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Editorial

Modeling, Control and Stability Analysis of Power Systems Dominated by Power Electronics

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With the growth of economic and social demand for electricity, the power system has gradually evolved into a complex network containing a high proportion of renewable generators and large-scale electrical devices [1]. Power electronics are one of the core technologies that are now widely used in modern power systems, with the advantages of flexible control and fast response [2]. Nowadays, the penetration rate of power electronic devices continues to increase due to their flexibility in power conversion, which significantly changes the dynamic behavior of power systems [3]. In recent years, various instability issues with unknown mechanisms have appeared in power systems, which has brought new challenges with regard to the safe and stable operation of these power systems [1].

In 2009, the first wind turbine generator (WTG-associated sub-synchronous oscillation (SSO) incident was observed in the power system of the Electric Reliability Council of Texas, where the resonance was caused by the interaction between the doubly fed induction generator (DFIG) and the series compensated transmission line [4]. In [5], the Electric Reliability Council of Texas (ERCOT) proposed that pre-screening studies should be performed for all types of generation proposed for installation near series compensated lines including normal (N-0) and reasonable contingency (N-x) conditions. In [6], a pre-screening study was performed in the N-x condition with wind farms and gas power plants, and the results shows that there is a risk of resonance in the system from 5 to 55 Hz for conditions of N-1 to N-6 in wind farms, and the screening results for gas power plants shows the presence of resonance at 10.14 Hz, 17.51 Hz and 25.76 Hz. Based on the PSCAD/EMTDC (electromagnetic transients including DC) simulation, ref. [7] suggested that the risk of resonance from 11 to 30 Hz in the Texas case can be analyzed using the pre-screening method.

In 2012, a sub-synchronous resonance occurred at the Guyuan wind farm in Hebei, China, and the resonance frequency varied in the range of 3–12 Hz with the change in the number of commissioned turbines. Ref. [8] established an RLC equivalent model of the Guyuan wind farm to illustrate the resonance phenomenon with the eigenvalue method, showing that the resonance had a relationship with the network parameters, control parameters of the converter and wind speed. Ref. [9] analyzed the sub-synchronous resonance with frequencies of 7.58 Hz, 6.92 Hz, 7.5 Hz and 5.89 Hz that occurred under four different operating conditions at the Guyuan wind farm by using the impedance analysis method. Ref. [10] established an equivalent model for the series complementary system of the Guyuan wind farm using the eigenvalue analysis method and validated the accuracy of the analysis in the PSCAD/EMTDC simulation.

In 2013, a medium frequency resonance with a frequency range of 250–350 Hz occurred during the operation of a German North Sea offshore wind farm, which led to a system shutdown. Ref. [11] pointed out that the interaction between the voltage source converter-based high-voltage DC (VSC-HVDC) and AC power grid was the main cause of resonance, and a change in wind farm operating conditions may lead to system instability. In addition, inaccurate control parameters of the converter affects the accuracy of the impedance model, and the traditional phase angle margin standard may not be applicable to the stability criterion at this time.

In 2015, a sub-synchronous resonance with a frequency range of 17–34 Hz at the PMSG wind farm in Hami Xinjiang, China was reported, which resulted in the shafting torsional vibration of nearby steam turbines and the tripping of three thermal power units. Ref. [12] explained the causes of oscillation based on the dq-frame impedance model and impedance aggregation analysis method. Ref. [13] adopted a complex dynamic analysis method to describe the admittance motion trajectories of different wind farm branches, which showed that there are multiple harmonic sources in the system and that the oscillation spectrum contains a large number of sub-synchronous and super-synchronous components.

The typical resonance issues above demonstrate that interaction stability problems have been encountered in such power systems dominated by power electronics. In addition, power electronics have been widely used in power systems, including renewable energy generation, static var generators (SVG), energy storage, HVDC transmission and flexible AC transmission systems (FACTS). Power electronic modeling methods and system stability analysis methods need to be developed for complex power electronics and systems. It is also necessary to explore the advanced control technology that can coordinate the various control degrees of power electronics to make the control of modern power systems more stable and flexible. To address the above issues, this Special Issue is devoted to the modeling, control, and stability analysis of power electronic-dominated power systems. The topics of main interest include (but are not limited to):

➢ Impedance analysis methods and other small-signal stability analysis methods adapted to power electronic-dominated power systems.
➢ Modeling, characteristic analyses and measurement methods for various power electronics and systems.
➢ Stability analyses of power electronic-dominated power systems covering low, medium and high frequencies.
➢ Theories, design methods and applications of stability control of power electronic devices in power systems.
➢ Real-time and hardware-in-the-loop simulations applied in power electronic-dominated power systems.
➢ The new control technologies adapted for power electronic-dominated power systems.
➢ Case studies, stability analyses and mitigation in real applications.

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