

TRANSMISSION AND GENERATION EXPANSION PLANNING WITH FLEXIBILITY METRICS, VIRTUAL POWER PLANTS, VIRTUAL TRANSMISSION LINES, ENERGY STORAGE, DISTRIBUTED RESOURCES INTEGRATION, AND NET DEMAND RAMPING CONSTRAINTS

Flavio Arthur Leal Ferreira

UFPR - Universidade Federal do Paraná - BR

Keywords: electrical power system, expansion planning, robust optimization, flexibility energy storage

Abstract

This research introduces a computational optimization model for Transmission and Generation expansion planning that accounts for the influence of Virtual Transmission Lines, which involve investments in energy storage (ESS) within the transmission system. This model enables the assessment of potential reductions and postponements in transmission line investments. Additionally, flexibility provided by the TSO-DSO interconnection is modeled to analyze its impact on system expansion decisions. Flexibility is provided to the AC transmission network through distribution systems connected at transmission system nodes, with the necessary flexibility requirements determined by expansion planning carried out by the connected DSOs. The primary objective of the optimization model is to minimize the overall system operation and investment costs across transmission, generation, and flexibility requirements. A Data-Driven Distributionally Robust Optimization (DDDRO) approach is proposed to address uncertainties in demand and Variable Renewable Energy generation. The framework adopts a two-level structure using the Column and Constraint Generation algorithm and Duality-Free Decomposition, supplemented by a third level to incorporate unit commitment and generator ramping constraints. Case studies applying the Garver 6-node system and the IEEE RTS-GMLC network were conducted to validate the model and analyze the value and impact of local flexibility on transmission expansion. Results demonstrate cost reductions, improved efficiency of the transmission system, and enhanced locational marginal pricing indicators.