Abstract

Two significant trends of recent power system evolution are: (1) increasing installation of dynamic loads and distributed generation resources in distribution systems; (2) large-scale renewable energy integration at the transmission system level. A majority of these devices interface with power systems through power electronic converters. However, existing transient stability (TS) simulators are inadequate to represent the dynamic behavior of these devices accurately. On the other hand, simulating a large system using an electromagnetic transient (EMT) simulator is computationally impractical. EMT-TS hybrid simulation approach is an alternative to address these challenges. Furthermore, to thoroughly analyze the increased interactions among the transmission and distribution systems, an integrated modeling and simulation approach is essential.

The thesis is divided into three parts. The first part focuses on an improved hybrid simulation approach and software development. Compared to the previous work, the proposed approach has three salient features: three-sequence TS simulation algorithm, three-phase/three-
sequence network equivalencing and flexible switching of the serial and parallel interaction protocols.

The second part of the thesis concentrates on the applications of the hybrid simulation tool. The developed platform is first applied to conduct a detailed fault-induced delayed voltage recovery (FIDVR) study on the Western Electricity Coordinating Council (WECC) system. This study uncovers that after a normally cleared single line to ground fault at the transmission system could cause air conditioner motors to stall in the distribution systems, and the motor stalling could further propagate to an unfaulted phase under certain conditions. The developed tool is also applied to simulate power systems interfaced with HVDC systems, including classical HVDC and the new generation voltage source converter (VSC)-HVDC system.

The third part centers on the development of integrated transmission and distribution system simulation and an advanced hybrid simulation algorithm with a capability of switching from hybrid simulation mode to TS simulation. Firstly, a modeling framework suitable for integrated transmission and distribution systems is proposed. Secondly, a power flow algorithm and a diakoptics based dynamic simulation algorithm for the integrated transmission and distribution system are developed. Lastly, the EMT-TS hybrid simulation algorithm is combined with the diakoptics based dynamic simulation algorithm to realize flexible simulation mode switching to increase the simulation efficiency.