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Editorial

Power Management for Distributed Generators Integrated System

Md Shafiul Alam

Applied Research Center for Environment & Marine Studies, Research Institute, King Fahd University of Petroleum & Minerals (KFUPM), Dhahran 31261, Saudi Arabia; mdshafiul.alam@kfupm.edu.sa

1. Introduction

The integration of distributed generation systems, including intermittent solar photovoltaic (PV) and wind, has a significant impact on the power system. Several challenges, e.g., low inertia, voltage fluctuation, power oscillation, power quality degradation, and energy imbalance, arise due to the high-level integration of solar and wind energy. The challenges of grid integration for solar and wind systems can be minimized if sufficient energy storage devices, including batteries and supercapacitors, are installed. However, the installation of these energy storage devices creates new control challenges due to the interface of the power electronic converters. New control, modeling, and energy-management algorithms must therefore be developed using cutting-edge technologies to address these difficulties. To reduce the negative effects on the main grids, a vast variety of energy sources, loads, and energy storage devices are carefully controlled and managed.

This Special Issue explores challenges and opportunities for the integration of distributed generators (DGs) in both grid-connected and islanded modes. It also deals with novel power management, frequency control, and voltage control for DG-integrated systems. A wide range of topics for energy storage systems is covered, including state of charge management, energy storage life cycle improvement, energy storage hybridization, and cost minimization. The control and operation of AC/DC and hybrid microgrids are discussed. Mathematical and heuristic optimizations and their applications in DG integrated systems are explored.

2. Overview of Challenges and Opportunities

In the last twenty years, the utilization of renewable energy sources including solar and wind has gained importance all over the world. Although the negative environmental impacts are reduced with renewable energy integration, several challenges arise due to the replacement of conventional synchronous generators. Especially, the disconnection of synchronous generator reduces the inertia of the system which badly affects the frequency control. The integration of distributed generators causes certain additional technical problems, including high uncertainties, poor fault ride-through capabilities, high fault current, inadequate generation reserves, and poor power quality [1]. Due to the varying nature of wind and sunlight, renewable energy sources such as solar and wind are quite unreliable. Modern technologies are used to address those concerns, including various control and optimization methods, energy storage systems, and fault current limiters. The grid integration challenges of solar and wind energy systems are summarized in [1]. For both wind and solar energy integration, frequency variation, power quality degradation, and uncertain outputs are the main challenges. The possible solutions are inertia emulation, the operation of solar and wind systems with de-loading, the first power reserve, and energy-storage-based techniques.

Among the several energy storage devices, supercapacitors have a very high power density which could improve the frequency stability of the low inertia power networks. Thus, in [2], the frequency stabilization of AC microgrids clusters is improved with a

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fractional-order controller approach. This approach maintains the frequency of microgrid clusters consisting of aqua electrolyzers, solar thermal power, solar PV, diesel generators, wind system, and fuel cells. The tuning of fractional-order supercapacitor is facilitated with a complete small-signal model of the microgrid clusters. The integral square error of the step response of the developed small-signal model is minimized with the whale optimization technique. The developed supercapacitor controller is used to test how the system responds to various contingencies, such as small, large, and repeated disturbances, as well as intermittent renewable energy supply to the system. In controlling system frequency during disturbances, the proposed methodology is more efficient than the conventional one.

The reference [3] summarizes the impacts of distributed generators and energy storage systems on the electrical power system. Distributed generators and energy storage units have a considerable impact on the electric power system mode's parameters, particularly the voltage profile and losses. It is advised to connect DG units to supply electrical energy to remote consumers to reduce the amount of power received from other sources. However, violation of the maximum output limit of DG units should not be allowed, so that the increased current in the branch cannot cause power to flow in the opposite direction. The widespread adoption of DG units, especially if it is based on unregulated energy sources, may cause a demand–supply imbalance or necessitate the installation of a large number of DG units to guarantee sufficient reserve power, which increases the DG systems installation costs. This problem can be resolved by a combined operation of the energy storage system (ESS) and DG units. It is shown that the DG units can participate in voltage regulation to lower transmission losses and enhance the voltage profile. In addition, the power electronic converters interfaced with the DG units can help regulate the reactive power. Modern research has focused on applying and developing a variety of optimization techniques, including heuristic algorithms to help find the optimal size and locations of DG units in AC/DC microgrid-integrated power networks.

For DG-integrated microgrids to operate at their best, it is crucial to plan and manage energy efficiently [4]. An integrated distributed planning model with demand-side management could play important role in reducing energy imbalance and allocation costs. Due to the unpredictable nature of the integration of distributed generation resources, the risk of recovering potential future expenses can be minimized by estimating and forecasting distributed energy precisely with several modern artificial intelligence techniques.

In a nutshell, although researchers and industrial personnel have developed several techniques to facilitate more DG integration, there are still scopes to further improve power quality, bus voltage, power management, and so on. Thus, this Special Issue intends to further study several research topics, including the control of power electronic converters for DG integration, integration of energy storage devices with AC/DC microgrids, and power management of systems integrated with renewable energy sources (such as PV, wind, and so on), control of an AC/DC microgrid, optimization and advanced energy management algorithms, modeling and control of DG, and machine learning for DG.

3. Conclusions

Power management, voltage control, and state of charge management of energy storage devices are challenging tasks for power electronic-based distributed generators integrated systems. The complexities increase with the increase of the number of distributed generators such as solar PV and wind integration. Several approaches, such as decentralized, centralized, distributed, hierarchical, and consensus-based methods, are developed to tackle control challenges. Both rule- and optimization-based power management algorithms are developed. Energy storage devices are utilized to reduce fluctuation and support system inertia. Nevertheless, the development of new, efficient, cost-effective solutions is a continuous process in the development of smart power systems. Thus, the development of new approaches and cutting-edge technologies is needed, whereas existing approaches need to be improved in order to facilitate more distributed generator integration. There is room for fresh research results that could bridge the knowledge gap and boost community confidence to facilitate the green effort of more renewable energy integration.

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