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Perspective

Supraharmonic Pollution Emitted by Nonlinear Loads in Power Networks—Ongoing Worldwide Research and Upcoming Challenges

Łukasz Michalec *, Paweł Kostyła and Zbigniew Leonowicz *

Faculty of Electrical Engineering, Wroclaw University of Science and Technology, 50-370 Wroclaw, Poland
* Correspondence: lukasz.michalec@pwr.edu.pl (Ł.M.); zbigniew.leonowicz@pwr.edu.pl (Z.L.);
Tel.: +48-71-320-26-26 (Z.L.)

Abstract: Researchers at many different institutions around the world study voltage and current waveform distortions in power networks using a variety of techniques. Due to the uncontrolled growing number of nonlinear devices supplied by electrical energy, more severe supraharmonic pollution has been observed. A bibliometric analysis of the topic development between 2013 and 2022 is presented in the paper. Using the selected search tools, a comparative review of articles published in the last three years was conducted. It organizes the existing knowledge about supraharmonic pollution generated by nonlinear devices and identifies current research challenges associated with the spread of these disturbances in electrical networks. The most frequently discussed topics by researchers are those that deal with the level of emissions generated by supraharmonic sources and their effects on components of the power system. The second most prominent research direction is the detection, measurement, analysis, and severity evaluation of supraharmonic pollution. Finally, the authors discuss areas of study related to the topic that offers perspectives for future research. The impact of high-frequency component pollution generated by nonlinear loads on emissions intentionally designed to carry communications signals through electrical networks needs to be explored under various power supply conditions.

Keywords: supraharmonic pollution; nonlinear loads; non-intentional emissions; conducted disturbances; power quality; powerline communication; low-voltage power system

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1. Introduction

The efficient transmission, processing, and use of electrical energy in devices are essential at a time of progressive development of power systems. The aim of a smart power grid is to improve not only the efficiency of power systems but also reliability, security, flexibility, and affordability. This can only be achieved with proper coordination between generating plants, networks, and consumers. This complex coordination brings economic and operational benefits while increasing the penetration of distributed generation, control systems, and nonlinear equipment into power networks. The number of modern electronic devices in distribution networks has grown rapidly over the past few years. Due to their nonlinear V–I characteristics, these devices introduce power quality (PQ) problems. One of the major factors contributing to the degradation of PQ is the harmonic emissions generated by nonlinear loads. Statistical analyzes of harmonic emissions are useful because they help to assess the severity of PQ degradation. By utilizing these analyses, distribution operators can properly plan network capacity and implement mitigation plans in order to reduce harmonic pollution [1,2].

For many years, one of the analyzed issues in this area of electrical engineering was the problem of disturbances propagating along supply lines in the frequency band below 2 kHz. Engineers began researching the voltage and current waveform distortion that dominate at higher frequencies relatively recently. The term “supraharmonics” was first introduced in 2013 during the summit entitled "IEEE Power & Energy Society" to indicate any kind of voltage and current waveform distortion within the range of frequencies from 2 to 150 kHz [3].

Energy transformation requires effective conversion, control, and transmission of electric power through power grids. The development of renewable energy systems, smart grids, communication via powerlines, the integration of distributed generation sources, the growing uncontrolled number of modern electric and electronic devices, network switching systems, control systems, and power electronic drive systems are the main reasons for concern regarding the emissions of conducted disturbances over a broad range of frequencies. The supraharmonics (SHs) generated by electrical equipment may become a serious source of disturbances deteriorating PQ. Thus, it is crucial to study the interaction of nonlinear devices between themselves and the low-voltage grid [4].

Supraharmonic disturbances can have a relevant influence on devices and the grid. One of the most significant is the fact that high-frequency components add thermal stress, reducing the lifetime of electrical equipment. This paper provides an overview of the existing knowledge regarding supraharmonics pollution caused by nonlinear loads in power networks. By analyzing different approaches based on the knowledge presented by scientists around the world, readers are able to identify current research challenges, uncover interesting topics, and determine possible future perspectives for study.

Section 2 presents a methodology for conducting a bibliometric analysis of the journal content using the chosen search tool. Section 3 consists of two subsections. Based on a literature review conducted within the last three years, Section 3.1 summarizes ongoing research directions regarding supraharmonic emissions generated by nonlinear loads. Section 3.2 proposes new directions for research on the topic. The final section of the paper is devoted to conclusions and selected perspectives.

2. Methodology

Searching the scientific literature is not an easy activity since it entails filtering high-quality works. It does not mean including only well-known sources and authors while excluding the rest. Those published documents that are relevant to the research area should be included in a literature review to state the perspective research direction in the selected area. The scholarly search engines available for researchers, e.g., Scopus, Web of Science, or Google Scholar, are useful since they limit the likelihood of conducting a scattered literature review. Each of the search methods has its advantages and disadvantages; thus, the search method chosen by the researcher depends on personal preferences.

In this paper, the method of review investigation is based on a structured selection using the Scopus database as one of the main scientific literature sources. This included all WoS-indexed journals, all IEEE and IoP conferences, and other verified venues. The search method used the keywords "supraharmonics" or "supraharmonic". The considered articles were accessed before 15 November 2022 and were written in English. The criteria selection of the articles is graphically summarized in Figure 1.

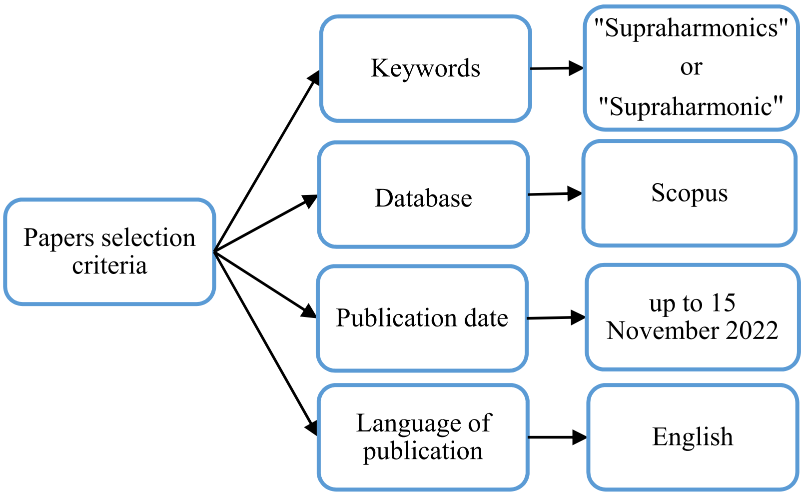

Figure 1. Methodology for materials selection.

3. Results

3.1. Statistical Analysis of Research Dealing with Supraharmonics in Power Networks

The bibliographic analysis of the area of supraharmonics domain over years is presented below. The number of published papers and publishing years related to the topic are shown in Figure 2. The dataset consists of 200 references that have been published over last ten years. There is generally an exponential distribution of published documents over time. The definition of supraharmonics is set to begin in 2013. The keyword "supraharmonics" did not appear in any publications that year. However, some publications addressed the topic, e.g., [5–7]. The number of scientific publications developed slowly during the first four years, and only a few papers (7–9) were published. Since 2016, the growth of published documents has been high, reaching its peak in 2020 (38 publications). This paper discusses the publications that were released between 2020 and 2022. There were 30 publications released on SHs pollution domain in 2021, compared to 31 publications in 2022.

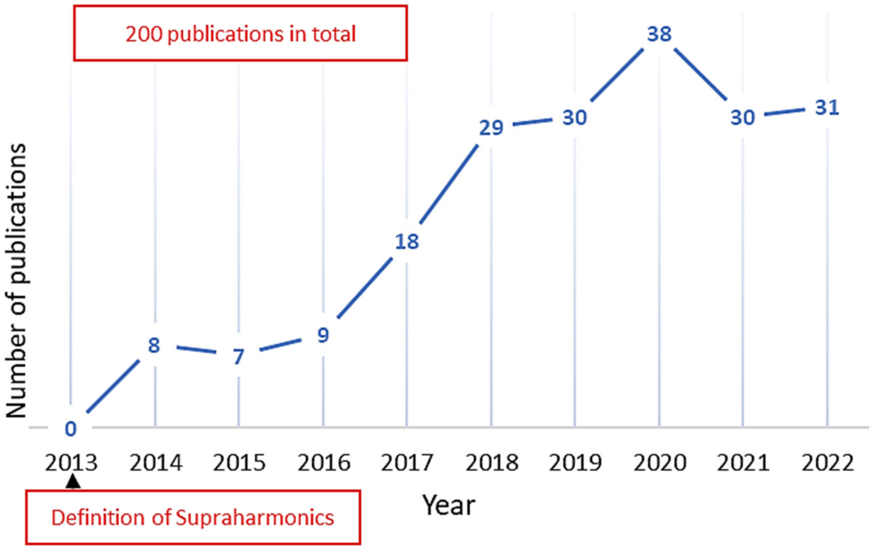

Figure 2. Evolution of the number of publications (blue line) dealing with supraharmonics pollution.

Figure 3 shows the distribution by the percentage of materials according to their type. The total number of scholarly documents published from 2020 to the present was 99, divided into six types. More than half constitute articles in journals (54.5%). Conference papers are the second group, which consists of 39.4% of all publications. The minor types of written sources that deal with supraharmonics are conferences, book chapters (1.0%), and letters (1.0%).

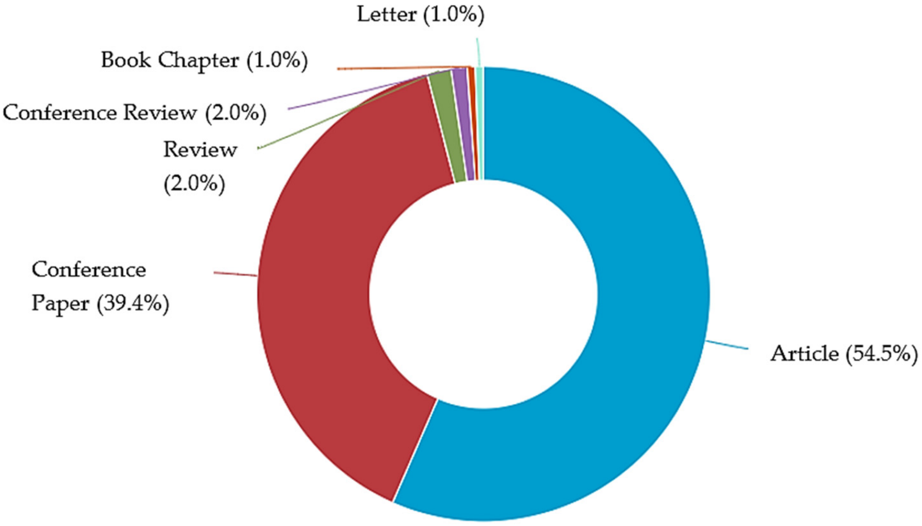

Figure 3. Distribution of materials by types.

There are review publications dealing with emissions in the 2–150 kHz frequency range in AC grids [4,8], DC grids [9,10], or microgrids [11,12]. They provide information about the sources and effects of SHs emission. They also evaluate the present standards, as well as introduce some recommendations for measuring techniques and analyzing SHs emissions under different conditions of the grid. The mitigation strategies and suggestions to improve PQ are also discussed.

3.2. Summary of Ongoing Research Directions Dealing with Supraharmonic Pollution Emitted by Nonlinear Loads

The results of searching the ongoing research directions based on the literature review of the last documents published between 2020 and 2022 are presented in Table 1. The table contains four main research directions and relevant findings dealing with SHs emitted by nonlinear loads. The most frequently discussed topics by researchers are those that deal with the level of emissions generated by supraharmonics sources and their effects on power system components. The detection, measurement, analysis, and severity assessment of supraharmonics pollution are the second most prominent research areas. There are some publications concerned with the acquisition path of disturbing signals. Some findings are associated with new SHs detection algorithms, the comparison of measurement methods, and the design of SHs monitoring systems. The SHs analysis methods have been highly developed in the last three years (nine publications). These findings include advanced signal processing, data clustering, and deep learning methods. There are 29 publications in total that prove and analyze the emission sources of supraharmonics. The typical sources of high-frequency emissions include different kinds of power electronic converters, electric vehicle chargers, household/office appliances, and modern lighting equipment. The research dealing with mitigation techniques of supraharmonic pollution are described in two publications during the last three years.

Table 1. Ongoing research directions and findings dealing with SHs emitted by nonlinear loads.

Main Research Directions	References	Research Novelties/Contributions/Methods
Causes of SHs: • Power electronic converters • Renewable energy sources • Electric vehicle chargers • End-user electronic equipment • Lighting appliances	 [13–19] [20–25] [26–33] [34–39] [40–42]	• The signal multiplication at PWM-based devices leads to a coupling of the harmonic components with the switching frequency of the device introducing additional emissions in the SHs frequency range. • The comparative analysis of the maximum level of emissions generated by six different SMPS products. • Impact of the controller clock error in the controllers of different converters on the level of SH emissions. • Presence of SHs in static frequency converters feeding the examined railway system. • Development of a new mathematical model for estimating the inverter-side current harmonics above 2 kHz that flow through the DC-link in adjustable speed drives. • The study of SHs presence in a real grid-connected 8 kWp PV system. • The case studies of high-frequency components in residential electrical installations with photovoltaic generation and nonlinear loads. • The level of SH emissions from wind power plants is related to the PWM modulation of the power inverter and to the length of transmission lines to the point of common coupling. • The study of the nature of time-varying emissions in the SHs frequency range during low power production of wind farms. • SHs need to be considered in simulation models of bidirectional electric vehicle charging stations. The level of distortion is influenced by the characteristics of a charger and the process of vehicle charging. • The SH emissions generally increased with the number of connected vehicles to charging stations; thus, these distortions should be expected in future grids. • New recommendation to test battery electric vehicles at their non-nominal charging currents. • The harmonic content of the supply voltage is one of the origins of the increasing level of SHs. • The propagation of SHs is highly dependent on the type of device and source impedance characteristics. • The study of SH disturbances growth as the number of nonlinear devices increases depending on the analyzed frequency. • Household electronic devices produce leakage currents. • The studies of SHs' primary and secondary emissions. • The study of noise produced by LED lamps. • Modelling the CFL ballast circuit to study the level of conducted emissions generated by the electronic ballast. • The study of the stabilization process for modern household appliances with regard to the variation of electrical and thermal parameters.
Effects of SHs on: • Power quality • PLC systems • Telecommunication • Protection devices • Capacitive dividers • Transformers • Insulation systems	 [40,43–47] [48,49] [50] [51–53] [54] [55–57] [58–60]	• The study of power losses caused by SHs. • Presence of SHs in applied voltage can lead to the production of visible flickers from LED lamps. • Interharmonics generation in AC–DC converters due to the presence of high-frequency non-synchronized distortion at the device under the test terminal. • Vehicle chargers from different manufacturers can react differently as the source of harmonics in the SHs frequency range. • The study examined the effects of turning off and on several inverters on a solar farm on power quality and grid equipment. • Experimental tests in a realistic scenario indicate the negative impact of various types of nonlinear loads installed at end-users on the performance of powerline communication. • SHs emitted due to inverter switching led to telephone interference for customers located around a solar PV plant. • Potential failures of residual current devices caused by the presence of SHs components. • Capacitive dividers can be used to measure voltages over a wide range of frequencies and temperatures. • Emphasis on the importance of considering SHs when calculating the K-factor and estimating transformer temperature rise and lifetime. • A high-frequency model of a transformer is established to evaluate SHs transmission characteristics. • SHs negatively influence the insulation of MV cables.

Table 1. *Cont.*

Main Research Directions	References	Research Novelties/Contributions/Methods
Methods of SHs: • measurement • analyzing • assessment	 [25,35,61–82] [24,38,83–87] [53,88–92]	• The time-varying nature of SH emissions. • Combining the hardware design with software development to design a new SHs measurement device. • The comparative survey of measurement methods for 2—150 kHz conducted emissions. • Uncertainties in measurements of SHs using a traceable method. • The study of SHs detection and measurement based on: —Deterministic measurement matrix and VT-SAMP; —Bimodal Spectral Line Interpolation Algorithm; —Radiated fields; —Identification of switching frequency; —Field Programmable Gate Array (FPGA) device; —Partial sampling and hybrid segmentation; —Combined Equidistant Sampling Method; —Robust Wavelet —Based Hybrid Method. • A multimethod approach to analyzing waveforms including SHs. • Characterization of two SHs analysis techniques: the Short-Time Fourier Transform (STFT) and Empirical Mode Decomposition (EEMD) methods. • An SHs dynamic analysis based on the Sliding-Window TLS—ESPRIT Algorithm. • Clustering and Dimensionality Reduction Methods for finding patterns in SHs data. • Deep learning in waveform high-frequency distortion variation analysis. • The frequency-dependent network impedance (FDNI) to determine SHs distortion level. • Monitoring power quality in the SHs frequency range using synchrophasors. • The development of inverter models that are suitable for studies of SH emissions. • The control variable method to analyze the supraharmonic resonance characteristics of the grid-connected system with multiple integrated inverters. • The stochastic approach for quantifying the impact of impedance on SHs propagation in low—voltage network with nonlinear loads. • The Phase-Locked Loop-based method for evaluating SH levels for current and voltage signals: computational cost reduction of a signal containing SH distortions generated by power electronics. • Lack of emission limits and standardized tests. • Urgency of understanding the origin and spread of SHs. • The interference-dependent approach to the development of methods for quantifying PQ in the context of SHs.
Mitigation techniques	[93,94]	• A new method for reducing SHs using active filters. • The multitone technique to measure the input impedance of power converters during operation as a conducted emission elimination tool below the 150 kHz frequency range.

3.3. Upcoming Challenges

Based on the review provided in Section 3.2, a number of significant advances relevant to SHs have been identified for further studies. They are indicated in Figure 4.

The frequency ranges below 2 kHz (IEC 61000—4—3, IEC 61000—4—7, IEC 61000—4—15, IEC 61000—4—30, etc.) and above 150 kHz (CISPR 11,12, etc.) are strongly covered by standards [95–99], but there is no generally recognized measurement technique and no emissions limitation for the frequency range of 2–150 kHz [11,26,100]. Many studies dealing with SHs have been conducted in the past decade. However, the establishment of international standards remains a challenging task. It is becoming more relevant, considering the expanding use of widely distributed production sources such as solar systems, wind turbines, microturbines, and charging machines in smart grids. Since 2013, several sources of supraharmonics pollution have been studied. However, it is likely that the number and type of these sources will increase in the future [25].

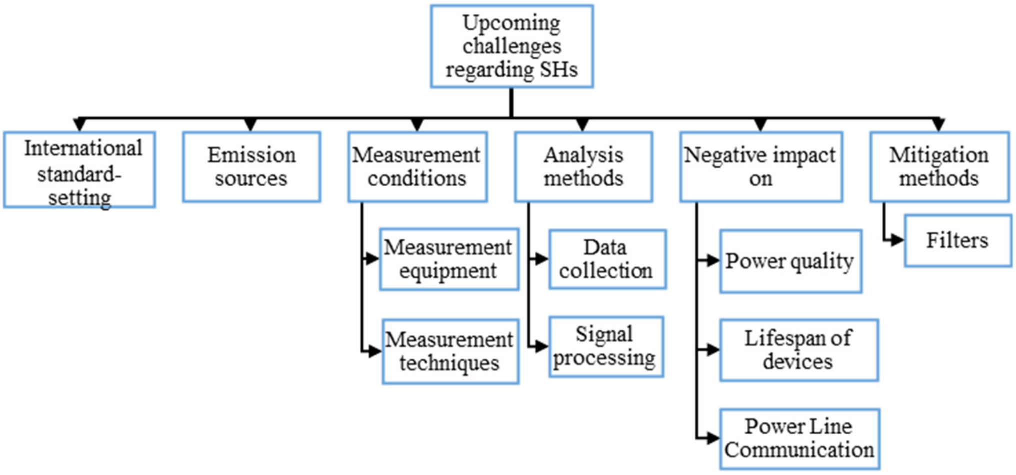

Figure 4. Upcoming challenges regarding supraharmonics domain.

The measurement, analysis, and assessment of supraharmonics pollution in power networks is not an easy task due to a number of obstacles. The laboratory tests can be conducted in specific conditions using filter systems based on the line impedance artificial network (LISN) and with specialized measurement equipment, which is the standard approach in electromagnetic compatibility testing. In real power systems, there are limitations due to the need to perform measurements without excluding the objects under study. As a result, it is difficult to supply power via artificial networks.

According to Figure 4, the next advances are analysis methods including data collection and signal processing. For stating new IEC standards or extending the existing ones, there is a recommendation to develop a new signal processing method to analyze supraharmonics. The methods which have already been identified have some advantages and drawbacks as well. Therefore, alternative methods of spectrum estimation methods are still an upcoming challenge.

The analyzed set of publications shows that researchers also focus on the negative impact of supraharmonics on:

- Power quality level, e.g., flicker severity or voltage unbalance [40,46];
- The thermal stress of electrical equipment, which reduces its useful life [4,60];
- Interference with powerline communication systems [48,49].

Active and passive harmonic filters are used to eliminate, or at least mitigate, harmonics pollution from networks. However, they have difficulties dealing with supraharmonics. In 2020, the hybrid power filter topology was proposed for the first time. The main circuit design was based on a hybrid shunt filter topology, which connects active and passive parts in series. The results based on experiments show that there is a positive filtering effect [93]. Further research on suppressing SHs with filters and other mitigation methods can be conducted worldwide in the future.

All the challenges listed above (Figure 4) related to supraharmonics would be beneficial in decreasing their emissions level and improving the power quality of electrical systems. This is especially true in power systems where modern nonlinear devices are widely used. Such systems, with the integration of renewable energy sources, are expected to grow rapidly in the coming years.

4. Conclusions and Perspective

There has been an increase in interest in high-frequency conducted emissions (between 2 and 150 kHz) since 2013. The number of groups working in this electrical engineering subfield has increased, as seen in the growing number of publications in the following years. Using the selected searching tool Scopus and restricting the dataset to the last three years, scientific documents dealing with supraharmonics pollution were identified and analyzed. The total number of scholarly publications from 2020 to the present was 99. More than half constituted articles in journals. It was noticed that researchers are most frequently interested in topics related to the detection, measurement, analysis, and evaluation of supraharmonics in relation to the type of disturbance sources.

Based on the literature review, there are significant advances relevant to SHs that can be developed for further research. The authors propose the following perspective study that can be worth studying in the future: the influence of inevitable variable supply conditions and the uncontrolled addition of nonlinear equipment on modern grids. This is especially true in the case of powerline communication systems, which are regarded as high-frequency conducted disturbances introduced intentionally to carry desirable signals.

Since powerline communication (PLC) technology is susceptible to disturbances caused by supraharmonics pollution presented in the operating band, legal guidelines have been adopted that reserve the working band for this technology [101]. Figure 5 shows the frequency ranges dedicated to intentional emissions provided by PLC systems (green color) related to the non-intentional conducted emission range (brown color). The frequency range of 3 kHz to 30 MHz has been designated for the transmission of signals and is further subdivided into narrowband (bright gray color) and broadband (yellow color) powerline communication. The frequency range in which the supraharmonics appear (orange color) is included in PLC operating frequency ranges adopted in Europe, Japan, and the United States (tones of blue color).

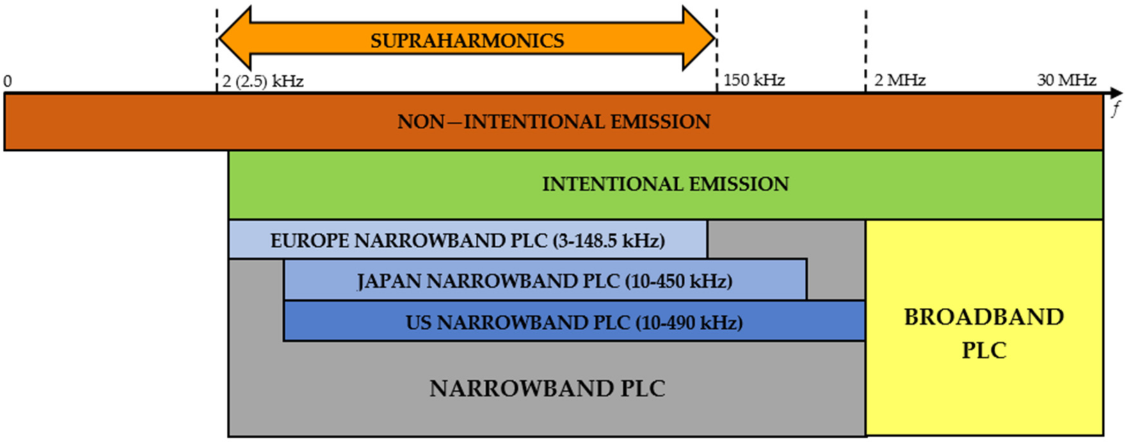

Figure 5. Frequency ranges dedicated to intentional emissions provided by PLC systems.

It is necessary to perform a supraharmonics analysis in order to determine the impact of non-intentional emissions on narrowband PLC transmission. It is especially significant because the dominant frequency bands where the maximum non-intentional emissions appear are not constant and change depending on network conditions. The paper [34] formulates the conclusion that waveform distortion has an impact on supraharmonic emissions. The paper [49] reviews real cases of supraharmonic emissions identified in the real power system that affect the PLC transmission.

In terms of the cited results, some perspectives may be constituted referring to emissions test conditions of nonlinear loads. The existing standards that referred to emission limits formulate the assessment process using nominal parameters of the load supply, i.e., at the nominal value of the supply voltage and with a sinusoidal waveform of the supply voltage. At the same time, international regulations on the quality condition of electricity supply in public power grids allow changes in supply voltage in the range of +/− 10% of the rated voltage. In the case of a distortion of the shape of the supply voltage, they allow for distortion of harmonics up to 2.5 kHz at the level of 8% [96]. Thus, we propose a comprehensive framework for testing nonlinear systems that would take into account the voltage supply condition.

An example of the results of the authors' research is presented in Figure 6.

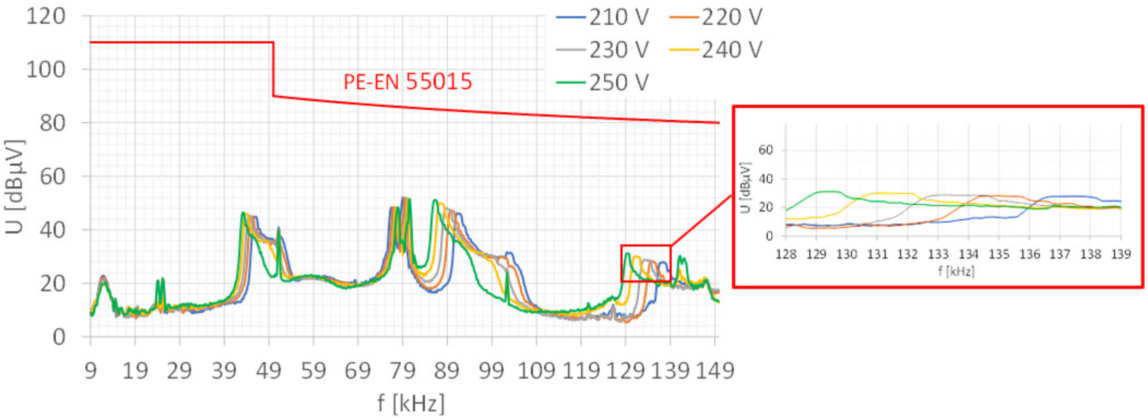

Figure 6. Supraharmonic spectrum and a close-up of the dominant emissions band of the set of lamps (CFL 20 W+LED 7 W) for various supply voltage values.

The study focused on measuring and analyzing the non-intentional conducted emissions introduced into the power grid by lighting devices after their thermal stabilization. The supplying conditions are as follows: the shape of the supply voltage remains sinusoidal, while the main voltage RMS level is varied between 210–250 V. The emissions value is examined for the spectrum 9–150 kHz. The used statistical tools show the nature of the emissions for modern lighting sources. The obtained results referred to the permissible limits specified in the recommended IEC standards. The analysis of the results shows the influence of the supply voltage level variation on the blurring of the disturbance characteristic in the spectrum domain. The relative emissions characteristic shifts is noticeable in the dominant emissions frequency bands but also in the entire spectrum. The significant change in parameters for the selected dominant emission band is bolded and presented in Table 2.

Table 2. Parameters of the selected dominant emission band for the set of lamps (CFL 20 W + LED 7 W) for various supply voltage values.

Un [V]	210	220	230	240	250
f [kHz]	137.4	135	133	131.2	129.4
Δf [kHz]	**4.4**	2	0	−1.8	**−3.6**
U [dBµV]	27.92	28.26	28.75	30.06	31.2
ΔU [dBµV]	−0.83	−0.49	0	1.31	2.45

The blurring of the disturbance characteristic is reverse proportional to the supply voltage level change. When the voltage is decreased below the nominal level, the disturbance characteristic shifts in the frequency domain towards higher frequencies. The maximum difference is 4.4 kHz for the frequency range within 128–139 kHz. However, when the voltage is increased above the nominal level, the disturbance characteristic shifts in the frequency domain towards lower frequencies. The maximum difference is 3.6 kHz for the frequency range within 128–139 kHz.

Providing knowledge and skills in appropriate spectral analysis methods may also be an aspect of perspectives in the development of supraharmonics research. The current recommendation is based on an extension of the IEC standards using a discrete Fourier transform-based method with an energy grouping concept around central frequencies or using the series of measurement intervals. The methods have already identified some drawbacks [68,69,81]. One of the issues is the synchronization requirement of the measurement window with fundamental system frequency, which naturally has a time-varying nature. Therefore, alternative spectrum estimation methods are permanently studied and proposed, e.g., in [67,73,76,82,87]. Promising results have been obtained using hybrid or combined methods which merge decomposition techniques and parametric spectrum estimation methods.

Using the spectrum estimation methods that identifies supraharmonics with a desirable frequency resolution, a novel perspective can be formulated for a filter design strategy. Filters may be used for the suppression of undesirable supraharmonics emissions in the frequency ranges addressed to intentional emissions related to PLC communication. Effective filters that may be able to improve PLC transmission by "cleaning" the spectrum of inherent high-frequency components are strongly desirable.

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References

1. De Falco, P.; Varilone, P. Statistical Characterization of Supraharmonics in Low-Voltage Distribution Networks. *Appl. Sci.* **2021**, *11*, 3574. [CrossRef]
2. Sahoo, S. Recent Trends and Advances in Power Quality. In *Power Quality in Modern Power Systems*; Elsevier: Amsterdam, The Netherlands, 2020.
3. Ahir, J.; Upadhyay, C. Harmonic Analysis and Mitigation for Modern Home Appliances. In Proceedings of the 4th International Conference on Electrical Energy Systems (ICEEA), Chennai, India, 7–9 February 2018; Institute of Electrical and Electronics Engineers Inc.: Piscataway, NJ, USA, 2018; pp. 218–223.
4. Alfalahi, S.T.Y.; Alkahtani, A.A.; Al-Shetwi, A.Q.; Al-Ogaili, A.S.; Abbood, A.A.; Mansor, M.B.; Fazea, Y. Supraharmonics in Power Grid: Identification, Standards, and Measurement Techniques. *IEEE Access.* **2021**, *9*, 103677–103690. [CrossRef]
5. Verzele, P.; Knockaert, J.; Desmet, J. Appropriate Methods to Analyse Power Conversion Harmonics. *Renew. Energy Power Qual. J.* **2013**, *1*. [CrossRef]
6. Gronwald, F.; Conrads, R.; Janssen, R.; Weber, T. Efficient Immunity Testing of Smart Meter Devices in the Frequency Range 2–150 KHz. In Proceedings of the IET Conference Publications, Beijing, China, 27–29 April 2013; Volume 2013.
7. Sudiarto, B.; Widyanto, A.N.; Hirsch, H. Voltage and Current Distortion Correlation Characteristics of Compact Fluorescent Lamp in Frequency Range of 2–150 KHz. In Proceedings of the International Conference on Quality in Research, QiR 2013—In Conjunction with ICCS 2013: The 2nd International Conference on Civic Space, Yogyakarta, Indonesia, 25–28 June 2013.
8. Thomas, T.; Michael, P.A. A Review of High Frequency Emission in 2–150 KHz Range. *Int. J. Adv. Appl. Sci.* **2020**, *9*, 132–141. [CrossRef]
9. Mariscotti, A. Power Quality Phenomena, Standards, and Proposed Metrics for DC Grids. *Energies* **2021**, *14*, 6543. [CrossRef]
10. Mariscotti, A.; Sandrolini, L.; Simonazzi, M. Supraharmonic Emissions from DC Grid Connected Wireless Power Transfer Converters. *Energies* **2022**, *15*, 5229. [CrossRef]
11. Alkahtani, A.A.; Alfalahi, S.T.Y.; Athamneh, A.A.; Al-Shetwi, A.Q.; Mansor, M.B.; Hannan, M.A.; Agelidis, V.G. Power Quality in Microgrids Including Supraharmonics: Issues, Standards, and Mitigations. *IEEE Access.* **2020**, *8*, 127104–127122. [CrossRef]
12. Romero-L, M.; Quintero-Molina, V.; Garzón, C.; Pavas, A.; Blanco, A.M.; Kannan, S.; Meyer, J. Analysis of Supraharmonic Emission in a Microgrid in Islanded and Interconnected Operation. In Proceedings of the 20th International Conference on Harmonics & Quality of Power (ICHQP), Naples, Italy, 29 May–1 June 2022; pp. 1–6.
13. Mariscotti, A.; Sandrolini, L.; Pasini, G. Variability Caused by Setup and Operating Conditions for Conducted EMI of Switched Mode Power Supplies Over the 2–1000 KHz Interval. *IEEE Trans. Instrum. Meas.* **2022**, *71*, 1–9. [CrossRef]
14. Mariscotti, A.; Sandrolini, L. Variability of EMI Measurement for Switched Mode Power Supplies EMI in the 2–1000 KHz Range. In Proceedings of the IEEE 11th International Workshop on Applied Measurements for Power Systems (AMPS), Virtual Event, 29 September–1 October 2021; pp. 1–6.

15. Kaufhold, E.; Meyer, J.; Schegner, P. Impact of Harmonic Distortion on the Supraharmonic Emission of Pulse-Width Modulated Single-Phase Power Electronic Devices. *Renew. Energy Power Qual. J.* **2021**, *19*, 577–582. [CrossRef]
16. Sandrolini, L.; Mariscotti, A. Waveform and Spectral Characteristics of Supraharmonic Unsymmetrical Conducted EMI of Switched-Mode Power Supplies. *Electronics* **2022**, *11*, 591. [CrossRef]
17. Zhong, Q.; Liang, M.; Chen, F.; Qiu, Y.; Luo, Q.; Lai, C. Impact of Controller Clock Error on Emission in Supraharmonic Caused by Converters. In Proceedings of the IEEE Power and Energy Society General Meeting, Virtual Event, 26–29 July 2021; Volume 2021.
18. Lennerhag, O.; Dernfalk, A.; Nygren, P. Supraharmonics in the Presence of Static Frequency Converters Feeding a 16 2/3 Hz Railway System. In Proceedings of the International Conference on Harmonics and Quality of Power, ICHQP, Virtual Event, 6–7 July 2020; Volume 2020.
19. Moradi, A.; Yaghoobi, J.; Zare, F. A Precise Model of DC-Link Current in Adjustable Speed Drives for the Harmonic Analysis of Electrical Networks. *IEEE Access.* **2022**, *10*, 45663–45676. [CrossRef]
20. Menti, A.; Barkas, D.; Kaminaris, S.; Psomopoulos, C.S. Supraharmonic Emission from a Three-Phase PV System Connected to the LV Grid. *Energy Rep.* **2021**, *7*, 527–542. [CrossRef]
21. Ortenzi, G.; Pomilio, J.A. Inside Residential Distributed Generation: A Look of High Frequency Contamination. In Proceedings of the Brazilian Power Electronics Conference, COBEP, João Pessoa, Brasil, 7–10 November 2021.
22. Carneiro, R.K.; Ota, J.I.Y.; Pomilio, J.A. Field Measurements of Non-Intentional Emissions above 2 KHz in Photovoltaic Inverter Installations. In Proceedings of the IEEE International Symposium on Industrial Electronics, Delft, The Netherlands, 17–19 June 2020; Volume 2020, pp. 1503–1508.
23. Zolett, B.; Leborgne, R.C. Propagation of Supraharmonics Generated by PMSG Wind Power Plants into Transmission Systems. In Proceedings of the IEEE PES Transmission and Distribution Conference and Exhibition—Latin America, T and D LA, Montevideo, Uruguay, 28 September–2 October 2020.
24. Darmawardana, D.; Perera, S.; Robinson, D.; Meyer, J.; Jayatunga, U. Important Considerations in Development of PV Inverter Models for High Frequency Emission (Supraharmonic) Studies. In Proceedings of the International Conference on Harmonics and Quality of Power, ICHQP, Virtual Event, 6–7 July 2020; Volume 2020.
25. Letha, S.S.; Delgado, A.E.; Rönnberg, S.K.; Bollen, M.H.J. Evaluation of Medium Voltage Network for Propagation of Supraharmonics Resonance. *Energies* **2021**, *14*, 1093. [CrossRef]
26. Mariscotti, A. Harmonic and Supraharmonic Emissions of Plug-In Electric Vehicle Chargers. *Smart Cities* **2022**, *5*, 27. [CrossRef]
27. Grasel, B.; Baptista, J.; Tragner, M. Supraharmonic and Harmonic Emissions of a Bi-Directional V2G Electric Vehicle Charging Station and Their Impact to the Grid Impedance. *Energies* **2022**, *15*, 2920. [CrossRef]
28. Singh, G.; Howe, W. Assessing the Harmonic and Supraharmonic Impact of Electric Vehicle Charging Facilities. In Proceedings of the 20th International Conference on Harmonics & Quality of Power (ICHQP), Naples, Italy, 29 May–1 June 2022; pp. 1–6.
29. Streubel, T.; Kattmann, C.; Eisenmann, A.; Rudion, K. Characterization of Supraharmonic Emission from Three Different Electric Vehicle Charging Infrastructures in Time and Frequency Domain. *Energies* **2022**, *15*, 394. [CrossRef]
30. Grasel, B.; Baptista, J.; Tragner, M.; Leonhartsberger, K.; Keusch, G. Supraharmonic Emissions of a Bidirectional Electric Vehicle Charging Station—A Research Methodology Based on Tests at Reconstructed Distribution Grid. In Proceedings of the IEEE 4th International Conference on Power and Energy Applications, ICPEA, Busan, Republic of Korea, 9–11 October 2021.
31. Darmawardana, D.; David, J.; Perera, S.; Robinson, D.; Meyer, J.; Jayatunga, U. Analysis of High Frequency (Supraharmonics) Emissions Caused by Electric Vehicle Charging. In Proceedings of the International Conference on Harmonics and Quality of Power, ICHQP, Virtual Event, 6–7 July 2020; Volume 2020.
32. Slangen, T.M.H.; van Wijk, T.; Cuk, V.; Cobben, J.F.G. The Harmonic and Supraharmonic Emission of Battery Electric Vehicles in the Netherlands. In Proceedings of the SEST 3rd International Conference on Smart Energy Systems and Technologies, Istanbul, Turkey, 7–9 September 2020.
33. Slangen, T.; van Wijk, T.; Ćuk, V.; Cobben, S. The Propagation and Interaction of Supraharmonics from Electric Vehicle Chargers in a Low-Voltage Grid. *Energies* **2020**, *13*, 3865. [CrossRef]
34. Wasowski, M.; Sikorski, T.; Wisniewski, G.; Kostyla, P.; Szymanda, J.; Habrych, M.; Gornicki, L.; Sokol, J.; Jurczyk, M. The Impact of Supply Voltage Waveform Distortion on Non-Intentional Emission in the Frequency Range 2–150 Khz: An Experimental Study with Power-Line Communication and Selected End-User Equipment. *Energies* **2021**, *14*, 777. [CrossRef]
35. Espin-Delgado, A.; Busatto, T.; Ravindran, V.; Ronnberg, S.K.; Meyer, J. Evaluation of Supraharmonic Propagation in LV Networks Based on the Impedance Changes Created by Household Devices. In Proceedings of the IEEE PES Innovative Smart Grid Technologies Conference Europe, Delft, The Netherlands, 26–28 October 2020; Volume 2020, pp. 754–758.
36. Blanco, A.M.; Moller, F.; Meyer, J.; Schegner, P. Characterization of the Leakage Currents Produced by Household Electronic Devices. In Proceedings of the International Conference on Harmonics and Quality of Power, ICHQP, Virtual Event, 6–7 July 2020; Volume 2020.
37. Michalec, Ł.; Jasiński, M.; Sikorski, T.; Leonowicz, Z.; Jasiński, Ł.; Suresh, V. Impact of Harmonic Currents of Nonlinear Loads on Power Quality of a Low Voltage Network—Review and Case Study. *Energies* **2021**, *14*, 3665. [CrossRef]
38. Espín-Delgado, Á.; Rönnberg, S.; Busatto, T.; Ravindran, V.; Bollen, M. Summation Law for Supraharmonic Currents (2–150 KHz) in Low-Voltage Installations. *Electr. Power Syst. Res.* **2020**, *184*, 106325. [CrossRef]
39. Sakar, S.; Ronnberg, S. Modeling and Analysis of DC-Link Capacitors Subjected to High Frequency Conducted Disturbances in Electronic Equipment. *IEEE Trans. Power Electron.* **2022**, *37*, 5949–5956. [CrossRef]

40. Singh, G.; Sharp, F.; Teh, W.Y. Effects of Supraharmonics Immunity Testing on LED Lighting. In Proceedings of the IEEE Madrid PowerTech, Madrid, Spain, 27 June–2 July 2021.
41. Yeshalem, M.T.; Khan, B.; Mahela, O.P. Conducted Electromagnetic Emissions of Compact Fluorescent Lamps and Electronic Ballast Modeling. *AIMS Electron. Electr. Eng.* **2022**, *6*, 178–187. [CrossRef]
42. Khokhlov, V.; Meyer, J.; Schegner, P. Test Procedure for Determining the Stabilisation Time of Lamps and Other Household Appliances. In Proceedings of the International Conference on Harmonics and Quality of Power, ICHQP, Virtual Event, 6–7 July 2020; Volume 2020.
43. Novitskiy, A.; Schlegel, S.; Westermann, D. Estimation of Power Losses Caused by Supraharmonics. *Energy Syst. Res.* **2021**, *3*, 28–36. [CrossRef]
44. Basta, B.; Morsi, W.G. Probabilistic Assessment of the Impact of Integrating Large-Scale High-Power Fast Charging Stations on the Power Quality in the Distribution Systems. In Proceedings of the IEEE Electric Power and Energy Conference, EPEC, Edmonton, AB, Canada, 9–10 November 2020.
45. Yaghoobi, J.; Zare, F.; Solatialkaran, D. Harmonic Emissions in 0–9 KHz Frequency Range and Transient Effects in Grid-Connected Inverters Utilised in Solar Farms. In Proceedings of the International Conference on Harmonics and Quality of Power, ICHQP, Virtual Event, 6–7 July 2020; Volume 2020.
46. Sutaria, J.; Rönnberg, S.; Espín-Delgado, Á. Analysis of Supraharmonics in a Three-Phase Frame. *Electr. Power Syst. Res.* **2022**, *203*, 107668. [CrossRef]
47. Sakar, S.; Ronnberg, S.K.; Bollen, M. Interharmonic Emission in AC-DC Converters Exposed to Nonsynchronized High-Frequency Voltage above 2 KHz. *IEEE Trans. Power Electron.* **2021**, *36*, 7705–7715. [CrossRef]
48. Bucci, G.; Ciancetta, F.; Fioravanti, A.; Fiorucci, E.; Landi, C.; Luiso, M.; Mari, S.; Silvestri, A. The Effects of LED Lamps Emissions on PLC: A Preliminary Study in a Realistic Scenario. In Proceedings of the IEEE International Workshop on Metrology for Industry 4.0 & IoT (MetroInd4.0&IoT), Trento, Italy, 7–9 June 2022; pp. 167–172.
49. Wasowski, M.; Habrych, M.; Sikorski, T.; Kostyla, P.; Jurczyk, M.; Gornicki, L.; Sokol, J.; Golemo, M. Sources of Non-Intentional Supraharmonics in LV Network and Its Impact on OSGP PLC Communication Experimental Study. *IEEE Trans. Power Deliv.* **2022**, *37*, 5244–5254. [CrossRef]
50. Singh, G.; Cooke, T.; Johns, J.; Vega, L.; Valdez, A.; Bull, G. Telephone Interference from Solar PV Switching. In Proceedings of the 20th International Conference on Harmonics & Quality of Power (ICHQP), Naples, Italy, 29 May–1 June 2022; pp. 1–6.
51. Sutaria, J.; Espín-Delgado, Á.; Rönnberg, S. Measurements and Modeling of the Frequency Behavior of Residual Current Devices-from 4 Hz to 40 KHz. *Electr. Power Syst. Res.* **2022**, *209*, 108052. [CrossRef]
52. Slangen, T.M.H.; Lustenhouwer, B.R.F.; Ćuk, V.; Cobben, J.F.G. The Effects of High-Frequency Residual Currents on the Operation of Residual Current Devices. *Renew. Energy Power Qual. J.* **2021**, *19*, 67–72. [CrossRef]
53. Espín-Delgado, Á.; Rönnberg, S.; Sudha Letha, S.; Bollen, M. Diagnosis of Supraharmonics-Related Problems Based on the Effects on Electrical Equipment. *Electr. Power Syst. Res.* **2021**, *195*, 107179. [CrossRef]
54. Mingotti, A.; Costa, F.; Pasini, G.; Peretto, L.; Tinarelli, R. Modeling Capacitive Low-Power Voltage Transformer Behavior over Temperature and Frequency. *Sensors* **2021**, *21*, 1719. [CrossRef]
55. Duan, R.; He, J.; Guo, C.; Zhou, F. Supraharmonics Transfer Characteristics of Transformer. In Proceedings of the IEEE 16th Conference on Industrial Electronics and Applications (ICIEA), Chengdu, China, 1–4 August 2021; pp. 1226–1231.
56. Yaghoobi, J.; Alduraibi, A.; Martin, D.; Zare, F.; Eghbal, D.; Memisevic, R. Impact of High-Frequency Harmonics (0–9 KHz) Generated by Grid-Connected Inverters on Distribution Transformers. *Int. J. Electr. Power Energy Syst.* **2020**, *122*, 106177. [CrossRef]
57. Zhang, Y.; Fang, J.; Lin, F.; Ruan, Z.; Zhang, W.; Chen, Y. Supraharmonics Transmission Characteristics in Three Phase Transformer. *Dianwang Jishu/Power Syst. Technol.* **2020**, *44*. [CrossRef]
58. Sefl, O.; Prochazka, R. Investigation of Supraharmonics' Influence on Partial Discharge Activity Using an Internal Cavity Sample. *Int. J. Electr. Power Energy Syst.* **2022**, *134*, 107440. [CrossRef]
59. Novitskiy, A.; Schlegel, S.; Westermann, D. Positive Sequence Impedances of LV Sector-Shaped Cables in the Frequency Range 2 to 9 KHz. In Proceedings of the IEEE PES Innovative Smart Grid Technologies Europe: Smart Grids: Toward a Carbon-Free Future, ISGT Europe 2021, Espoo, Finland, 18–21 October 2021.
60. Sefl, O.; Prochazka, R. Study on Aging Rate of XLPE and Its Nanocomposites under Nonstandard Voltage Stresses. In Proceedings of the Annual Report Conference on Electrical Insulation and Dielectric Phenomena, CEIDP, Vancouver, BC, Canada, 12–15 December 2021; Volume 2021.
61. Espin-Delgado, A.; Ronnberg, S.K. Modeling and Analysis of Supraharmonic Propagation for Stochastic Studies. *IEEE Trans. Power Deliv.* **2022**, *37*, 4899–4910. [CrossRef]
62. Zhou, H.; Gui, Z.; Zhang, J.; Zhou, Q.; Liu, X.; Ma, X. A Quantification Method for Supraharmonic Emissions Based on Outlier Detection Algorithms. *Energies* **2021**, *14*, 6404. [CrossRef]
63. Sandrolini, L.; Mariscotti, A. Impact of Short-Time Fourier Transform Parameters on the Accuracy of EMI Spectra Estimates in the 2–150 KHz Supraharmonic Interval. *Electr. Power Syst. Res.* **2021**, *195*, 107130. [CrossRef]
64. Frigo, G.; Braun, J. Supraharmonic Dynamic Phasors: Estimation of Time-Varying Emissions. *IEEE Trans. Instrum. Meas.* **2022**, *71*, 1–11. [CrossRef]

65. Mendes, T.M.; Ferreira, D.D.; Silva, L.R.M.; Khosravy, M.; Meyer, J.; Duque, C.A. Supraharmonic Estimation by Polyphase DFT Filter Bank. *Comput. Electr. Eng.* **2021**, *92*, 107202. [CrossRef]
66. Erhan, V.; Slangen, T.M.H.; Ćuk, V.; Cobben, J.F.G.; van Wijk, T. Measurement and Analysis of the Low Voltage Network Impedance in the Supraharmonic Range. In Proceedings of the 20th International Conference on Harmonics & Quality of Power (ICHQP), Naples, Italy, 29 May–1 June 2022; pp. 1–6.
67. Carpinelli, G.; Varilone, P.; Sikorski, T.; Rezmer, J.; Kostyła, P.; Bracale, A. Accurate and Fast Parallelized Assessment of Waveform Distortions in Presence of Low and High Frequency Spectral Components. In Proceedings of the 20th International Conference on Harmonics & Quality of Power (ICHQP), Naples, Italy, 29 May–1 June 2022; pp. 1–6.
68. Khokhlov, V.; Meyer, J.; Grevener, A.; Busatto, T.; Ronnberg, S. Comparison of Measurement Methods for the Frequency Range 2–150 KHz (Supraharmonics) Based on the Present Standards Framework. *IEEE Access.* **2020**, *8*, 77618–77630. [CrossRef]
69. Ritzmann, D.; Lodetti, S.; de La Veg, D.; Khokhlov, V.; Gallarreta, A.; Wright, P.; Meyer, J.; Fernandez, I.; Klingbeil, D. Comparison of Measurement Methods for 2–150-KHz Conducted Emissions in Power Networks. *IEEE Trans. Instrum. Meas.* **2021**, *70*, 1–10. [CrossRef]
70. An, Z.; Shen, M.; Wang, T. Supraharmonics Measurement Based on Hybrid Online Measurement and Offline Analysis. In Proceedings of the 5th International Conference on Energy, Electrical and Power Engineering (CEEPE), Chongqing, China, 22–24 April 2022; pp. 1095–1099.
71. Istrate, D.; Amaripadath, D.; Toutain, E.; Roche, R.; Gao, F. Traceable Measurements of Harmonic (2 to 150) KHz Emissions in Smart Grids: Uncertainty Calculation. *J. Sens. Sens. Syst.* **2020**, *9*, 375–381. [CrossRef]
72. Shen, M.; An, Z.; Wang, T.; Zhou, S.; Tao, S. Supraharmonics Detection Algorithm Based on Bimodal Spectral Line Interpolation Algorithm. In Proceedings of the IEEE 4th Conference on Energy Internet and Energy System Integration: Connecting the Grids Towards a Low-Carbon High-Efficiency Energy System, EI2 2020, Wuhan, China, 30 October–1 November 2020; pp. 4043–4046.
73. Wang, Y.; Xu, Y.; Tao, S.; Song, X.; An, Z.; Wang, T. Combined Equidistant Sampling Method of Supraharmonics. *Dianli Xitong Zidonghua/Autom. Electr. Power Syst.* **2020**, *44*, 161–170. [CrossRef]
74. Serov, A.N.; Dolgacheva, E.A.; Shatokhin, A.A.; Novitskiy, A.; Schlegel, S.; Westermann, D. Comparative Analysis of Digital Frequency Measurement Methods for Power Networks. In Proceedings of the 3rd International Colloquium on Intelligent Grid Metrology, SMAGRIMET, Virtual Event, 20–23 October 2020; pp. 7–14.
75. Wang, Z.; Li, Q.; Jiang, J.; Zhang, H.; Zheng, C. A Measurement Method of Supraharmonics Based on Partial Sampling and Hybrid Segmentation. *Dianwang Jishu/Power Syst. Technol.* **2021**, *45*, 2526–2532. [CrossRef]
76. Wang, Y.; Xu, Y.; Tao, S.; Siddique, A.; Dong, X. A Flexible Supraharmonic Group Method Based on Switching Frequency Identification. *IEEE Access.* **2020**, *8*, 39491–39501. [CrossRef]
77. An, Z.; Shen, M.; Li, Y.; Feng, D.; Tao, S. On-Line Detection Method of Supraharmonic in Distribution Network Based on Identification of Switching Frequency. In Proceedings of the IEEE 4th International Conference on Power and Energy Applications, ICPEA, Busan, Republic of Korea, 9–11 October 2021.
78. Singh, G.; Auel, E.; Owens, J.; Cooke, T.; Stephens, M.; Howe, W. Detection of High Frequency Conducted Emission Using Radiated Fields. In Proceedings of the IEEE PES Innovative Smart Grid Technologies Conference Europe, Delft, The Netherlands, 26–28 October 2020; Volume 2020, pp. 334–338.
79. Liu, J.; Song, Z.; Zhou, Y.; Kong, P. Supraharmonics Measurement Algorithm Based on a Deterministic Measurement Matrix and VT-SAMP. *Dianli Xitong Baohu yu Kongzhi/Power Syst. Prot. Control* **2020**, *48*, 75–83. [CrossRef]
80. Barkas, D.A.; Ioannidis, G.C.; Kaminaris, S.D.; Psomopoulos, C.S. Design of a Supraharmonic Monitoring System Based on an FPGA Device. *Sensors* **2022**, *22*, 2027. [CrossRef]
81. Mendes, T.M.; Duque, C.A.; Manso da Silva, L.R.; Ferreira, D.D.; Meyer, J.; Ribeiro, P.R. Comparative Analysis of the Measurement Methods for the Supraharmonic Range. *Int. J. Electr. Power Energy Syst.* **2020**, *118*, 105801. [CrossRef]
82. Lodetti, S.; Bruna, J.; Melero, J.J.; Khokhlov, V.; Meyer, J. A Robust Wavelet-Based Hybrid Method for the Simultaneous Measurement of Harmonic and Supraharmonic Distortion. *IEEE Trans. Instrum. Meas.* **2020**, *69*, 6704–6712. [CrossRef]
83. Firlit, A.; Hanzelka, Z.; Piatek, K.; Barczentewicz, S.; Chmielowiec, K.; Dutka, M. Monitoring the Power Quality, Including Supraharmonics and Synchrophasors. *Prz. Elektrotechniczny* **2020**, *96*, 59–62. [CrossRef]
84. Bade, T.G.; Roudet, J.; Guichon, J.-M.; Kuo-Peng, P.; Sartori, C.A.F. Analysis of the Resonance Phenomenon in Unmatched Power Cables with the Resonance Surface Response. *Electr. Power Syst. Res.* **2021**, *200*, 107466. [CrossRef]
85. Wang, Y.; Luo, D.; Xiao, X.; Cao, Z.; Sun, J. Analysis on Supraharmonic Resonance Characteristics with Integration of Multiple Inverters. *Dianli Xitong Zidonghua/Autom. Electr. Power Syst.* **2020**, *44*, 192–199. [CrossRef]
86. Yalcin, T.; Kostyla, P.; Leonowicz, Z. Supra-Harmonic Band Patterns in Smart Grid. In Proceedings of the 2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe, EEEIC/I and CPS Europe, Madrid, Spain, 9–12 June 2020.
87. Zhuang, S.-Y.; Zhao, W.; Zhao, D.-F.; Huang, S.-L. A Supraharmonics Dynamic Analysis Method Based on Sliding-Window TLS-ESPRIT Algorithm. *Jiliang Xuebao/Acta Metrol. Sin.* **2020**, *41*, 475–483. [CrossRef]
88. Sandrolini, L.; Mariscotti, A. Signal Transformations for Analysis of Supraharmonic EMI Caused by Switched-Mode Power Supplies. *Electronics* **2020**, *9*, 2088. [CrossRef]
89. Espín-Delgado, A.; Rönnberg, S.K.; Bollen, M.H.J. Uncertainties in the Quantification of Supraharmonic Emission: Variations over Time. *Renew. Energy Power Qual. J.* **2020**, *18*, 36–41. [CrossRef]

90. Espín-Delgado, Á.; Sutaria, J.; de Oliveira, R.A.; Rönnberg, S. Application of Clustering and Dimensionality Reduction Methods for Finding Patterns on Supraharmonics Data. In Proceedings of the 20th International Conference on Harmonics & Quality of Power (ICHQP), Naples, Italy, 29 May–1 June 2022; pp. 1–6.
91. Salles, R.S.; de Oliveira, R.A.; Rönnberg, S.K.; Mariscotti, A. Analytics of Waveform Distortion Variations in Railway Pantograph Measurements by Deep Learning. *IEEE Trans. Instrum. Meas.* **2022**, *71*, 1–11. [CrossRef]
92. Mendes, T.M.; Ferreira, D.D.; Silva, L.R.M.; Ribeiro, P.F.; Meyer, J.; Duque, C.A. PLL Based Method for Supraharmonics Emission Assessment. *IEEE Trans. Power Deliv.* **2022**, *37*, 2610–2620. [CrossRef]
93. Xu, L.; He, Y.; Lei, C.; Qiu, J.; Deng, Q. Research on Active Filter for Supraharmonics Suppression of Power Grid. In Proceedings of the IEEE Student Conference on Electric Machines and Systems, SCEMS 2020, Jinan, China, 4–6 December 2020; pp. 735–740.
94. Jensen, P.T.; Davari, P. Power Converter Impedance and Emission Characterization Below 150 KHz. In Proceedings of the 2021 IEEE International Joint EMC/SI/PI and EMC Europe Symposium, Virtual Event, 26 July–20 August 2021; pp. 255–260.
95. *EN61000-4-3*; Electromagnetic Compatibility (EMC)—Part 3–2: Limits—Limits for Harmonic Current Emissions (Equipment Input Current ≤16 A per Phase) 2019. iTeh Standards: Newark, DE, USA, 2019.
96. *European Standard EN50160*; Voltage Characteristics of Electricity Supplied by Public Distribution Systems 2010. iTeh Standards: Newark, DE, USA, 2010.
97. *European Standard EN61000-4-15*; Electromagnetic Compatibility (EMC)—Part 4–15: Testing and Measurement Techniques—Flickermeter—Functional and Design Specifications 2011. iTeh Standards: Newark, DE, USA, 2011.
98. *European Standard EN61000-4-7*; Electromagnetic Compatibility (EMC)—Part 4–7: Testing and Measurement Techniques—General Guide on Harmonics and Interharmonics Measurements and Instrumentation, for Power Supply Systems and Equipment Connected There 2011. iTeh Standards: Newark, DE, USA, 2011.
99. *European Standard EN61000-4-30*; Electromagnetic Compatibility (EMC)—Part 4–30: Testing and Measurement Techniques—Power Quality Measurement Methods 2015. iTeh Standards: Newark, DE, USA, 2015.
100. *European Standard EN55015*; Limits and Methods of Measurement of Radio Disturbance Characteristics of Electrical Lighting and Similar Equipment 2019. iTeh Standards: Newark, DE, USA, 2019.
101. *European Standard EN50065-1*; Signalling on Low-Voltage Electrical Installations in the Frequency Range 3 KHz to 148.5 KHz—Part 1: General Requirements, Frequency 2012. iTeh Standards: Newark, DE, USA, 2012.

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