

Unbalanced Low Voltage Distribution Network Reinforcement

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Unbalanced low voltage distribution network reinforcement

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Abstract

The growing electrification of transportation and heating systems is leading to a significant increase in electricity demand, resulting in increasingly congested and unbalanced low-voltage distribution networks. The objective of this work is to implement an innovative network reinforcement method that considers the phase connections of households in order to reduce reinforcement costs. To this end, the effects of phase imbalance in distribution networks are first examined, revealing that assuming a balanced system can obscure critical issues such as voltage violations or line overloads.

Subsequently, a residential load profile generator incorporating electric vehicle charging profiles is developed and validated on real consumption data. The generated profiles lead to an underestimation of the average household consumption by 6% in the case without electric vehicles and by 0.5% in the case with electric vehicles, following the calibration of the model parameters.

A network reinforcement model is then developed, taking into account the results of power flow analyses under different household-to-phase connection configurations, with the goal of minimizing both investment and operational costs. The algorithm is tested on a benchmark network comprising 69 households equipped with EVs and solved using genetic algorithm. Results indicate that phase reassignment enables a reduction of the total annualized cost of operations and investments by 16% in a network without PV panels, and by 20% in a specific scenario including PV panels. A final scenario considering residential storage systems used as peak shaving devices was explored. The results indicate that, at current storage system costs, such residential devices are not economically viable. However, it is also demonstrated that, at lower costs, the storage strategy developed in this work could significantly reduce investment needs for new line reinforcements.

Keywords: Distribution Network, Genetic algorithm, Reinforcement, Unbalanced, Residential load profile generator, Reinforcement, Phase reassignment

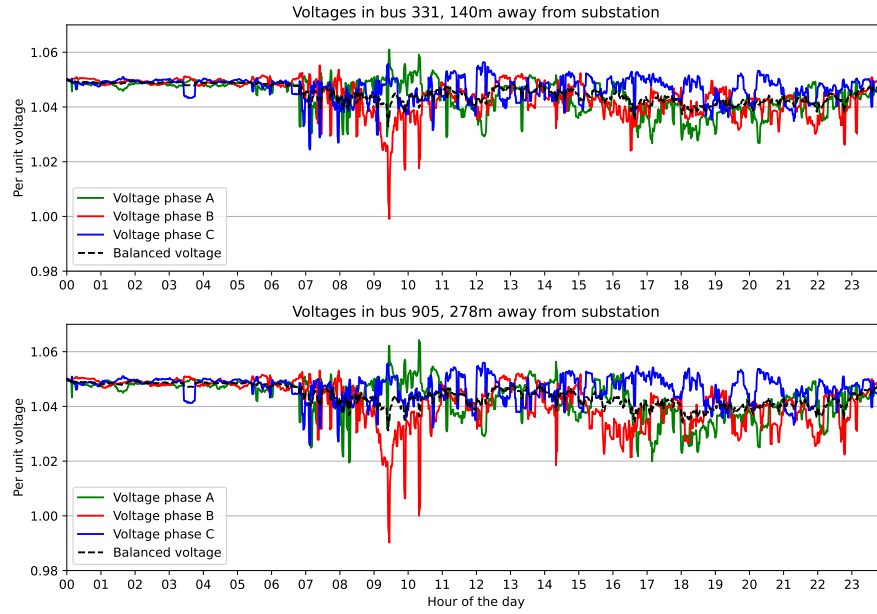
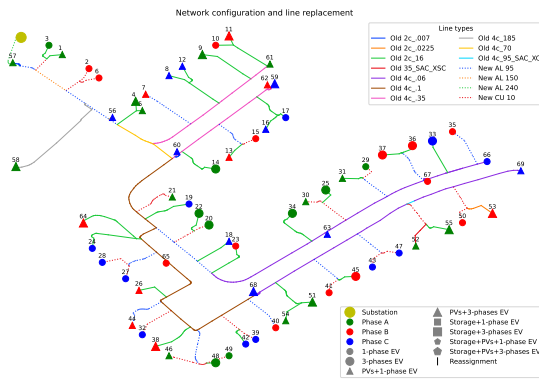
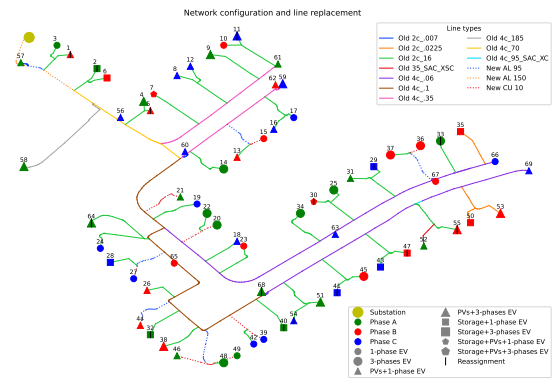


Figure 1: Voltage profile for each phase for two buses for 1 minute time step simulation. The first bus 331 is located halfway between the substations and the bus furthest from the substation. Bus 905 is the bus furthest from the substation.



(a) Initial configuration



(b) Optimized configuration

Figure 2: Comparison of network reinforcement requirements between the initial configuration and the optimized scenario with integrated storage systems.