IET Energy Systems Integration

DOI: 10.1049/esi2.12146

GUEST EDITORIAL

Guest Editorial: Dynamic analysis, control, and situation awareness of power systems with high penetrations of power electronic converters

1 | INTRODUCTION

In recent decades, global power grids have evolved with a rapid and extensive development of power electronic converters (PEC), including renewable energy systems (RES), high-voltage DC (HVDC) transmission, flexible AC transmission system (FACTS), energy storages, and microgrids. The distinct characteristics of power electronic devices traditional synchronous generators, especially their rapid control speed, wide-band performance and lack of inertia response and spinning reserve, are altering grid dynamics, and inducing new stability challenges. Continuation of such trends could further exacerbate the risk to the stability of power grids because of factors such as low inertias, lack of spinning reserve to quickly nullify active power mismatch between demand and supply.

Therefore, scientific investigations on novel dynamic modelling and stability analysis methods, data-driven monitoring and situation awareness on grid inertia-power-frequency evolution, grid dynamic frequency forecast methodologies in consideration of novel PEC control schemes, and advanced PEC grid integration control schemes to minimise frequency management risks become increasingly crucial for the secured operations of power systems with high PEC penetrations. In this Special Issue, namely 'Dynamic Analysis, Control, and Situation Awareness of Power Systems with High Penetrations of Power Electronic Converters', we have presented eight original papers of sufficient quality and innovation. The 10 eventually accepted papers can be clustered into three two categories, namely novel control design, stability and fault analysis.

2 | PART 1: NOVEL CONTROL DESIGN

Zhu et al. present a supercapacitor-based coordinated synthetic inertia (SCSI) scheme for a voltage source converter-based HVDC (VSC-HVDC) integrated offshore wind farm (OWF). The proposed SCSI allows the OWF to provide a designated inertial response to an onshore grid. The results show that the proposed SCSI scheme can provide required inertial support from WTG-installed supercapacitors to the onshore grid through the VSC-HVDC link, significantly improving the onshore frequency stability (https://doi.org/10.1049/esi2.12137).

Ghamari et al. design a Lyapunov-based adaptive back-stepping control approach for a power Buck converter, as an advanced version of the Backstepping method utilising Lyapunov stability function to reach a higher stability and a better disturbance rejection behaviour in the practical applications. In addition, to compensate for disturbances with wider ranges such as supply voltage variation, parametric variation and noise, this paper applies a metaheuristic algorithm in the control scheme called grey wolf optimisation algorithm of a nature-inspired algorithm with faster decision-making dynamics along with more accuracy over different optimisation algorithms (https://doi.org/10.1049/esi2.12098).

Arunagiri et al. present a new technique based on active damped dual loop $\alpha\beta$-frame current controllers to control the DSTATCOM with LCL filter for achieving improved load compensation. The dual loop controller is enhanced by using capacitor current in the inside loop and grid current at the outside loop with proportional resonant (PR) regulator parallel with harmonic compensator (HC). The proposed method effectively dampens the resonance peak under stationary $\alpha\beta$ reference frame: The PR controller offers unlimited gain at the fundamental frequency and HC can offer more gain at the specific harmonic frequencies (https://doi.org/10.1049/esi2.12088).

Sun et al. propose a distributed optimal dispatching method of the smart distribution network (SDN) and considering the integrated energy microgrid (IEMG) with multiple gird-connected points, improving the SDN operation flexibility and increase the operation benefits of all entities. Firstly, an IEMG connection mode, in which each IEMG can be connected to multiple nodes of the SDN is designed. A distributed optimal dispatching method is proposed, by which the IEMG operation privacy and the SDN responsibility to consume renewable power can be considered. Then, the electric power on tie-lines is taken as the coupling variable to

establish the IEMG and SDN coordinated dispatching model (https://doi.org/10.1049/esi2.12089).

3 | PART 2: STABILITY AND FAULT ANALYSIS

Zhang et al. investigate the DC-side stability of the grid-tied converter under different control modes using electrical torque analysis. It finds that the system stability mainly corresponds with DC network dynamics under constant active power control mode. On the contrary, the grid-tied converter under constant DC-link voltage control mode has no stability problem. Generally, elevating the DC-link capacitance or decreasing the droop gain can greatly improve the stability margin reserve of the VSC-HVDC links. In addition, the control gains of the classical PQ controller are proven to have limited impacts on DC-side system stability (https://doi.org/10.1049/esi2.12110).

Liu et al. present small-signal modelling and analysis of microgrids with synchronous and virtual synchronous generators. To explicitly reveal the oscillatory modes over all frequency bands, a high-fidelity full-order state-space model is first developed, identifying a potentially destabilising sub-synchronous oscillation mode resulting from the interaction between grid-forming virtual synchronous generators voltage controller and synchronous generators q-axis damper winding. Then, an enhanced quasi-stationary model dedicated to low-frequency oscillation evaluation is simplified from the full-order type, to make a reasonable trade-off between the accuracy and simplicity of system modelling (https://doi.org/10.1049/esi2.12099).

Chen et al. propose an instance-based power system dynamic security assessment method, with interpretation of machine learning models where effective adversarial attacks and its mitigation countermeasure are developed by assigning the perturbations on features with high importance. Then, these generated adversarial examples are employed for adversarial training and mitigation. By the proposed method with the merit of reducing the trade-off between the model accuracy and robustness vary and the quantity of used adversarial examples, the correlation between model accuracy and robustness can be clearly stated, considerable assistance can be provided in decision making (https://doi.org/10.1049/esi2.12118).

Xian et al. propose an improved system structure with a dynamic switching topology and a corresponding control scheme improve the fault ride-through capability of doubly-fed induction generator systems. The proposed method firstly designs a dynamic switching topology, based on the mechanism analysis that the series impedance of the stator can effectively reduce the overcurrent on the rotor side. Then, the method allows the rotor-side converter to use active flux attenuation for effectively reducing the overcurrent on the rotor side, and use reactive power support for accelerating the voltage recovery. It is proved that the scheme can dynamically adjust the topology structure and control scheme under different voltage dips (https://doi.org/10.1049/esi2.12097).

4 | SUMMARY

All of the papers selected for this special issue highlight the technical importance of novel control design and stability analysis, to guarantee flexible and secured operations of future power electronificated grids.

ACKNOWLEDGEMENTS

The Guest Editors would like to thank all the contributors for their high-quality original papers. We also appreciate your continuous support for IET Energy Systems Integration. We express our gratitude to the anonymous reviewers, without whom this Special Issue would not be successful. Last but not least, we should thank the journal editor-in-Chief Prof. Chengshan Wang and Deputy Editors-in Chief Prof. Hongjie Jia and Jianzhong Wu for their support and advice throughout this venture.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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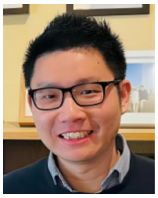

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