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Energy Storage Modelling for Power System Reliability and Environmental Compliance

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Abstract : Reliable and economic operation of power systems are becoming extremely challenging with large scale integration of renewable energy sources due to the intermittency and uncertainty associated with renewable power generation. It is, therefore, important to make a quantitative risk assessment and explore the potential resources to mitigate such risks. Probabilistic models for different energy storage systems (ESS), such as the flywheel energy storage system (FESS) and the compressed air energy storage (CAES) incorporating specific charge/discharge performance and failure characteristics suitable for probabilistic risk assessment in power system operation and planning are presented in this paper. The proposed methodology used in FESS modelling offers flexibility to accommodate different configurations of plant topology. It is perceived that CAES has a high potential for grid-scale application, and a hybrid approach is proposed, which embeds a Monte-Carlo simulation (MCS) method in an analytical technique to develop a suitable reliability model of the CAES. The proposed ESS models are applied to a test system to investigate the economic and reliability benefits of the energy storage technologies in system operation and planning, as well as to assess their contributions in facilitating wind integration during different operating scenarios. A comparative study considering various storage system topologies are also presented. The impacts of failure rates of the critical components of ESS on the expected state of charge (SOC) and the performance of the different types of ESS during operation are illustrated with selected studies on the test system. The paper also applies the proposed models on the test system to investigate the economic and reliability benefits of the different ESS technologies and to evaluate their contributions in facilitating wind integration during different operating scenarios and system configurations. The conclusions drawn from the study results provide valuable information to help policymakers, system planners, and operators in arriving at effective and efficient policies, investment decisions, and operating strategies for planning and operation of power systems with large penetrations of renewable energy sources.

Keywords : flywheel energy storage, compressed air energy storage, power system reliability, renewable energy, system planning, system operation
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