

Machine Learning Based Transient Stability Emulation and Dynamic System Equivalencing of Large-Scale AC-DC Grids for Faster-Than-Real-Time Digital Twin

Shiqi Cao¹, Ning Lin¹, Venkata Dinavahi¹

¹University of Alberta

Modern power systems have been expanding significantly including the integration of high voltage direct current (HVDC) systems, bringing a tremendous computational challenge to transient stability simulation for dynamic security assessment (DSA). In this work, a practical method for energy control center with the machine learning (ML) based synchronous generator model (SGM) and dynamic equivalent model (DEM) is proposed to reduce the computational burden of the traditional transient stability (TS) simulation. The proposed ML-based models are deployed on the field programmable gate arrays (FPGAs) for faster-than-real-time (FTRT) digital twin hardware emulation of the real power system. The Gated Recurrent Unit (GRU) algorithm is adopted to train the SGM and DEM, where the training and testing datasets are obtained from the off-line simulation tool DSATools™/TSAT®. A test system containing 15 ACTIVSg 500-bus systems interconnected by a 15-terminal DC grid is established for validating the accuracy of the proposed FTRT digital twin emulation platform. Due to the complexity of emulating large-scale AC-DC grid, multiple FPGA boards are applied, and a proper interface strategy is also proposed for data synchronization. As a result, the efficacy of the hardware emulation is demonstrated by two case studies, where an FTRT ratio of more than 684 is achieved by applying the GRU-SGM, while it reaches over 208 times for hybrid computational-ML based digital twin of AC-DC grid.