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Power Quality and Harmonics Issues of Future and Smart Grids

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EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: POWER QUALITY AND HARMONICS ISSUES OF FUTURE AND SMART GRIDS

Penetration of grid connected renewable energy systems and smart loads based on power electronics technology has been increasing in low and medium voltage distribution. *Power Electronics* is a key technology for distribution networks which can transfer electrical power from renewable energy sources to grids or generate regulated frequency and/or voltage for different loads such as variable speed drives and battery chargers. New demands for a) cost and size reduction, b) performance and quality improvement and c) flexibility on power management have promoted power electronics applications extensively in industrial, commercial and residential sectors such as transportation, utility and home appliances in recent years.

Harmonics are integer multiples of the fundamental signal (voltage or current at 50 or 60 Hz). They have short and long term effects on grids and grid-connected electronics as well as power electronics equipment, such as malfunction, failure and losses. These reduce the reliability, lifetime and efficiency of the electricity networks. The main drawback of power electronics systems is low (below 2 kHz) and/or high (above 2 kHz) frequency harmonics emissions. Power electronics converters with Wide Band Gap (WBG) switches generate more high frequency harmonics than the conventional switches due to their ability to operate at higher switching frequencies. They can increase and shift the harmonics emissions from 0-2 kHz to the higher frequency ranges (2-150 kHz) and create new power quality problems of the current and future electricity networks.

This Special Section in IEEE ACCESS focuses on emerging harmonics and power quality issues of future and smart grids. The main objective of this Special Section is to bring together researchers from both academia and industry to share the most recent power quality and harmonics issues of grid-connected power electronics systems.

The following four articles addressed different forms of power quality issues in distribution networks with high penetration of grid-connected power electronics converters.

In "Harmonic emissions of three-phase diode rectifiers in distribution networks," by Zare *et al.*, harmonic emissions have been changed in distribution networks, with respect to frequency range and magnitude, due to the penetration of modern power electronics systems. Two new frequency ranges (2-9 and 9-150 kHz) have been identified as new disturbing frequency ranges affecting distribution networks. This article presents the effects of grid-connected three-phase systems with different front-end topologies: conventional, small dc-link capacitor, and electronic inductor. A power converter with a small dc-link capacitor can create a resonant frequency with the line impedance below and above 1 kHz depending on the grid configurations. The resonant effects depend on many factors, such as load power levels, filter types, and the number of parallel drives. These issues can affect the grid current harmonics and power quality of the distribution networks. Analyses and simulations have been carried out for three different topologies and the results have been verified by experimental tests at system level. Current harmonic emissions have been considered for 0-2, 2-9, and 9-150 kHz frequency ranges.

In "DC microgrid technology: system architectures, ac grid interfaces, grounding schemes, power quality, communication networks, applications, and standardizations aspects," Kumar *et al.*, discuss how, in order to meet to meet the fast-growing energy demand and, at the same time, tackle environmental concerns resulting from conventional energy sources, renewable energy sources are integrated in power networks to ensure reliable and affordable energy for the public and industrial sectors. However, the integration of renewable energy in the ageing electrical grids can result in new risks/challenges, such as security of supply, base load energy capacity, seasonal effects, among other issues. Recent research and development in microgrids have proved that microgrids, which are fueled by renewable energy sources and managed by smart grids (use of smart sensors and smart energy management system), can offer higher reliability and more efficient energy systems in a cost-effective manner. Further improvement in the reliability and efficiency of electrical grids can be achieved by utilizing DC distribution in microgrid systems. DC microgrid is an attractive technology in the modern electrical grid system because of its natural interface with renewable energy sources, electric loads, and energy storage systems. In the recent past, an increase in research has been observed in the area of DC microgrids, which brings this technology closer to practical implementation. This article presents the state-of-the-art DC microgrid technology that covers AC interfaces, architectures, possible grounding schemes, power quality issues, and communication systems. The advantages of DC grids can be exploited in many applications to improve their reliability and efficiency. This article also discusses benefits and challenges of using DC grid systems in several applications, highlights the urgent need of standardizations for DC microgrid technology, and presents recent updates in this area.

Kontos *et al.* in ''High order voltage and current harmonic mitigation using the modular multilevel converter STATCOM,'' explain that, due to the increase of power electronic-based loads, the maintenance of high power quality poses a challenge in modern power systems. To limit the total harmonic distortion in the line voltage and currents at the point of the common coupling (PCC), active power filters are commonly employed. This article investigates the use of the multilevel modular converter (MMC) for harmonics mitigation due to its high bandwidth compared with conventional converters. A selective harmonics detection method and a harmonics controller are implemented, while the output current controller of the MMC is tuned to selectively inject the necessary harmonic currents. Unlike previous studies, the focus on the experimental verification of the active filtering capability of the MMC. For this reason, an MMC-based double-star STATCOM is developed and tested for two representative case studies, i.e., for grid currents and PCC voltage harmonics. The results verify the capability of the MMC to mitigate harmonics up to the thirteenth order, while maintaining a low effective switching frequency and thus, low switching losses.

In the article, ''A hidden block in a grid connected active front end system: modelling, control and stability analysis,'' by Sharma *et al.*, the authors discuss how an LCL filter utilized in an active front end (AFE) converter can generate significant resonance, which can affect quality and stability of the system. Thus, a proper active or passive damping technique and/or a suitable controller is required to be designed for the converter. The duty cycle constraint—though inevitable in practical inverter systems—is often ignored in most of the existing literature. The effects of measurement noise on filter control system performance must be considered and evaluated under different conditions. Finally, almost all inverter control systems are implemented digitally using microcontrollers. Consequently, the effects of sampling on control system stability and performance should be evaluated as well. Thus, this article presents stability analysis of an AFE converter-based filter design with a complete practical system configuration, including saturation and sampling blocks and measurement noises. Mathematical analysis and simulations have been carried out to validate the proposed method.

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