of the hybrid control approach with respect to the two previous strategies. Nevertheless, this type of approach does not allow the knowledge of the system stability and it does not establish any criterion for the election of the design parameters. Here, the state model of a compensated system has been found by means of a series active filter. From it, the three types of compensation strategies have been analyzed. In the state space, the terms of the hybrid control have been analyzed. Then, the system dynamic behavior and the design parameters election have been studied. Finally, the results of a practical case have allowed the verification of the proposed scheme validity.