Optimal Model Coordination for Integrated Transmission and Distribution Systems

Final Project Report

T-61

Power Systems Engineering Research Center
Empowering Minds to Engineer the Future Electric Energy System
Optimal Model Coordination for Integrated Transmission and Distribution Systems

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Executive Summary

The integrated analysis and coordination of transmission and distribution systems is considered as one of the key requirements for efficient operation of the future grid with high penetration of renewable energy resources. The primary focus of the existing literature on integration studies can be categorized into, (i) developing generic co-simulation platforms and (ii) application specific integrated analysis. The literature survey conducted for this work found that a research gap existed in the optimal models for coordinating transmission and distribution (T and D) system and analysis. This work presents the initial attempt to identify the limitations and opportunities of data and load aggregation for integrated T and D analysis, and the exploration of potential impacts of optimal coordination of T and D systems.

The main contributions of this work can be delineated as follows (i) Error correction model for distribution system data aggregation (ii) framework for distribution system load aggregation and management, (iii) new technique to provide estimates of unmonitored distributed solar photovoltaic (PV) generation on a distribution system, (iv) development of a co-optimization framework to coordinate T and D operational decisions. All of these aspects were developed with the focus on future data-centric system solutions for integrated T and D operations. The numerical analysis performed show the significance and the improvements provided by the proposed methods.

Part #1: Distribution System Data Aggregation for Coordinated Operation of Transmission and Distribution System: Impacts and Modeling

- The reliance on real-time distribution system data and load management is high in case of performing system operations using integrated analysis of T and D. In such cases the need for accurate representation of distribution system becomes paramount. A detailed study was done to realize the significance of data aggregation and granularity on distribution system analysis.

- Based on the study it was found that error correction models developed in this work are significant for improving the accuracy of distribution system representation, which is a key factor in integrated T and D analysis.

- Secondly, a two-part framework to aggregate and manage responsive distribution system load and resources is developed in this work. The novelty of this work is the development of a heterogeneous clustering technique that can be used for aggregating loads/energy resources considering the customer behavior and system requirements.

- The proposed framework/models for distribution system load and data aggregation can be incorporated as a part of any integrated T and D analysis. And including them would result in optimal coordination.
Part #2: Modeling Distributed Rooftop Solar Generation

- A new technique is presented to provide estimates of unmonitored distributed solar photovoltaic (PV) generation on a distribution system for transmission planning and operations estimates that can be made in real time.
- The data required are the total capacity of distributed PV generation on the distribution system and historical data of the output of those systems. Distribution operators collect capacity data for all interconnected systems. Smart meters can provide the historical data on actual energy generated. Once the model is developed for a feeder or substation, it should be updated annually. To provide generation estimates, the model uses real-time or historical solar radiation data as its only input.
- In practice, the model parameters would be developed by the distribution operator and provided to the transmission operator for use. The limited data needed for the model is all aggregate data for a service area, and the actual model provided to the transmission operator should pose no privacy concerns for customers.

Part #3: Co-optimization of Transmission & Distribution Operations

In Part 3, a co-optimization formulation is developed to analyze the potential for coordinated decisions in T and D systems, with highlights as follows:

- The proposed co-optimization framework can be implemented for a single transmission system in coordination with multiple distribution systems, showing that operational decisions leverage differences between system capabilities.
- A bi-level formulation of the co-optimization problem incorporates the network model and power flow for the distribution systems in the transmission optimization problem.
- Co-optimization enables competition between distribution systems to provide flexibility to the transmission system, which is not possible in the single level optimization approach commonly used.

Project Publications:


Student Theses:


