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Editorial

Advancing Grid-Connected Renewable Generation Systems

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1. Introduction

If we look at the history of renewable energy sources (RESs), how it all began, and how rapidly they continue to develop, it can be argued that one of the main reasons is due to the rapid improvements in power electronics technology in interfacing the renewable source to the grid. Power electronics play an important role and are completely responsible for many important tasks, as well as having different power ranges where at a high penetration-level the RESs may cause instability if not carefully designed and implemented into the grid. In other words, power electronics have to efficiently harvest the maximum energy from the renewable energy sources/systems and then make it suitable, sustainable, and resilient, as well as transfer it to the power grid. Here it is important to apply suitable control techniques for such grid-connected systems, as it can be a challenge for the traditional grid to integrate the additional amount of electricity from an unpredictable and unsteady renewable energy resource. Contemporary grid-connected renewable generation systems stand in need of further advances in techniques for the utilization of renewable energy. This Special Issue focuses on challenging and advanced control methods to integrate RESs into power grid systems to enhance the performance of grid-connected renewable energy systems. This special issue on Advancing Grid-Connected Renewable Generation Systems contains the 14 papers we accepted; some of the most auspicious papers selected from those submitted. The selected papers have been organized into the followings groups, which are all very timely in renewable energy systems:

Part 1. → Control Techniques and AI (6 papers)
Part 2. → Power Converters (5 papers)
Part 3. → Rural Applications and Power Quality (3 papers)

2. Part 1: Control Techniques and AI

The authors in [1] present a solution for inverter-based generation (IBG) systems using virtual synchronous generator (VSG) control, which controls the external characteristics of power electronic interfaces (PEIs) to emulate the concept of synchronous generators (SGs), in order to replace the traditional SGs and to establish the modern power systems. For the power system, the main challenges are stability and reliability, because renewable energy generation (REG) is unpredictable or depends on meteorological conditions and the PEIs suffer from being almost inertia-less.

The main tendencies of grid-connected photovoltaic (PV) systems are decreased price and size, e.g., by reducing the number of passive elements of DC-DC converters, which in turn might enhance the efficiency and reliability of the whole PV system. Accordingly, in [2], the authors represent a grid-connected PV system based on a differential step-up inverter working as an adaptive DC–AC inverter topology providing voltage boost capability and it could be one of the future candidates for many DC–AC electrical energy conversion applications. The main objective of the paper is a control-oriented full-order model and the design of a control strategy for a PV-fed grid-tied boost inverter as a whole system is presented without any decoupling between the two loops in the control system.

The authors of [3] raised the issue of soiling in PV installations. The soiling will provoke a reduction in the performance of the PV plant, due to energy losses and degradation of the panels. This research has predicted the losses due to dust soiling in a photovoltaic plant, taken into account metrological conditions depending on installation placement of the PV plant, the short-circuit current (Isc), the module temperature (Tpanel), global irradiation (Iglo), relative humidity (RH), ambient temperature (Tamb), atmospheric pressure (P), and solar altitude (α) by applying artificial intelligence techniques.

Renewable energy sources, especially photovoltaic systems and wind turbines, are directly dependent upon unpredictable meteorological conditions. In the case of photovoltaic systems, the main challenge for scientists and design engineers is partial shading conditions. The work in [4] presents a new global maximum power point tracking (GMPPT) method, which is based on a machine-learning algorithm and seems to be effective. The proposed method has the preference that it does not require knowledge of either the operational characteristics of the PV modules comprising the PV system or the PV array structure.

The main goal of micro-grids is to improve power reliability and power quality, increase system efficiency and provide the possibility of grid-independence to individual end-users. In [5] is proposed a novel control method intended for compensating the micro-grid power factor and load asymmetries by utilizing advanced functionalities enabled by grid-tied inverters of photovoltaics (PV) and energy storage system (ESS). In addition, a micro-grid central controller (MGCC) allows at the same time to deliver reactive power (RP) and provide phase balancing (PB) services using grid-tied inverters.

Power electronic interfaces (PEI) connect the link between renewable generation technologies and the power grid/consumers. Despite the importance, the power electronic interfaces have a major disadvantage which is the absence of inertia. The long-term inertia will strongly affect the indicator, which is used for assessing the strength of the power system. In [6] the authors present an adaptive parameter tuning method to determine load deviations. In the beginning, the concept and implementation of the virtual synchronous generator (VSG) were explored performing an inertia response (IR), and the primary frequency responses (PFR) were seen. Next, a simplification of the transfer function for the dynamic system of the stand-alone VSG-PEI was investigated and completed according to the distributed poles and zeros in the overall system.

3. Part 2: Power Converters

The next important step towards an energy-efficient world is the use of new materials, such as wide bandgap (WBG) semiconductors like silicon carbide (SiC) and gallium nitride (GaN), the advantages of which are increased energy efficiency, higher power density, and cooling density, thanks to an improved electrical and thermal conductivities. WBG transistors are expected to be applied to a wide range of power conversion applications, which nowadays are dominated by the traditional silicon (Si)-based power devices. In [7] the authors present a comparative analysis using a high-power converter with and without a light-load upgrade circuit and the paper includes the calculation of total (switching and conduction) losses of a high-power Si–IGBT converter and a low power SiC–MOSFET converter. In addition, the utilization of GaN transistors in such applications is considered.

In [8], the authors discuss the dilemma between a transformer and transformerless grid-connected photovoltaic system. On one side, the transformer makes the system bulky, heavy, and increases the cost and losses, which in turn also reduces the efficiency by 1% or 2%. Correspondingly, transformerless systems are used to avoid the mentioned disadvantages. Nonetheless, the main drawback of transformerless topologies is the presence of a leakage current between the terminals of the photovoltaic cell and the physical ground of the grid. The main efforts in [8] are leakage current reduction in transformerless inverters. Description and analysis of the common-mode voltage and its influence on the value of the leakage current are performed in the paper. At last, it is also shown that the modulation strategy is a critical factor in reducing the leakage current.

The modular multilevel converter (MMC) is one of the promising candidates from the family of multilevel converters to be applied in PV system power conversion. Its promising advantages are quality of output performance, high modularity, simple scalability, and low voltage and current rating demand for the power switches. In [9] the authors investigate the MMC with an advanced submodule (SM) capacitor, which is a key element in the MMC. A practical method for sizing the capacitors is proposed, which takes into account the grid-fault-ride-through operation of the MMC, impact on the MMC control system, and also the aging mechanism of capacitors.

One of the options to reduce leakage currents in grid-connected transformerless photovoltaic (PV) systems is the implementation of a proper common-mode voltage (CMV) control; in turn, CMV depends on the converter topology and modulation strategy. In [10] the authors explore a new split-input quasi-Z-source inverter (qZSI) inductor which is divided into two parts for CMV reduction. On one side, all CMV reduction strategies for voltage source inverter (VSI) can be used directly here with an appropriate shoot-through (ST) state usage. On the other side, the proposed split-inductor qZSI shows the same operating features as the original qZSI. Finally, the proposed method can be extended to other impedance source converters of a similar design.

Understanding the thermal-mechanical stress in semiconductors is becoming very important. As semiconductors heat up, thermal expansion is induced, mechanical stresses can cause either failure or a change in the performance due to changes in electron transport in the material. In [11] the authors experimentally examine loss and thermal models of power semiconductors, shown by an example of an H-bridge circuit for emulating various loading conditions taking into consideration influential factors like power factor, current amplitude, and fundamental and switching frequencies for the loading condition in order to obtain the desired thermal stress.

4. Part 3: Rural Applications and Power Quality (3)

With the rapid growth of the large-scale wind power industry, new innovations in the off-grid sector can bring significantly localized economic and environmental changes, but small-scale wind energy is still remarkably little investigated for rural areas. The work in [12] presents a novel genetic algorithm (GA)-based operational method, which is developed to maximize the local usage of wind energy. The GA is used as an optimization strategy to determine the operational scheme for a multi-vector energy system, and as a result this provides an alternative to battery energy storage and the method can be widely applied to wind-rich rural areas.

Community-based Microgrid (CM) is a new approach for operating the electric grid, carried out by local renewables and distributed energy resources, such as energy storage, in order to achieve a more sustainable, secure, and cost-effective energy system. In [13] the authors focus on the rural community using PV and a storage-based microgrid system. They propose an economically advanced operation strategy, which is suitable for a "self-generated self-use and surplus electricity to the utility" mode. In addition, an annual time-scale parameter optimization method based on particle swarm optimization (PSO) is presented.

At present, in distributed power generation systems, power quality might be a serious problem and need to be taken care of in order to apply an efficient system with a high power quality (PQ). In [14] the authors have developed deep learning-based techniques for power quality disturbance (PQD) classification in order to extract grid features automatically and simultaneously analyze all nonlinear, non-stationary synthetic, and operational signals.

The idea combines the combination of phase space reconstruction (PSR) with convolutional neural networks (CNNs) for PQDs classification and detection. The PSR method is used first to transform 1D raw data of PQD into a 2D image file and then a CNN model is applied to be used for image classification.

As can be seen from the above, this special issue in Advancing Grid-Connected Renewable Generation Systems has many exciting new contributions to the topic and demonstrates the agility of the field. Enjoy the reading.

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