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Editorial

Power Quality of Renewable Energy Source Systems: A New Paradigm of Electrical Grids

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1. Introduction

The power quality delivered by the distribution companies to consumers has always been a relevant issue, especially to industrial consumers, where power quality is directly related to productivity. However, until a few years ago, power quality was mostly synonymous with continuity of service, and the main concern was the minimization of power interruptions. Since the last decade of the twentieth century, power quality has become a strategic issue for all sectors involved in this market, from distribution companies to consumers, with a particular emphasis on industrial consumers as well as equipment manufacturers.

The concept of power quality involves a wide range of electromagnetic phenomena that can occur in the power grid. Such changes may occur in different parts of the electrical power system, at customer facilities, or in the distribution network. In recent years, the electric power market has undergone huge transformations, electricity production has become decentralized, and consumers (who can now also be producers) have the opportunity to choose their supplier. The integration of renewable-based microgeneration systems into distribution grids has brought various disturbances to the grid (harmonics, voltage unbalance, voltage fluctuations, frequency deviations, etc.), leading to increasingly degraded power quality.

This Special Issue focuses on the analysis of the consequences that renewables-based microgeneration systems have on power networks by finding new solutions for networks management (network optimization models, efficiency, and losses), integrating consumers and micro-producers in order to keep quality parameters at high levels.

In this Special Issue, we can see that the interdisciplinarity of these issues is very present among researchers and scholars, who are well aware of the importance and impact that the new paradigm of network management brings in various domains, reflecting on the quality of the contributions submitted.

Accordingly, the papers selected for publication cover a wide range of application topics, including electrical mobility, energy storage systems, facility management and control, impact analysis of different types of renewable energy sources, with focus on wind and solar generation, in both low-voltage (LV) and medium-voltage (MV) networks.

2. A Short Review of the Contributions in This Special Issue

The development of tools and platforms to support network management has been a thematic area that has been greatly explored by several researchers in the last years. In this Special Issue, two efficient tools for acting in two different domains are presented.

In Steinschaden et al. [1], the authors address the topic of electrical mobility, providing an overview of the different EV charging stations (EVCS), integrating renewable energies

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and energy storage systems. Furthermore, technical and economic aspects between different EVCS under different load conditions are evaluated, helping the management of such systems. To achieve this goal, an effective and easy Excel®-based tool was developed. By offering various input parameters, the tool supports customer decision making. It is a tool that aims to help in the planning and management of EV solar charging stations. This tool also makes it possible to study the economic viability of the solutions found, indicating efficiency measures, leading the user to choose the most energy-efficient options. Results show that solar charging stations for private and commercial use can be designed efficiently, although they have higher investment costs than conventional ones. Furthermore, reduced consumption consequently flattens the amortization curve.

In Mannelli et al. [2], Energy Storage Systems (EES) are explored in the context of a wind park management. Discrete wavelet transform was used to decompose the power output of utility-scale wind turbines. Four-year Supervisory Control and Data Acquisition (SCADA) real data were used related to on-shore wind turbines. On one hand, the performance of different storage designs was compared in terms of ramp rate violations, showing that wavelet transform leads to a more efficient battery use. On the other hand, a suitable moving window centered on the actual sample in which the wavelet transform can be applied was generated. It has been shown that, again, the discrete wavelet transform provides a better solution than conventional approaches.

Also considering storage systems but more devoted to a control approach, the work in [3], by Mehmood et al., brings a methodology devoted to undertaking the impacts of volatility/fluctuations in energy due to wind power sources. A Voltage Source Converter (VSC)-based induction generator is controlled, coupled with a Battery Energy Storage System (BESS). The implemented Proportional Integral (PI) regulators are determined by Monte Carlo optimization. As novelty, bowtie, risk matrix, and ALARP are used for risk analysis. It resulted in a potential reduction in the risk of high fluctuations and disturbances, compliant with the standards of IEEE 519-2014 and EN 50160.

In the article by Vale et al. [4], the platform MARTINE (Multi-Agent based Real-Time INfrastruture for Energy) is presented. This platform has as its main aim simulation, emulation, and energy management for the study of problems related to buildings and smart grids. It is part of the "Real-Time Energy Management And Simulation Infrastructure For Buildings And Smart Grids", which aggregates several prototypes resulting from the research made in the GECAD research group. The paper presents the detailed structure of the platform with its various levels and features, integrating other tools developed by the research group. The results show that MARTINE enables the representation and experimentation of diverse test scenarios related to buildings and smart grid energy management, allowing for a comprehensive validation of different types of management and decision support solutions, as well as their impact on the physical resources and on communication and control actions.

In [5], Orynycz et al. present a work devoted to managing a facility, such as a hotel or a building, by determining the main sources of losses. Savings were achieved by introducing technical improvements in energy and water-consuming areas, such as replacing lighting and ventilation. The results obtained represent savings of about 20%. It was extrapolated that by replacing lighting in staircases and underground garages, as well as by replacing ventilation, savings of 68% can be achieved for lighting and ventilation.

Dawid Buła et al. [6] deals with the analysis of long- and short-term changes in power and energy generated by three types of renewable energy sources with similarly rated power operating in the same region (i.e., located no more than tens of kilometers away). The highest variability in both the short- and long-term perspectives is verified in the photovoltaic system. However, the wind farm is the source with the highest variability, with an average of 15-min power—almost 2 times higher than the other sources. Despite the results not revealing any power quality problems and the limits imposed by standards on THD or voltage variability not being exceeded, the variability of power generated by renewable energy sources remains a valid issue.

The work presented in [7] proposes a robust pitch angle control system for wind turbine power using a proportional–integral–derivative (PID) controller. Ant colony optimization, particle swarm optimization, and classical Ziegler–Nichols algorithms are used for tuning the PID controller parameters to obtain within rated stable output power of wind turbines from fluctuating wind speeds. The proposed model presents several benefits which include the simplification of implementation, the tolerance of turbine parameters and several nonparametric uncertainties, and the robust control of the generator output power with wind-speed variations.

Ref. [8] quantify and evaluate the impact of PV injection on the PQ of a low-voltage (LV) network by applying a statistical analysis through hypothesis testing for the mean comparison of populations of parameters with and without a PV system. The effects of PV power injection and load demand at the point of common coupling on PQ are also monitored. The model includes the selection and monitoring of PQ, using a matrix to classify data with similar load and PV power injection conditions, and applying the Wilcoxon rank-sum test. The results obtained by the Wilcoxon rank-sum test indicate that PV injection affects between 20 and 40% of scenarios of the PQ parameters analyzed. Specifically, PV injection can cause an average variation in Vrms (+1.0%), TDD (−4.2%), THDV (+32.4%), and VH5 (+16.5%), with a confidence level of 95%, for the load-interval of 0–2.5% and PV injection intervals of 0 to 40%.

In [9], Shimi Sudha Letha et al. evaluate an existing Swedish MV electrical network and study the pattern of supraharmonic resonance and the propagation of supraharmonics. With this work, the knowledge about the transfer impedance and resonant peaks in the MV network, the possible amplification, and the expected levels of these emissions in the grid can be predicted. In addition, the proposed work would help the standardization committee to set compatibility levels or emission limits for these non-intentional emissions in the MV network.

3. Conclusions

The works published in the scope of this Special Issue address the topic of the power quality of renewable energy systems through a complementary view on several of the most important topics in this domain. The incorporation of renewable energy sources in electrical vehicles charging stations planning and management is analyzed, contributing to the quality of power in the context of such synergy. The contribution of energy storage systems to help manage the fluctuations in wind-based generation is addressed, including a control and risk management perspective. The management of renewable energy integration in different facilities is studied, including the analysis of losses in facilities and the interaction between physical and software components in buildings. Long- and short-term changes in power and energy generated by different types of renewable energy sources are analyzed, and the impact of PV injection on the low-voltage and medium-voltage networks is evaluated.

In summary, this Special Issue provides a broad spectrum of works covering essential and complementary topics in the scope of power quality considering the increasing penetration of renewable energy sources. The views presented in this Special Issue are relevant for a more comprehensive understanding of the already achieved solutions in this domain but also act as a catalyzer for the many contributions that are still needed in future research and development.

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