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ACTIVE POWER FILTERS IN ORDER TO LIMIT THE HARMONIC DISTURBANCE FROM ELECTRICAL NETWORKS

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Abstract: This paper addresses a high-current field of research, under the conditions of proliferation of nonlinear loads - generally static converters with power semiconductors - generating current harmonics. A series of simulations of the voltage and current harmonics compensation system are made and control and adjustment methods are proposed. A nonlinear consumer simulation model was created with the Matlab-Simulink software package. The simulation results are analyzed to determine the compensation issues that the active filter will have to solve.

Key words*:* Nonlinear loads, harmonics, power converters, active filters, parallel filters, series filters.

1. INTRODUCTION

Active filters are static power converters that can perform various functions. Current filter schemes allow the synthesis of any current form with relatively high harmonic components [1].

The consumer may choose one of the following solutions:

- waives the equipment that absorb the current distorted and invests in new equipment,
- maintain the equipment and invest in tools for limiting issuance in the form of disruptive harmonics: passive or active filters.

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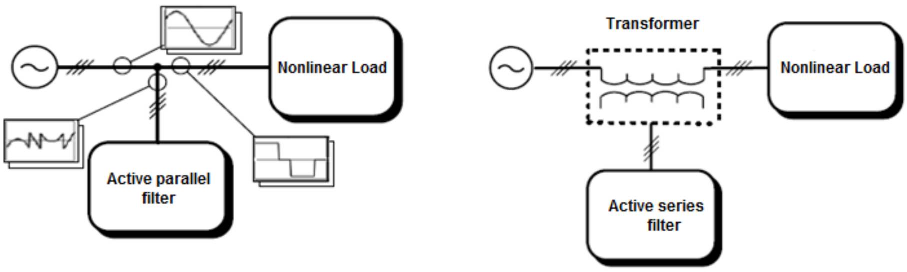
2. CONNECTION MODE AND TOPOLOGY OF ACTIVE FILTERS

Harmonic filters are available to the user or to the electricity supplier. Filters from energy suppliers are of great powers and in most cases it is passive filters. Users can place filters:

- common connection points (CCP), which takes a global information;
- at the point of connection of a consumer important, current harmonics generator.

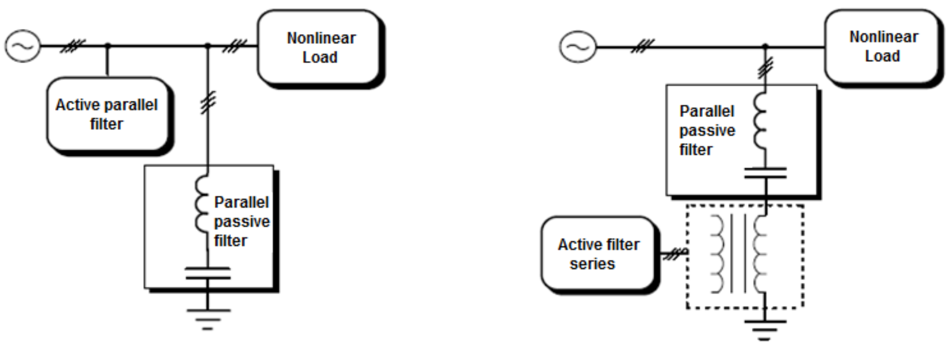
Power circuit can be connected in two ways: in parallel or in series. Parallel structure (fig. 1.a) is the most widespread. Active filter compensates current harmonics content, which would have been injected into the supply network in the absence of such compensation [2], [5]. Such filters are implemented with voltage inverters in the current.



a) b)

Fig.1 Active filter connected in parallel (a) and in series (b)

Active filter fig.1.b is connected in series with the load through a nonlinear transform. The strategy of the command filter series aims to produce such a voltage transformer, the mayor who ensures a pure sine wave voltage at the terminals. Such filters are implemented with voltage inverters without current loop [3], [8]. The main disadvantage is that the series of filters should drive the entire current task.



a) b)

Fig.2. Combinations of filters a) Active parallel filter – parallel passive filter; b) Active filter series – parallel passive filter

Special interest presents the combination of parallel active filter and passive filter. From passive filter fig. 2.a shall be designed so as to largely eliminate low harmonics - e.g. 5, 7, 11, 13 - who is important, and the active filter is sized for a lower rated current.

Active filter fig. 2.b shall be installed in series with the battery of capacitors to compensate reactive power or with a passive filter. Active filter topology is voltage inverter with the command in the current directory[4],[7].

3. SIMULATION OF ACTIVE POWER FILTERS

3.1. Nonlinear Simulink model of the consumer

To study the harmonic content of the nonlinear consumer to be compensated, a model of the thyristor rectifier was developed using the Matlab-Simulink software package and modules from the PowerSys auxiliary tool kit [6]. The rectifier (Fig. 3.) consists of a three-phase tri-phase bridge, a pulse generator and a current regulator. On each thyristor two pulses are applied at 60 degrees.

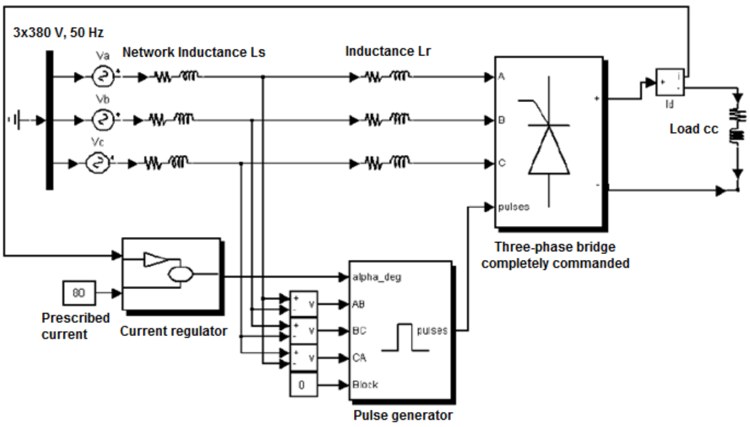


Fig. 3. Simulink model of three-phase rectifier with thyristors

In Fig. 4 the simulation results and the waveforms obtained for the nonlinear consumer are presented. The evolution over time and spectrum of current recovered by the rectifier at different current values were compared. It has been found that the current distortion factor decreases as the current increases.

3.2. Simulink model of the active filter

With the Matlab-Simulink software package, a simulation model was developed (fig. 5.). The model's structure contains the network and rectifier (nonlinear consumer) models and the active filter model.

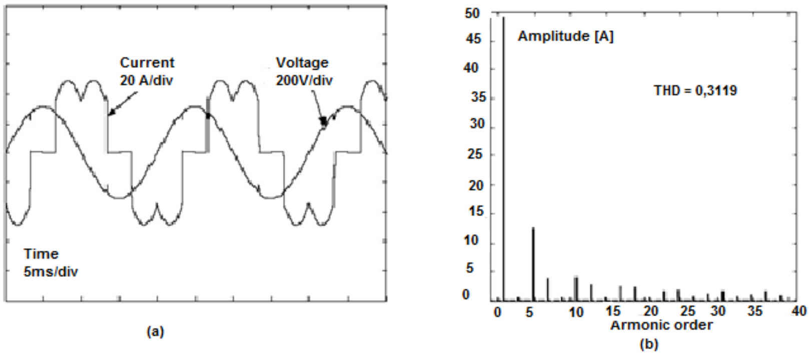


Fig. 4. The current absorbed from the mains voltage and phase (a) and the spectrum of current drawn from the mains (b)

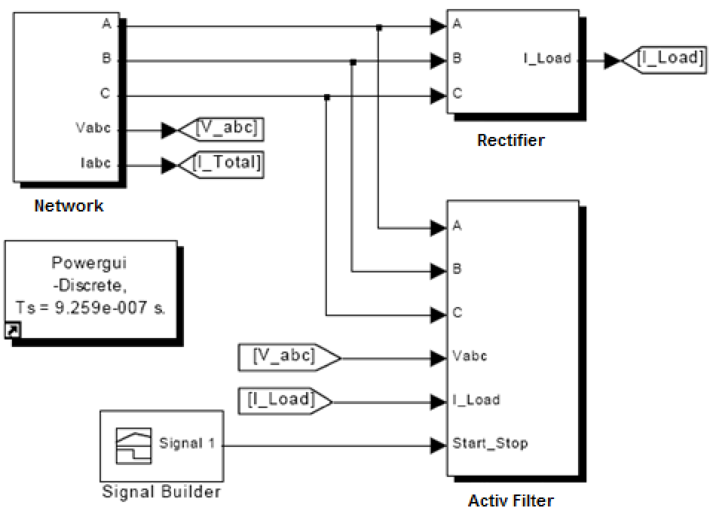


Fig. 5. Simulink model of nonlinear consumer assembly; active filter

3.3. Active filter simulation results

The effect of the passive filter for the wavelength waves and its multiples is emphasized by comparing the absorbed current in the presence of the filter (Fig. 7) and the current absorbed in the absence of the filter (Fig. 6).

It is observed the effect of the circuit given on the switching frequency, which removes the harmonics of current with this frequency and the effect of the reactive power compensation.

Mains voltage in the CCP has a high content of harmonics in the absence of passive filter, which can have a negative influence on other consumers. In Fig. 8 shows the simulation results for the reference signal and the measured value of the filter current for a phase in coordinates (a, b, c).

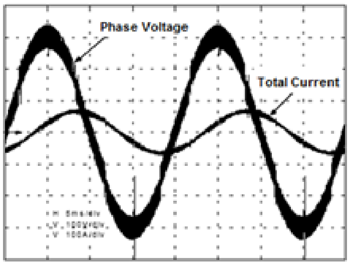


Fig. 6. Phase voltage and total current without passive filter

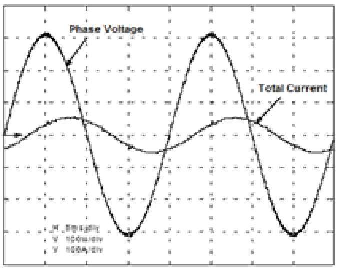


Fig. 7. Phase voltage and total current with passive filter

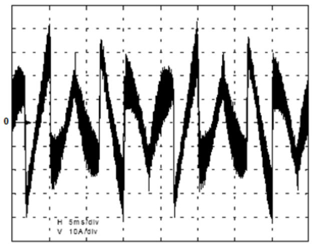


Fig. 8. Reference signal and measured value of filter current in coordinates (a, b, c)

As the consumer's current is slow, it is possible to calculate the current reference based on the preceding period but with one or more switching steps to compensate for the delay introduced by the current regulators and the execution element.

In Fig. 9 shows the reference signal and the measured value of the filter current on the q axis.

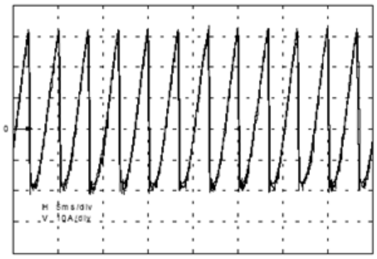


Fig. 9. The reference signal and the measured value of the filter current on the q axis.

4. CONCLUSIONS

We developed a method of compensation of the harmonic current absorbed by the adjustable drives with DC or AC motors, which that are most prevalent industrial consumers. We achieved two active filter structures in parallel topology, with a voltage inverter, at two different power levels and two harmonic generator test benches, on which the experimental method of compensation was implemented and tested.

The paper presents the elements of the active filter. It makes a classification of active filters depending on power and response speed. Then the different ways of locating the active filters, the main topologies, and the way in which the active filters can be connected to the network and the nonlinear consumer are treated.

To mitigate the impact of an active filter's price, there are additional features that the filter could offer besides compensating the harmonics: reactive power compensation, resonance damping, protection against temporary voltage drops.

With the Matlab-Simulink software package a simulation model of the nonlinear consumer and the power supply network was created. The simulation results are analyzed to determine the compensation issues that the active filter will have to solve and at a future stage to be validated by comparing with the experimental results.

Based on mathematical models, simulation schemes were developed as follows:

- Simulation scheme of a disturbed source with fully rectifier structure and thyristor supply network at the test bench connection point;
- Parallel active filter simulation scheme with voltage inverter structure with Matlab, Simulink and PowerSys modules.

The experimental results are similar to those obtained by simulation. This concordance allows us to conclude that the computational assumptions and mathematical models underlying this work are correct.

REFERENCES

[1]. Marcu, M., Popescu, F.G., Samoila, B. L., *Modeling and simuling power active filter using method of generalized reactive power theory*, IEEE International Conference on Computer Science and Automation Engineering, Shanghai, China, 10-12 June 2011.

[2]. Marcu M.D., Popescu F.G., Niculescu T., Pana L., Handra A.D., *Simulation of power active filter using instantaneous reactive power theory*, Harmonics and Quality of Power (ICHQP), IEEE 16th International Conference, Page(s):581 – 585, Bucharest, 2014.

[3]. Niculescu T., Marcu M., Popescu F., Slusariuc R., *MATLAB applications in the study of connection schemes of inductive circuits to alternative power source*, 17th International multidisciplinary Scientific Geoconference, Vol. 17-Informatics, Geoinformatics and Remonte Sensing, pp. 407- 412, Albena, Bulgaria, 2017.

[4]. Popescu F.G., Arad S., Marcu M.D., Pana L., *Reducing energy consumption by modernizing drives of high capacity equipment used to extract lignite*, Papers SGEM2013/Conference Proceedings, Vol. Energy and clean technologies, pp. 183 - 190, Albena., Bulgaria, 2013.

[5]. Popescu F.G., Marcu M.D., *Metode moderne de analiză şi reducere a armonicilor de curent şi tensiune*, Editura Universitas, Petroşani, pag. 265, 2016.

[6]. Shklyarskiy Y. E., Skamyin A. N., *Compensation of the reactive power in the presence of higher voltage harmonics at coke plants*, Coke Chem., vol. 59, no. 4, pp. 163–168, Apr. 2016.

[7]. Solovev S. V., Kryltcov S. B., Voytyuk I. N., *Static load characteristics consideration for determination of transmission line power capacity*, in Proceedings of the 2018 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering, ElConRus 2018, 2018, vol. 2018–Janua.

[8]. E. O. Zamyanit, Y. E. Shklyarskiy, *Concept for electric power quality indicators evaluation and monitoring stationary intellectual system development*, Int. J. Appl. Eng. Res., vol. 11, no. 6, pp. 4270–4274, 2016.