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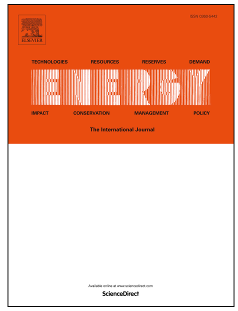

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The Multi-Scale Generation and Transmission Expansion Model

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Abstract

One of the challenges in electrical grid expansion planning is how to expand the infrastructure while considering fundamental changes in demand and supply, in part due to "game-changing" consumers, such as electric vehicles (EVs), and optional distributed generation (DG) by consumers. This work proposes an optimization model that addresses the generation and transmission expansion of the grid, including the facilities' locations, upgrades, and the network's design decisions. In contrast to some other models, it is not static in time: the model considers time-dependent demand in short-term (hourly) and long-term (yearly) variations. The proposed optimization model considers energy loss, transmission substations upgrades, constraints such as demand, capacities, and more. The model minimizes the long-term costs of infrastructure investments and the operational costs of generation. The work is supplemented by numerical experiments of the model in simulated scenarios. Sensitivity analysis conducted on some of the model features, demonstrates the importance of including them in the model.

Keywords: Generation and Transmission Expansion Planning, Distributed Generation, Electric Vehicles, Facility Location/Network Design, Smart Grid

1. Introduction

The electricity grid has existed for a long time, as have the challenges of planning its upgrade (expansion). Finding an optimal expansion plan includes various aspects that must be considered, such as generation capacity investments, and transmission upgrades. These decisions are referred to as the expansion problem.

The grid is transforming into a *smart grid*, a term that refers to any one (or a combination) of the following aspects: the exchange and use of real-time consumer information, automated decision making on power supply, pricing and bidding on electricity, and the incorporation of new elements into the grid, such as "smart homes", as discussed in [1]: with privately owned generators, a capacity to store energy (batteries), more control over energy requirements and the ability to postpone requirements.

To illustrate a possible significant change that has the potential to influence the infrastructure quickly, imagine a neighborhood that in just a few years' time changes its electrical consumption habits by switching to electric vehicles (EVs). The nature of EVs is that they are expected to require a considerable amount of energy at some bursts. With proper management, some of the energy requirements may be postponed to a time when the grid is not fully utilized, however above a certain adoption level the grid must be upgraded accordingly. In [2] the influence of EV adoption on the grid's infrastructure is examined by considering various charging profiles. Similarly, [3] compare the influence of EV adoption when coordinated vs. uncoordinated charging is considered. The effect of real-time coordination of EVs on the grid is examined in [4], and in [5] the effects of demand response and customer choice are shown with respect to the grid's infrastructure. Understanding and planning the grid within this delicate balance requires a model that combines a fine resolution of time, a horizon of years ahead, and a neighborhood grid's network representation.

Similar examples can be given with other elements that will be incorporated into the grid's model, such as distributed generation (DG). The addition of DG can somewhat decrease the requirements from the main power generation facilities, but it increases the requirements within the transmission network that relays the generated electricity further. In [6] the integration of solar power, wind power and diesel-engine is discussed, specifically from the aspects of providing control mechanisms and stability for the grid.