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Editorial

Active Power Filters and Power Quality

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The transmission of electricity from the source to the load is mainly carried out using a three-phase line. Most of the industrial loads are also three-phase loads. The three-phase voltages produced in synchronous generators can be considered sinusoidal and symmetrical. The reason for the voltage and current distortion at a given point in the supply network is the widespread use of power electronic systems and large industry asymmetrical loads (e.g., arc furnaces), as well as a large number of low-power loads (switching power supplies, energy-saving lighting), which have non-linear and non-stationary characteristics. In countries with modern industrial technology, more than 70% of the electricity produced is transformed with the use of power electronic systems. Additionally, the number of renewable energy sources is growing every year. On the one hand, they increase the reliability of the energy supply, but on the other hand, they can also have an adverse effect on the supply network. This applies, in particular, to networks that were designed several or several dozen years ago. In conjunction with the constantly growing number of non-linear loads, both high and low power, it is a significant problem, as it can cause serious local and non-local failures. Therefore, issues related to the power quality and ways to improve it are becoming very topical. This problem is given a lot of attention, both in discussions and technical analyses, in numerous publications, and in international regulations [1–3].

The Special Issue "Active Power Filters and Power Quality" includes three reviews [4–6] and seven papers [7–13] presenting various aspects of the issue of power quality and in particular methods of its improvement with the use of active power filters (APF).

The first review [4] concerns the issues of optimizing the sizing and placement of active power filters in the supply network. These systems are the best power quality conditioners, but they are also the most expensive devices of this type. Therefore, they are often replaced by cheaper passive circuits. By optimizing the placement of these systems in the supply network, investment costs can be significantly reduced. The review compares the optimization methods used in the work so far, as well as indicates possible directions for further research in this area.

The second review [5] presents an overview of the construction of power electronic systems used in the process of improving the power quality and devices that guarantee a high level of power supply. It presents a comprehensive overview and classification of the main problems of power quality in relation to current standards, as well as an overview of quality problems in the areas related to power production from renewables, electric mobility, electrical railway systems, and with solid-state transformers.

The third review [6] complements the review [5]. Each power electronic device requires a control algorithm. In the case of APF, the most important goal of the control algorithm is to determine the reference compensation currents. These currents are then fed into the grid at the point of APF connection. In the ideal case, the source current then becomes a sinusoidal active current (with the minimum RMS value) and all unfavorable components are closed in the APF-load circuit. Due to the high dynamics required, this is usually done in the time domain, but control algorithms using the frequency domain are also available. The review [6] also presents some technical and economic aspects related to this topic, as well as the roles of APF in different DG (distributed generation) systems.

In [7], another method of determining the reference compensating currents was proposed. In this case, the matrix pencil method was adopted for this purpose. This allowed for the elimination of the low-pass filter traditionally used in other time methods. The dynamic properties of this filter have a significant impact on the final result of the compensation, so its elimination may contribute to the improvement of the APF compensation properties. The simulation tests carried out showed the high dynamics of this solution.

The paper [8] concerns the issues of identifying harmonics and interharmonics in the current and voltage waveforms of the supply network. The authors proposed synchro-squeezing adaptive S-transform (SAST) for this purpose. The results of the analyses showed that its use allows for achieving a higher time-frequency representation precision in relation to the S-transform (ST) analysis and synchro-squeezing short-time Fourier transform (SSTFT). Moreover, it was shown that the use of SATS in the analyzed signals showed its superiority in detecting harmonic parameters, especially for interharmonics that vary over time.

The authors in [9] presents an algorithm for finding the optimal control for a current controller. It is a part of a control system of each shunt active power filter. The proposed algorithm is based upon the Karush–Kuhn–Tucker conditions for finding an optimal value. The criterion was the state in which control signal is limited and constraints create a cube. The results were compared with the classically used PI algorithm. The paper also presents the software and hardware platforms used by the authors to run the presented algorithms in real-time.

In the paper [10], the authors performed an analysis of the stability of the APF control system connected to the power system via an LCL filter. It included the evaluation of the system as a function of the accuracy of the identification of the coupling system parameters, as well as the sampling frequency and the PI controller coefficients. The results showed that the scope of identification of the coupling system parameters in the area where the system is stable is quite wide. However, incorrect identification may not only lead to the loss of stability, but also deteriorate the parameters of the active power filter and thus the final effect of the compensation of unfavorable components.

The calculation of the previously mentioned reference compensating currents requires the use of the so-called power theory. For power systems containing distorted current and voltage waveforms, many theories have been developed to interpret the phenomena occurring in them. However, to this day, none of them has received full approval from the entire community of scientists dealing with this subject. The article [11] presents one of such theories called CPT (Conservative Power Theory), which, according to the authors, is to be particularly useful in power supply systems with a large share of power electronic converters. This theory uses the so-called moving averages (MA). The article presents a new hybrid method of calculating the moving average, which allows its use, e.g., in isolated networks with low-inertia.

The next paper [12] describes the possibility of reducing APF power (and thus also costs) by including in the generation algorithm the reference compensating currents only the components of loads in a given PCC (point of common coupling). Excluding distortions from the rest of the supply network. This approach may be of particular interest to industrial consumers, who may be required by the energy supplier to eliminate grid adverse effects. This may allow for the minimization of investment costs.

The last paper [13] is related to the problem of modeling and optimizing power systems supplying, among others, nonlinear loads. The software simulating the power flow in the supply network is necessary to assess the impact of connecting the APF in a given network node on the improvement of the power quality parameters. The examples presented in the article show that the appropriate software allows for an in-depth analysis of possible solutions and, furthermore, the selection of the optimal one for a specific case, depending on the adopted limitations, expected effects, and investment costs. The authors presented their own package of algorithms developed in the JAVA language, allowing the analysis of any power supply system in the frequency domain, while maintaining high precision and results and very high computational efficiency.

The directions of further research on this subject will certainly be related, on the one hand, to the current problems in power grids and, on the other hand, to the development of power electronics technology. The current geopolitical situation indicates that, in the coming years, we can expect even greater dynamics of growth of renewable energy generators than at present. This will be a big challenge, especially for power grids designed many years ago. Voltage fluctuations and an increase in the harmonic content may cause deterioration of the power quality parameters. Which, in turn, can be a source of additional costs and network failures, as well as sensitive loads. Counteracting these phenomena requires the use of effective tools that additionally enable work in conditions of high variability of parameters. The use of APF seems to be the best solution in this case, so we can expect further research in the field of:

- Control algorithms for determining the standard compensating currents,
- Predictive control algorithms, in particular in the area of central control of a group of devices,
- Use of artificial intelligence to optimize APF placement.

On the other hand, the development of technology may contribute to the improvement of the efficiency of the APF system. In particular, new transistor designs, such as GaN (Gallium Nitride) or SiC (Silicon Carbide), may contribute to this. They are characterized by much lower switching losses than the previously used IGBTs. Therefore, they can operate with significantly higher switching frequencies than before. This will allow to improve the effectiveness of the compensation (lower THD value after compensation) while reducing the size of the entire system (the inverter can be even 30% smaller).

Summarizing, it can be said that electricity is the most important source of energy in the modern world. Because at the same time it is also a commercial commodity, its quality is important as in any other commodity. Additionally, although it seems that everything in this area has been researched and developed a long time ago, it is highly probable that many publications on this subject will be published in the coming years, which will provide many interesting and perhaps even groundbreaking solutions.

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References

1. *IEEE Standard 519-2014*; IEEE 519 Recommended Practice and Requirements for Harmonic Control in Electric Power Systems. IEEE: New York, NY, USA, 2014.
2. *IEC Standard 61000-4-30*; Testing and Measurement Techniques-Power Quality Measurement Methods. International Electrotechnical Commission (IEC): Geneva, Switzerland, 2015.
3. *IEC Standard 61000-4-7*; General Guide on Harmonics and Interharmonics Measurements, for Power Supply Systems and Equipment Connected Thereto. International Electrotechnical Commission (IEC): Geneva, Switzerland, 2010.
4. Buła, D.; Grabowski, D.; Maciążek, M. A Review on Optimization of Active Power Filter Placement and Sizing Methods. *Energies* **2022**, *15*, 1175. [CrossRef]
5. Afonso, J.L.; Tanta, M.; Pinto, J.G.O.; Monteiro, L.F.C.; Machado, L.; Sousa, T.J.C.; Monteiro, V. A Review on Power Electronics Technologies for Power Quality Improvement. *Energies* **2021**, *14*, 8585. [CrossRef]
6. Das, S.R.; Ray, P.K.; Sahoo, A.K.; Ramasubbareddy, S.; Babu, T.S.; Kumar, N.M.; Elavarasan, R.M.; Mihet-Popa, L. A Comprehensive Survey on Different Control Strategies and Applications of Active Power Filters for Power Quality Improvement. *Energies* **2021**, *14*, 4589. [CrossRef]
7. El Ghaly, A.; Tarnini, M.; Moubayed, N.; Chahine, K. A Filter-Less Time-Domain Method for Reference Signal Extraction in Shunt Active Power Filters. *Energies* **2022**, *15*, 5568. [CrossRef]
8. Lou, Z.; Li, P.; Ma, K.; Teng, F. Harmonics and Interharmonics Detection Based on Synchrosqueezing Adaptive S-Transform. *Energies* **2022**, *15*, 4539. [CrossRef]
9. Kołek, K.; Firlit, A. A New Optimal Current Controller for a Three-Phase Shunt Active Power Filter Based on Karush–Kuhn–Tucker Conditions. *Energies* **2021**, *14*, 6381. [CrossRef]

10. Bielecka, A.; Wojciechowski, D. Stability Analysis of Shunt Active Power Filter with Predictive Closed-Loop Control of Supply Current. *Energies* **2021**, *14*, 2208. [CrossRef]
11. Mota, D.d.S.; Tedeschi, E. On Adaptive Moving Average Algorithms for the Application of the Conservative Power Theory in Systems with Variable Frequency. *Energies* **2021**, *14*, 1201. [CrossRef]
12. Špelko, A.; Blažič, B.; Papič, I.; Herman, L. Active Filter Reference Calculations Based on Customers' Current Harmonic Emissions. *Energies* **2021**, *14*, 220. [CrossRef]
13. Buła, D.; Grabowski, D.; Lewandowski, M.; Maciążek, M.; Piwowar, A. Software Solution for Modeling, Sizing, and Allocation of Active Power Filters in Distribution Networks. *Energies* **2021**, *14*, 133. [CrossRef]