

Project Title: Dynamic Operating Envelopes Using Voltage Sensitivity for Distribution Networks

Project Type: Master Thesis or Semester Project

Project Description: The increasing penetration of distributed energy resources (DERs), such as photovoltaic systems and electric vehicles, introduces significant operational challenges in distribution networks, particularly related to voltage and thermal constraint violations. Dynamic Operating Envelopes (DOEs) [1,2] have emerged as a promising solution to define time-varying limits on power injection or consumption to ensure safe operation. Conventional DOE methods typically rely on detailed network models, forecasts, and centralized optimization, which can be computationally intensive and sensitive to model inaccuracies. Recent approaches have explored the use of local voltage measurements [3, 4] to estimate DOEs, enabling more decentralized and real-time implementations. However, these methods primarily rely on the system state (voltage levels) and do not explicitly account for how sensitive the network is to power changes.

This project proposes a new framework for computing DOEs that integrates both voltage measurements and voltage sensitivity information. The key idea is to define operating envelopes not only based on how close the system is to constraint limits (voltage magnitude), but also on how rapidly those limits may be reached (sensitivity). This enables adaptive, risk-aware, and real-time DOE computation. The proposed framework aims to: reduce reliance on full models, adapt to changing grid conditions, enable decentralized implementation at the node level

Key tasks during the project:

1. Literature review and problem formulation
2. Simulation environment setup: Implement a distribution grid model (e.g., IEEE test feeder),
3. Baseline DOE implementation,
4. Feedback-based DOE design: Design algorithm for real-time updating based on voltage measurements, incorporating adaptive safety margins,
5. Performance Evaluation: compare against baseline DOE.

Useful skills software: Python, OpenDSS, Pandapower, MATLAB.

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Reference:

- [1]. Liu, B., & Braslavsky, J. H. (2023). Robust dynamic operating envelopes for DER integration in unbalanced distribution networks. *IEEE Transactions on Power Systems*, 39(2), 3921-3936.
- [2]. Blackhall, L. (2020). On the calculation and use of dynamic operating envelopes. Australian National University, Canberra, ACT.
- [3]. Gupta, R., Sossan, F., & Paolone, M. (2022). Model-less robust voltage control in active distribution networks using sensitivity coefficients estimated from measurements. *EPSR*, 212, 108547.
- [4]. Gupta, R., & Paolone, M. (2023, June). Experimental validation of model-less robust voltage control using measurement-based estimated voltage sensitivity coefficients. In *2023 IEEE Belgrade PowerTech* (pp. 1-8). IEEE.