



Model Reduction and Translation for Coordinated Expansion Planning Studies

Final Project Report

S-98G

Power Systems Engineering Research Center
*Empowering Minds to Engineer
the Future Electric Energy System*



Model Reduction and Translation for Coordinated Expansion Planning Studies

Final Project Report

Project Team

James McCalley, Professor and Project Leader

Ali Jahanbani-Ardakani

Iowa State University

Nicolas Lhuillier

Oliver Despouys

RTE-France

Graduate Student

Yanda Jiang

Zohreh Parvini

Iowa State University

PSERC Publication 24-05

December 2024

For information about this project, contact:

James McCalley
Iowa State University
Department of Electrical and Computer Engineering
Ames, IA 50011
Phone: 515-460-5244
Email: jdm@iastate.edu

Power Systems Engineering Research Center

The Power Systems Engineering Research Center (PSERC) is a multi-university Center conducting research on challenges facing the electric power industry and educating the next generation of power engineers. More information about PSERC can be found at the Center's website: <http://www.pserc.org>.

For additional information, contact:

Power Systems Engineering Research Center
Arizona State University
527 Engineering Research Center
Tempe, Arizona 85287-5706
Phone: 480-965-1643
Fax: 480-727-2052

Notice Concerning Copyright Material

PSERC members are given permission to copy without fee all or part of this publication for internal use if appropriate attribution is given to this document as the source material. This report is available for downloading from the PSERC website.

© 2024 Iowa State University. All rights reserved.

Acknowledgments

We would like to express our deepest gratitude to PSERC for their invaluable support and funding throughout this project. Their commitment to advancing research in power systems has been instrumental in the success of our work.

We also extend our heartfelt thanks to the teams at RTE and MISO for their collaboration, insights, and the data they provided. Their practical expertise and real-world perspectives have greatly enriched the quality and relevance of this research.

The collective efforts and contributions from these organizations have made this project possible, and we are truly grateful for their partnership.

Executive Summary

This report presents the development and application of a comprehensive network reduction procedure that is specifically designed for use by Coordinated Expansion Planning (CEP) tools. CEP tools are optimizers designed to identify generation and transmission investments that minimize the long run (e.g., 20 years) investment and operational costs of running a power system. Although state-of-the-art hardware, parallelization, and advanced optimization algorithms offer ways to provide high-speed computing, the desire for increased modeling fidelity motivates deployment of these methods *together with* network reduction, and not *instead of*. The primary objective of this research was to identify network reduction methods to minimize the computational time required for CEP while maintaining high modeling fidelity. This is important due to the increasing complexity and size of power systems, which makes full-scale CEP computationally intensive and often impractical.

The motivation for this research arises from the need to manage the computational burden of CEP, which is exacerbated by the large size and complexity of modern power systems. Traditional network reduction methods, though well-established, are not directly applicable to CEP due to the specific requirements of CEP, such as the need to handle multiple operating conditions and the necessity to model equivalent branches with both flow capacity and expansion cost attributes.

The research methodology involved developing an eight-step network reduction procedure tailored to CEP. This procedure starts by identifying “key branches,” i.e., those likely to receive investment in the multi-year CEP; and then “trimming” the network by eliminating certain buses. The system is then divided into zones, followed by the selective retention and elimination of buses using a guided Ward elimination approach. For each zone, the remaining network, which is dominated by generator buses, is aggregated; capacities and expansion costs are then estimated for equivalent branches. Finally, CEP is applied to the reduced network, and the results are translated back to the full network.

The key achievement of this research lies in the development of a comprehensive network reduction procedure that addresses different aspects of model reduction and effectively balances the trade-off between computational efficiency and model fidelity. The procedure was tested on several networks, including the IEEE 118-bus system and large-scale networks of the French grid and of the MISO grid. The results demonstrated significant reductions in network size, with minimal impact on the fidelity of the CEP outcomes. Specifically, the developed procedure maintained a high degree of accuracy in representing the power flows and investment decisions of the full network while achieving substantial reductions in computational time.

There were seven specific innovations in this work: (1) Efficient identification of key branches using a high-speed rolling simulation method; (2) Application of trimming methods to significantly reduce network size; (3) Identification of zones within the network using a minimum spanning tree algorithm; (4) Development of a guided Ward elimination procedure using a genetic algorithm to strategically eliminate buses and produce equivalent branches to minimize CEP compute time; (5) Aggregating generator buses within zones while maintaining the impedances seen from one boundary bus to another; (6) Estimating capacities and assigning expansion costs

to equivalent branches using specialized optimization methods; (7) Performing translation from reduced model results to the full model using an iterative linear program.

The implications of this research are significant for the field of power systems engineering, particularly in the context of expansion planning. The developed network reduction procedure enables more efficient CEP analyses, making it feasible to apply CEP to larger and more complex networks. This contributes to the broader goal of ensuring reliable and cost-effective expansion of power systems in the face of increasing renewable integration and the corresponding need for significant transmission investments.

Future research will focus on further refining the network reduction procedure, particularly in the context of handling even larger networks and more complex operating conditions. Additionally, there is potential for developing software tools based on this procedure, which could be made available to the power systems research community and industry practitioners for more efficient CEP studies.

Project Publications:

- [1] Y. Jiang, Z. Parvini, J. McCalley, N. Lhuillier, O. Despouys, A. Figueroa-Acevedo, and J. Okullo. "Network Reduction for Power System Planning: Zone Identification." In *2023 North American Power Symposium (NAPS)*, pp. 1-6. IEEE, 2023.

Student Theses:

- [1] Yanda Jiang. "Power system reliability evaluation and long-term planning: integrating network reduction and adaptive co-optimization expansion planning," Ph. D. dissertation, Iowa State University, Nov 2024.
- [2] Zohreh Parvini. Power system coordinated expansion planning: model reduction. Ph. D. dissertation, Iowa State University, May 2026