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Modeling and Simulation of Grid Current Controller for Grid Connected Distributed System under Nonlinear Loads

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ABSTRACT:

This paper deals with reactive power compensation and harmonics elimination in medium-voltage industrial networks using a hybrid active power filter. It proposes a hybrid filter as a combination of a three-phase, two-level, voltage-source converter connected in parallel with the inductor of a shunt, single-tuned, passive filter. This topological structure greatly decreases the voltage and current stress over the elements of the active filter. Since the topology is composed of a single-tuned branch, the control algorithm also has to ensure sufficient filtering at other harmonic frequencies. We propose using a proportional-resonant, multi loop controller. Since the controller is implemented in a synchronous-reference frame, it allows us to use half the number of resonators, compared with the solution using proportional-integral controllers in the harmonic-reference frame. Theoretical analyses and simulation results obtained from an actual industrial network model in PSCAD verify the viability and effectiveness of the proposed hybrid filter. In addition, the simulation results are validated by a comparison with the results obtained from a real-time digital simulator.

Index Terms:

Harmonic distortion, hybrid filters, proportional resonant controller, reactive power.

INTRODUCTION:

NONLINEAR loads, which, these days, form a large portion of the overall electrical load, are known to be a major source of current harmonics in the electrical system. In addition, most of these loads impose varying reactive-power demands that have to be compensated in order to improve the power factor (PF) and efficiently deliver the active power to the loads. This results in harmonic distortion-related problems, reducing the quality of the electrical power and the performance of the power system. The operation of these devices may, therefore, prove to be very problematic. Traditional solutions to reduce the harmonic current flows into the supply system and to improve the power factor at the customer utility point of common coupling (PCC) involve the placement of resonant-tuned passive filters at the PCC of the load. These filters represent a well established technology; however, in addition to their fundamental task of providing reactive power compensation and harmonics filtering, they may cause unwanted resonance conditions. Their other limitation is an inability to adapt to the changing conditions in the network and their size.

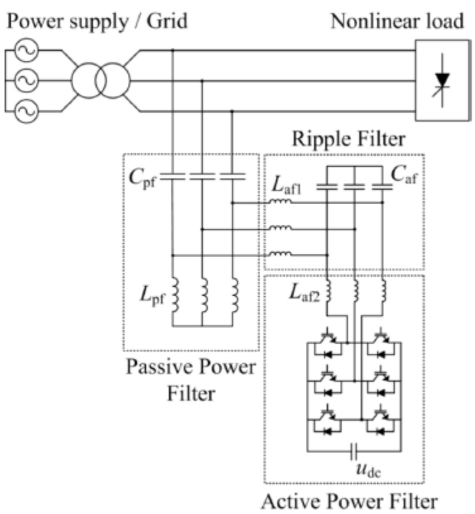

Fig. 1. Scheme of the proposed shunt-connected HAPF.

Existing System:

Fig. 1 shows the proposed circuit configuration. In this system, a nonlinear load is supplied by a balanced voltage source and compensated by the proposed HAPF. A ripple filter is used to reduce the high-frequency harmonic currents injected into the network. In Fig. 2, a simplified, equivalent circuit of the proposed topological structure is shown. The symbols used are as follows: supply voltage, and are the supply-system resistance and inductance (short-circuit impedance and transformer impedance connected in series), and are the load resistance and inductance, is the passive filter capacitance, and are the passive filter resistance and inductance, and are the ripple filter inductances and capacitance. The active part of the HAPF is presented with an ideal voltage source, while the nonlinear load is considered to be a current source .

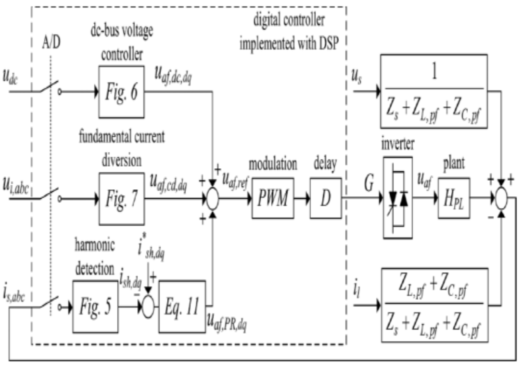

Fig. 4. Control block diagram of the HAPF.

Proposed System:

Proportional-resonant (PR) controllers are equivalent to conventional PI controllers implemented in the reference frame, separately for the positive and negative sequences. Therefore, the PR controller is capable of simultaneously tracking the reference for the positive and negative sequence with zero steady state error. For example, a sixth harmonic PR compensator is effective for the fifth and seventh harmonics of both sequences; hence, four harmonics are filtered with one PR filter implemented in the SRF.

Control Algorithm

voltage control and the fundamental current diversion controller . The PR controller is closed with the measured and filtered values from the actual system. Since the objective is to eliminate the harmonics from the supply current, this current represents the PR controller input. At first, the fundamental frequency component has to be extracted from the measured current. This is done by using first order, high-pass filters in the fundamental frequency and synchronous reference frame with a cutoff frequency of 20 Hz. Fundamental angular frequency is obtained using a conventional qPLL system.

NETWORK UNDER STUDY:

filter is upgraded with the active part. As will be To illustrate some practical implications of the proposed PR controlled HAPF and to evaluate its filtering performance, the operation is demonstrated on a real industrial network model. A simplified scheme of the modelled system is shown in Fig. 10. This system was chosen because it represents a typical example of an industrial network with a poorly designed passive compensator, producing unwanted resonant amplifications of the current harmonics. Since the proposed HAPF topology enables retrofitting applications, the existing reactive power shown, the active part damps the resonances and ensures sufficient filtering of the characteristic harmonics.

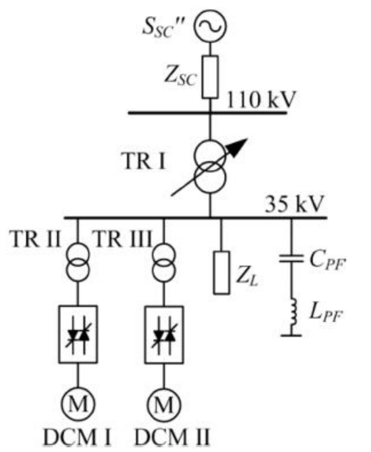

Fig. 10. Simplified single-line diagram of a real industrial network.

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HYBRID FILTER PERFORMANCE EVALUATION:

The HAPF filtering characteristic is analyzed using The steady and transient state performances are demonstrated in PSCAD software.

Filtering Performance Analysis:

Fig. 12 shows the relationship between the and for different values of land. When 0, the HAPF behaves as a pure passive filter tuned to 314 Hz. It creates a parallel resonance point very close to the 5th harmonic component with the ratio reaching high values of more than 5 dB. This may result in overheating and a shorter lifespan for certain equipment (transformers, cables, filters), the occurrence of noise and vibrations (motors, generators), the incorrect operation of certain devices (computers, printers), and equipment Out ages or destruction. In the past few years, several cases were reported by this particular customer, related to the problem of harmonic resonance.

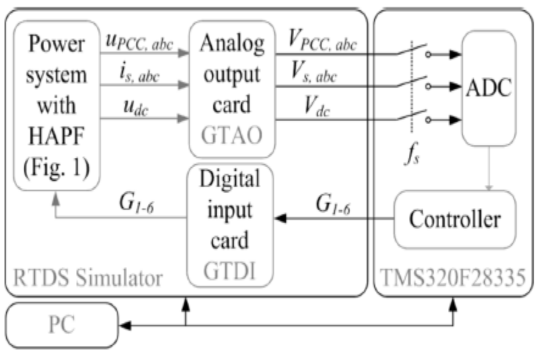

Fig. 18. Schematic overview of the testing setup.

digital simulator (RTDS), which is one of the simulators that makes real-time calculation of power-system electromagnetic phenomena possible. The achieved calculation time steps are about 50 s for the modelling of power-electronics elements such as IGBT converters, even as low as 1.5 s. Special hardware also makes it possible for the importing and exporting of signals to external devices, which is a basis for the closed-loop testing of external equipment (e.g., DSP) with a power system model. In this way, the RTDS user has the possibility to analyze the external device itself as well as its impact on the rest of the modelled system. Therefore, we can consider the model within the RTDS simulator to be a replacement of a real system.

Steady-State Performance Evaluation

Fig. 19 shows the RTDS results of the HAPF operation under the same conditions as Fig. 14. As can be seen, the system current and the PCC voltage waveforms are nearly sinusoidal. The supply current has the THD reduced to 2.01%, while the PCC voltage THD is only 1%. The harmonic content of the and in terms of the percentage of the fundamental component .

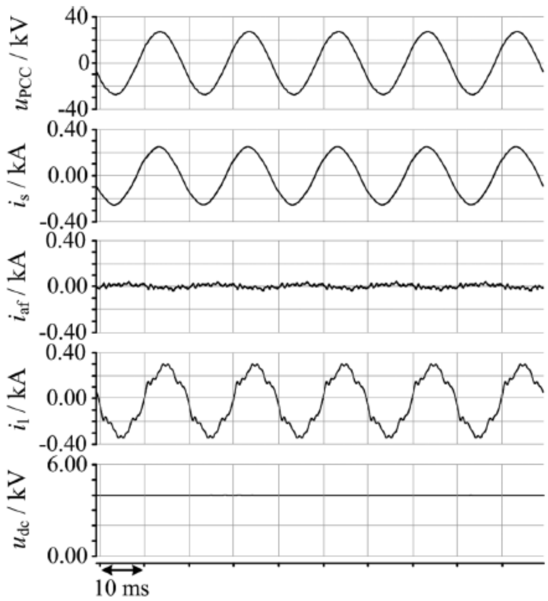

Fig. 19. RTDS waveforms in the steady state—HAPF.

Transient State Performance Evaluation

Fig. 20 shows simulated waveforms of the hybrid filter for a step load change from 50% to 100%. The supply current is distorted for less than three fundamental cycles and after that, the benefits of the HAPF are clearly seen. The load change does not produce any other unwanted effect. A comparison of the results in Figs. 14–17 and Figs. 19 and 20 shows very good matching, which validates the simulation results obtained with PSCAD software.

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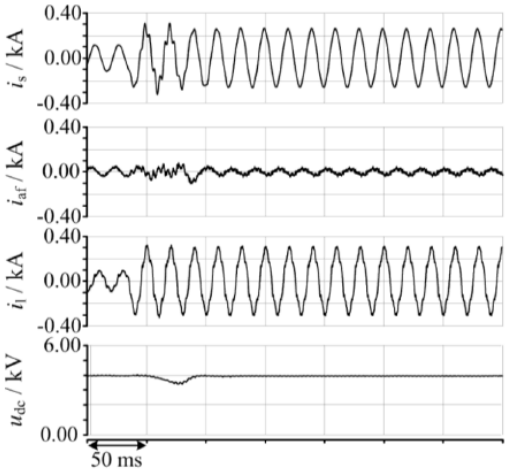

Fig. 20. RTDS waveforms in the transient state—50% step load increase.

CONCLUSION:

In this paper, a hybrid active power filter for reactive power compensation and harmonics filtering has been presented. It is composed of a small-rating VSC connected in parallel with the inductor of a shunt single-tuned passive filter. Since the rated power of the active filter is relatively low, the HAPF represents a viable solution for reactive power compensation and harmonic filtering. A PR current control scheme for selective harmonics compensation with the HAPF has been proposed. As shown, each controller acts as a resonant filter tuned to a certain harmonic frequency. The proper selection of the parameters ensures high selectivity and improves the transient performance of the HAPF. Another key feature is that each pair of harmonics , is filtered by one controller and, thus, important savings in terms of computational burden are achieved.

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