Composite Load Modeling and Application in Power Systems

**Abstract**: Load modeling is essential to power system stability analysis, optimization, and controller design as shown in many research. Although the importance of load modeling is recognized by power system researchers and engineers, obtaining an accurate load model remains challenging due to the large number of diverse load components. The traditional static and dynamic load models can hardly capture the dynamic behavior of modern loads, especially for fault-induced delayed voltage recovery (FIDVR) events. Thus, a more comprehensive composite load model with the combination of static load, three different classes of equivalent three-phase induction motors, single-phase A/C motor, electronic load and an aggregated DER has been proposed by the Western Electricity Coordinating Council (WECC). However, the high model order and the large number of parameters raise new challenges to power system studies such as high computational burden in large-scale simulation and large search space in parameter identification. To overcome these challenges, it is imperative to develop a systematic high-fidelity model simplification scheme for the WECC composite load model (WECC CMLD) from the aspects of model order reduction and model parameter reduction. Moreover, an appropriate parameter identification method that can deal with nonlinearity and large searching space problems is also critical.

This dissertation solves the above problems with the following four pertinent works: (1) A large-signal model order reduction technique is developed based on singular perturbation theory for the WECC CMLD. Specially, a solid accuracy assessment criterion is proposed and strictly proved. By embedding the criterion into the order reduction process as a correction procedure, the accuracy of the obtained reduced-order model is guaranteed. (2) We propose a novel parameter reduction method based on active subspace method. With this approach, the sensitivities of parameters are computed while the interdependency among the parameters is taken into consideration. By applying the proposed algorithm to the WECC CMLD, the dimension of parameter space can be significantly reduced. (3) A new parameter identification approach for the WECC CMLD is proposed using evolutionary deep reinforcement learning (EDRL) with an embedded intelligent exploration mechanism, which can handle the high nonlinearity and nonconvexity of the WECC CMLD. Specially, the extracted parameter sensitivity weights are innovatively integrated into the EDRL with intelligent exploration to improve discovery efficiency. The proposed approach can efficiently avoid deceptive local optima and can handle the high-dimensional parameter vector. (4) We innovatively apply the load modeling technique to the practical conservation voltage reduction (CVR) effect evaluation problem by utilizing the nature of CVR, i.e., the load is sensitive to voltage. Specially, taking into consideration that the loading condition is changing from time to time and the real utility data usually contains outliers and noises, we proposed a robust time-varying CVR effect evaluation method using soft constrained gradient analysis based on load modeling.