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COMPARATIVE ANALYSIS OF APPF MODELLING AND SIMULATION

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Abstract: The paper is dealing with a comparative analysis of active parallel power filters behaviour (APPF) for different control strategies implemented to the prototypes achieved in the project CRESC-INTEL. The analysis has been made based on results obtained through MATLAB simulation for each control strategy used. Based on this analysis, at the end of the paper conclusions are drawn and recommendations are offered so as to choose the appropriate solution for a given appliation.

Keywords: Active parallel power filter, control strategies.

1. INTRODUCTION

The main goal of this paper is a comparative analysis of modelling and simulation of active parallel power filters (APPF). These filters are studied in the project "Knowledge transfer regarding increasement of energy efficiency and intelligent power systems (CRESC-INTEL)". It is worth mentioning that both the research institute and the partner firms have worked together on choosing and dimensioning the APPFs, starting with practical requirements to the study of various control strategies that are worth to be implemented – as function of application requirements – to the modelling and simulation in the most suitable software able to offer relevant data to the customer.

In the beginning of the development of this paper it was already considered the specific configuration of the APF desired (given by a specific application) by analysing - through modelling and simulation – the specificities given by the use of each APF of a control strategy (generated by a variety in the unit as a consequence of many partner companies working in the project).

Moreover, to visualize the influence on performance of the control strategy for a certain active parallel power filter (APPF), the type of load had to be imposed for simulation.

2. CONTROL STRATEGIES USED FOR APPFs

Based on a thorough reference study, the most important APF general control strategies were identified, especially for APPF.

Thus, certain particularities of many control strategies were looked over and analysed SWOT as regarding the customer facilities (technical performance/price ratio), considering also the disadvantages (advantages/resources ratio).

The control strategies analysed are given in Table 1, specifying also the partner company and the partner company that implemented the control for the prototype.

TABLE 1: CONTROL STRATEGIES AND THE COMPANIES THAT IMPLEMENTED THEM FOR THE PROTOTYPE

APPF control stategies		Partner company that implemented the control for the prototype
Developed on the principle of instantaneous powers (PQ)		SC Smartech Automation SRL
Developed on the principle of synchronous algorithm (DQ)		SC Uniel Serv SRL
Developed on the principle of maximum (MAX)		ICPE ACTEL SA
Developed on the principle of indirect control (IC)		ELECTRO-TOTAL SRL
Developed on the principle of synchronization of current with the positive voltage sequence component (SEC-POZ)		SC Electrosistem SRL
Developed on the method of separation the pollutive components	Stop-band filter - SBF	SPIRU ELECTRA SRL
	Low-pass filter - LPF	DOCEROM SISTEM SRL

For each specific topology of active power filter (APF) and considering the problems to be reduced/balanced out in the energetic system, there is only a certain control strategy able to offer maximum of efficency for less resources. The modelling and simulation for a given APF topology (parallel APPF) for a given nonlinear load point out the shorts and overs for each control strategy. Alltogether, the simulation (using models based on the specific structure of APF) is to establish a reference for the results to be obtained by testing the prototypes both by the research institute and the partner companies. This last goal has been one of the specific objectives of the project CRESC-INTEL.

3. APF BEHAVIOUR FEATURES FOR EACH IMPLEMENTED CONTROL STRATEGY. COMMENTS

In order to perform a comparative analysis of the influence of each implemented control strategy (as to APF APPF behaviour and balance the efficiency of distortion regime in the energetic system) the results of simulations in MATLAB for the given topologies of APF and the nonlinear load considered are given below.

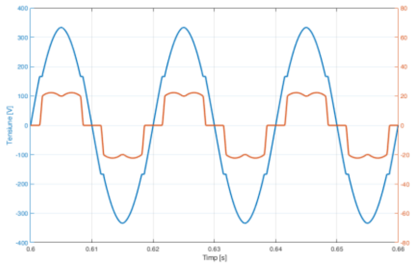

Fig. 1. Waveforms of power supply voltage and current without APF

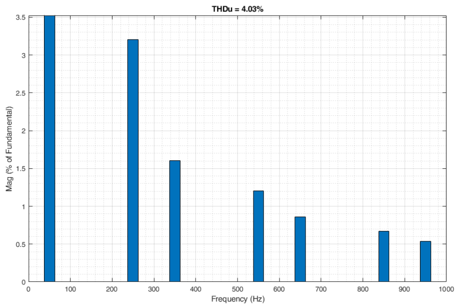

Fig. 2. FFT analysis of voltage waveform without APF

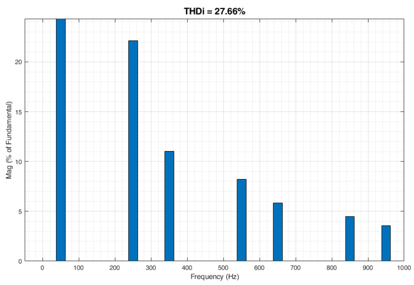

Fig. 3. FFT analysis of current waveform without APF

3.1 APF control strategy developed on the principle of instantaneous powers (PQ)

This method allows the balance of harmonic power in the balanced/unbalanced power grids, based on instantaneous power (PQ) [1] [2].

The block diagram of PQ control method is shown in Fig. 4.

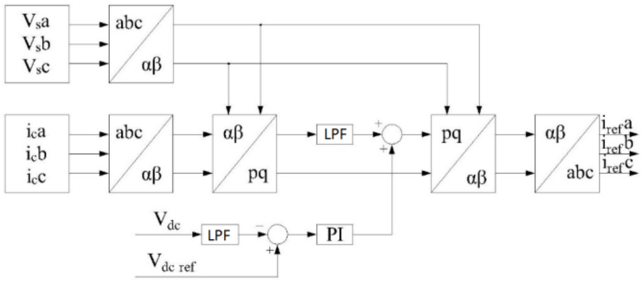

Fig. 4. Block diagram of PQ method

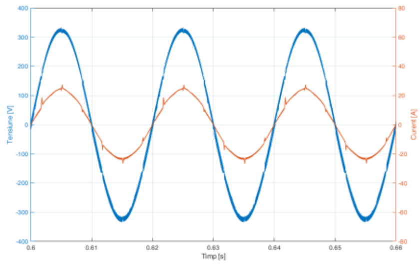

Fig. 5. Waveform of power supply voltage and current using PQ control method of APF

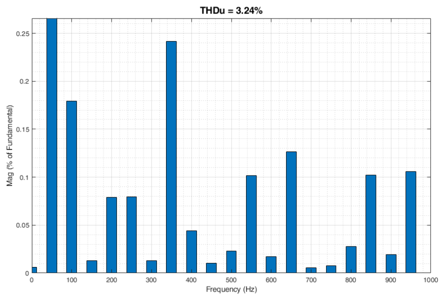

Fig. 6. FFT analysis of voltage waveform using PQ control method of APF

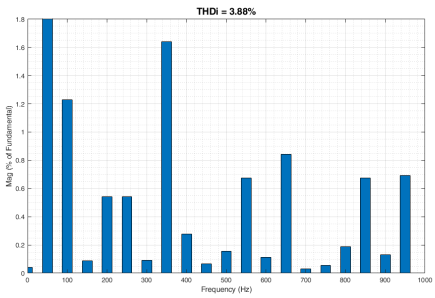

Fig. 7. FFT analysis of current waveform using PQ control method of APF

3.2 APF control strategy developed on the principle of synchronous algorithm (DQ)

In the Fig. 8. is shown the principle of synchronous algorithm for the control of APF [3] [4].

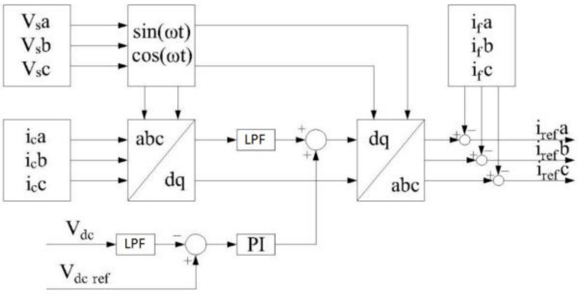

Fig. 8. Block diagram of DQ method

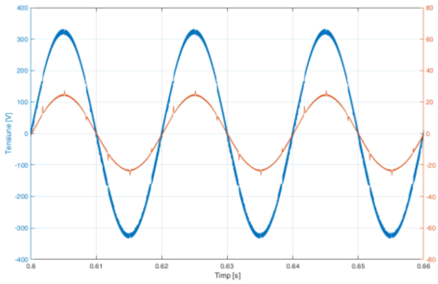

Fig. 9. Waveforms of power supply voltage and current using DQ control method of APF

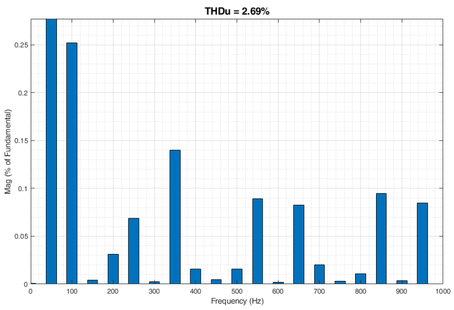

Fig. 10. FFT analysis of voltage waveform using DQ control method of APF

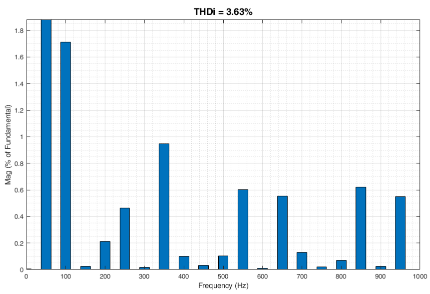

Fig. 11. FFT analysis of current waveform using DQ control method of APF

3.3 APF control strategy developed on the principle of maximum (MAX)

This method works by filtering the distorted current from the load so as to leave out the fundamental component. In Fig. 12 is shown the principle of MAX method.

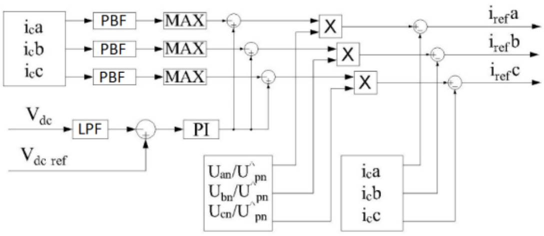

Fig. 12. Block diagram of MAX method

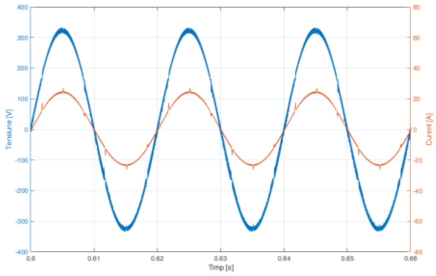

Fig. 13. Waveforms of power supply voltage and current using MAX control method of APF

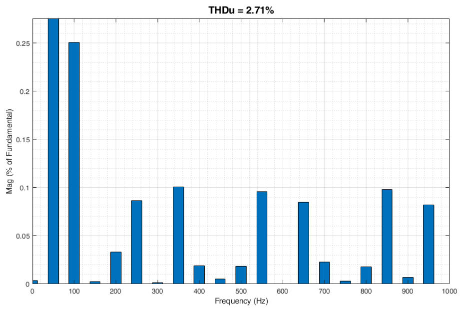

Fig. 14. Analiza FFT analysis of voltage waveform using MAX control method of APF

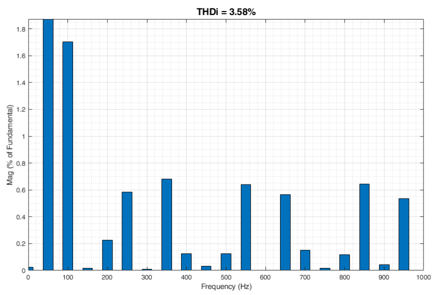

Fig. 15. Analiza FFT analysis of current waveform using MAX control method of APF

3.4 APF control strategy developed on the principle of indirect control (IC)

This control method may work without knowing the values of load current spectra [5]. The principle of work is shown in Fig.16.

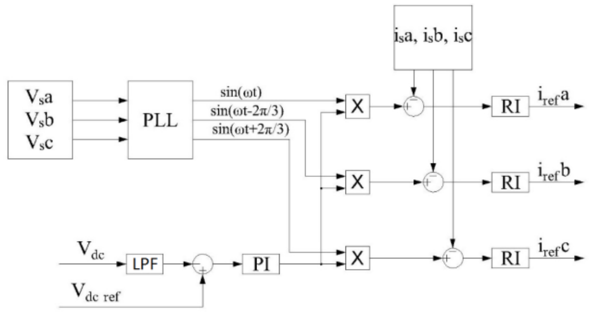

Fig. 16. Block diagram of IC method

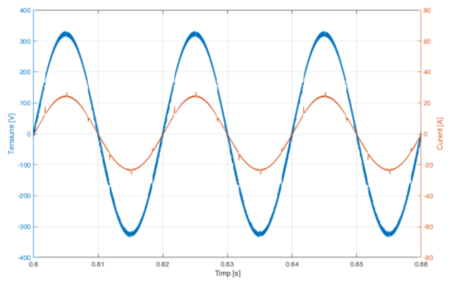

Fig. 17. Waveforms of power supply voltage and current using IC control method of APF

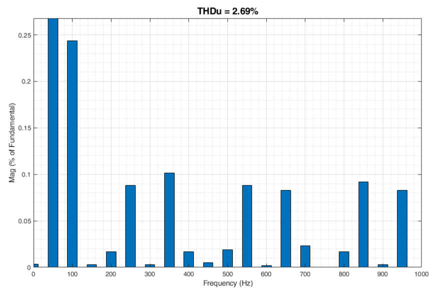

Fig. 18. FFT analysis of voltage waveform using IC control method of APF

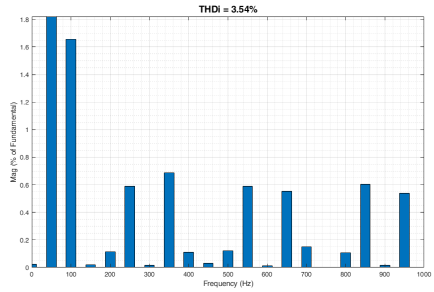

Fig. 19. FFT analysis of current waveform using IC control method of APF

3.5 APF control strategy developed on the principle of synchronization of current with the positive voltage sequence component (SEC-POZ)

This method is shown in Fig. 20 and works with power supply current balanced in phase with positive voltage sequence [6].

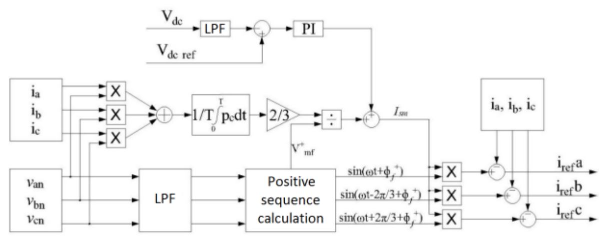

Fig. 20. Block diagram of SEC-POZ method

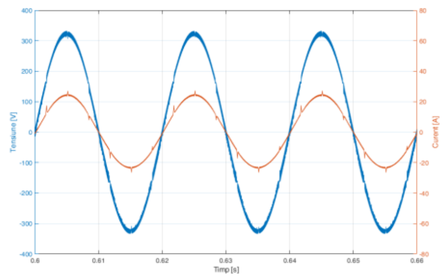

Fig. 21. Waveforms of power supply voltage and current using SEC-POZ control method of APF

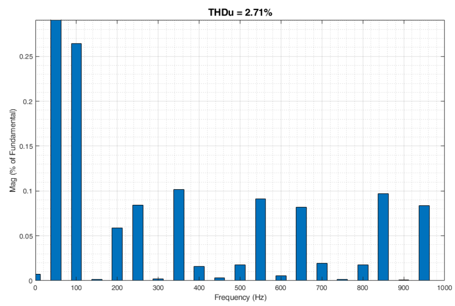

Fig. 22. FFT analysis of voltage waveform using SEC-POZ control method of APF

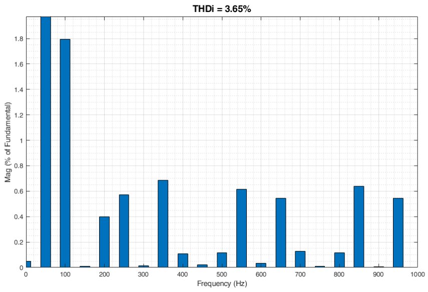

Fig. 23. FFT analysis of current waveform using SEC-POZ control method of APF

3.6 APF control strategy developed on the method of separation the pollutive components

3.6.1 Stop-band filter SBF

The working principle is simple, the currents from load pass through a stop-band filter which is set to eliminate the fundamental frequency, obtaining the reference of current harmonics for all the three phases (Fig. 24).

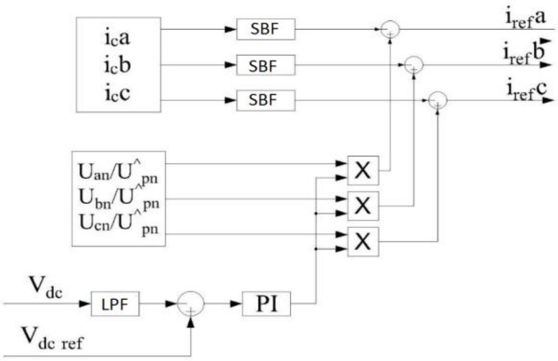

Fig. 24. Block diagram of SBF method

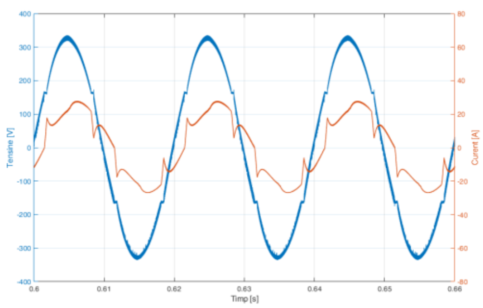

Fig. 25. Waveform of power supply voltage and current using MSPC-SBF control method of APF

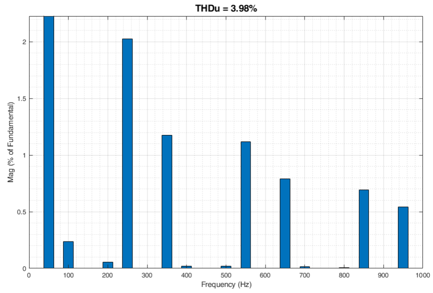

Fig. 26. FFT analysis of voltage waveform using MSPC-SBF control method of APF

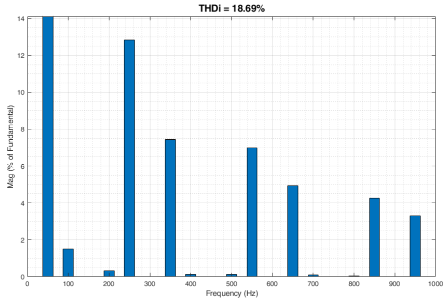

Fig. 27. FFT analysis of current waveform using MSPC-SBF control method of APF

3.6.2 Low-pass filter LPF

This control method use a low-pass filter (LPF) to eliminate the fundamental frequency from the pollutive component (Fig. 28).

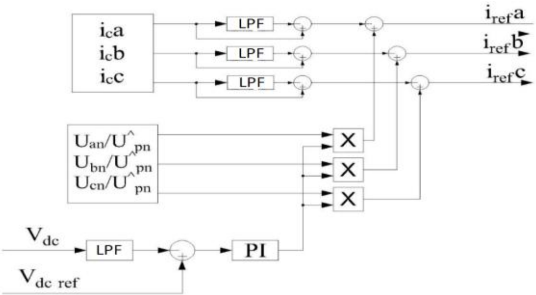

Fig. 28. Block diagram of LPF method

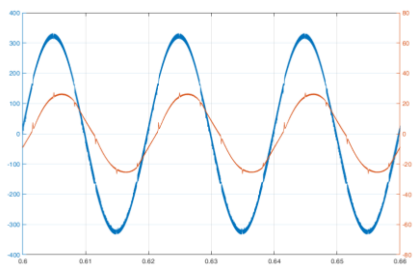

Fig. 29. Waveform power supply voltage and current using MSPC-LPF control method of APF

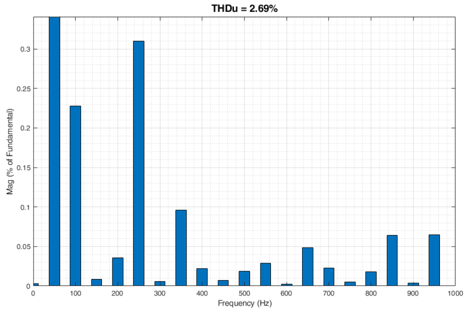

Fig. 30. FFT analysis of voltage waveform using MSPC-LPF control method of APF

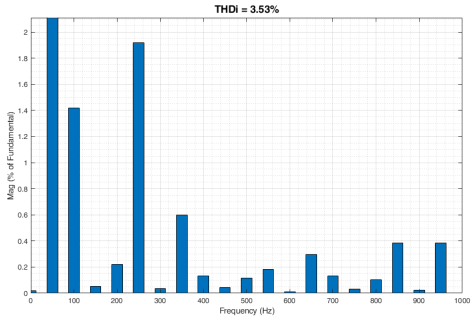

Fig. 31. FFT analysis of current waveform using MSPC-LPF control method of APF

TABLE 2: FINAL RESULTS

APPF control strategy		**THDu [%]**	**THDi [%]**	**PF**
Nonlinear load		4.03	27.66	0.95
Developed on the principle of instantaneous powers (PQ)		3.24	3.88	0.99
Developed on the principle of synchronous algorithm (DQ)		2.69	3.63	0.99
Developed on the principle of maximum (MAX)		2.71	3.58	0.99
Developed on the principle of indirect control (IC)		2.69	3.54	0.99
Developed on the principle of synchronization of current with the positive voltage sequence component (SEC-POZ)		2.71	3.65	0.99
Developed on the method of separation the pollutive components	Stop-band filter - SBF	3.96	18.69	0.91
	Low-pass filter - LPF	2.69	3.53	0.91

4. CONCLUSIONS

As a consequence of the analysis the following conclusions can be drawn:

- ✓ The best control strategy is that of indirect control considering the performances;
- ✓ Very good results are obtained also with DQ (synchronous algorithm), respectively MSPC-LPF (separation the pollutive components), SEC-POZ (positive sequence) , MAX (maximum principle);
- ✓ The worst results for APPF are obtained in case of using MSPC-SBF, respectively PQ (instananeous powers).

Thus, the following recommendations can be made:

- ➢ To reduce the distortion regime in current wave it is advisable to avoid using the control strategies based on MSPC-SBF, respectively PQ for a given nonlinear load; for a certain nonlinear load;
- ➢ To produce a high power factor in the these grids which include APPF and decrease reactive power consumption it is advisable to avoid using the control strategies MSPC-SBF and MSPC-LPF (method of separation the pollutive components).

ACKNOWLEDGMENT

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