Guest editorial: power quality and protection in renewable energy systems and microgrids

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Guest Editorial: Power Quality and Protection in Renewable Energy Systems and Microgrids

Electric power grids are facing unprecedented challenges due to the recent rapid development of renewable energy technologies leading to an increase in electric transportation and requirement for advance protection schemes, high reliability and efficient power quality. Intelligent microgrids and smart grid are key to increase the use of renewable energy and integration of electric vehicles with the grid. However, due to the intermittent and distributed nature of renewable energy sources and electric vehicles, and also the crucial role of power electronic converters for grid interconnection, both power quality and protection issues are becoming challenging issues affecting the development of smart grid technology. Advancement of AC, DC and shipboard microgrids has introduced new challenges mainly regarding intelligent control, power quality and protection. Recognizing that many academic, governmental, and industrial research centers across the globe are collectively working to the future power quality problems of microgrids and smart grids, the IET set out to collect this activity in one place so that the interested participant might get a sense of the breadth of the work underway. This issue presents seven papers that provide some data points within the spectrum of ongoing research and development. These seven papers were selected from the fifteens that were submitted; all accepted papers have undergone multiple reviews. You will see some common themes within these papers, including: Power quality improvement of renewable energy systems, protection design for AC and DC microgrids, stability improvement of microgrids and advanced control strategy for grid-connected inverters. All of these attributes are vitally important to power quality and protection in microgrid applications.

In the paper 'Extended High-Gain Observer-Based DC-link Voltage Regulation in Dual-Stage Grid-connected PV System under Normal and Abnormal Condition' by Errouissi et al., the authors consider the design and experimental validation of feedback control along with high-gain observer to regulate the DC-link voltage in dual-stage grid-tied photovoltaic (PV) system. High observer gain is compulsory for the composite controller to ensure a fast disturbance rejection and nominal performance recovery. The idea is to use a large observer gain only during transients; however, in the steady-state regime, the observer gain can be reduced to mitigate the effect of the measurement noise. The performance of the composite controller was experimentally evaluated for both balanced and unbalanced grid voltages. Test results showed good accuracy, fast disturbance rejection, and negligible sensitivity to the measurement noise.

In the paper 'Study of the Communication System Effects on the Secondary Control Performance in Microgrids' by Tavassoli et al., the authors study the communication system effects on the secondary control performance in microgrids. This work aims at studying this effect in the case of a typical AC microgrid in the islanded mode. For this purpose, stochastic delay models for industrial communication protocols are combined with a simulation model of the microgrid together with its control system up to the secondary level. The results illustrate how the choice of communication technology can affect the transient response. Additionally, compensation of the control performance for the effects of communication is considered. A simple method is used to improve the control performance only by retuning the controller coefficients, without altering the standard control structure. It is shown that appropriate retuning of the secondary controller can prevent from oscillations caused by the delays and improve the power quality to some extent. The presented framework can be used for designing and verifying the combination of communication and control subsystems in microgrids.

In the paper 'Enhanced performance controller for high power wind converters connected to weak grids' by Shahparasti et al., the authors design a control scheme for high power grid-connected wind power converters, which is oriented to enhance their performance when connected to weak grids with low short circuit ratio. The proposed controller consists of an outer current reference generation loop and an inner current loop, working in stationary reference frame. In the outer loop, the current reference is calculated to comply simultaneously with the grid code requirements, the control of the DC link, and the operational safety margins of the converter during faulty conditions. On the other hand, the proposed inner current loop consists of a proportional resonant controller, a capacitor voltage feedforward and a phase shifter. Moreover, simulation results considering different weak grid conditions, as well as experimental results of a full-scale 4 MW converter test-bench are presented to validate the good performance of the proposed method.

In the paper 'Distributed LMI-based control of heterogeneous microgrids considering fixed time-delays and switching topologies' by Raeispour et al., the authors present a a distributed cooperative control protocol for inverter-based islanded microgrids (MG). The MG consists of distributed generation units and battery energy storage systems (BESSs). Despite most of the reported works which assumed the ideal conditions and did not considered any delay in information exchange between local controllers, the authors design a controller for the restoration of voltage and frequency fluctuations, achieving accurate active power-sharing and state of charge (SoC) balancing of BESS in the presence of fixed communication time-delay and changing topology of the network. The stability analysis is performed based on the Lyapunov–Krasovskii method, and sufficient conditions are presented based on linear matrix inequalities (LMIs) to guarantee the system stability and to reach consensus under arbitrary switching topologies. The upper bound of communication delay that the system can tolerate is given, too. Finally, to evaluate the performance of the control laws, offline digital time-domain simulation studies are performed on a test MG system in MATLAB/Simulink, and simulation results reveal the effectiveness, efficiency, authenticity and accuracy of the proposed method in regulating MG voltage and frequency and providing accurate proportional active power-sharing and SoC balancing.

In the paper 'Active power optimization for wind farms under generator inter-turn short-circuit fault' by Kuichao Ma et al., the authors study the effect of inter-turn short-circuit fault of the stator winding which is one of the most common faults of asynchronous generators and often found in doubly-fed wind turbines. The improper treatment methods will lead to unnecessary power loss or further damage to the insulation layer. To solve this problem, an Optimal Power Dispatch Strategy (OPDS) is proposed which combines the control at the turbine level and the optimization at the farm level. At the turbine level, the faulty turbine is down-regulated based on the principle that the fault current does not exceed the rated current. At the farm level, Particle Swarm Optimization algorithm is used to optimize the power references considering wake effects to compensate for the power loss caused by the down-regulated turbine. The effectiveness of OPDS is illustrated in the case study by comparing with two usually used strategies, one takes Proportional Dispatch Strategy (PDS) and directly shuts down the faulty turbine under fault, the other takes PDS but ignores the fault. The results show that OPDS can minimize power loss under the premise of protecting the faulty turbine. The study contributes to reduce the maintenance costs of wind farms and improve the operational capability of the wind turbine under fault conditions.

In the paper 'Synchrophasor based islanding detection for microgrids using moving window principal component analysis and extended mathematical morphology' by Micky R et al., the authors propose a zero non-detection zone, the reliable and precise islanding detection method for data-intensive grid-connected MG. Voltage phasors, frequency and rate of change of frequency from various locations are processed through moving window principal component analysis (MWPCA) cascaded with extended mathematical morphological filter (EMMF). MWPCA reduces data dimensionality and Q statistics obtained are passed to EMMF, which acts as a non-linear filter. Further, the islanding detecting factor identified all IEs within the prescribed time limit with minimum false alarms. Accuracy, precision and reliability demonstrated by using a case study model using DIgSILENT are encouraging. It can be adopted by operators to run MG securely. Further, testing of the proposed method on a typical utility feeder shows promising results.

In the paper 'Low-voltage ride-through operation of grid interfaced solar PV system enabling harmonic compensation capabilities' by Priyank Shah et al., the authors present a robust Kalman filter-based multifunctional control strategy, to enable wide-scale utilisation of the grid-interfaced solar energy conversion system (SECS). The presented control technique offers multifunctional features such as unity power factor, harmonics mitigation, reactive power compensation along with ride through operation under balanced and unbalanced low-voltage faults in the distribution grid. Under fault in the grid side area, the DC–DC converter is controlled in a way that it reduces the active power injection and restricts the inverter currents within its maximum current limit. Based on the depth of grid voltage sag, reactive power supply to the grid is adaptively adjusted, as recommended by IEEE 1547-2018 standard. To minimise the inverter losses, adaptive DC link voltage is introduced, which adapts the DC link voltage in proportion to the grid voltages. Simulation results exhibit the efficacious of the presented robust control strategy in achieving multifunctional features such as harmonics mitigation, grid currents balancing feature and reactive power requirement, under unbalanced line to ground (L-G) and double line to ground faults. Test results demonstrate the satisfactory performance for diverse operating scenarios such as imbalanced currents in the load side network, SECS to DSTATCOM mode and vice-versa, and L-G fault.

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