# A two-stage stochastic MILP model for generation and transmission expansion planning with high shares of renewables

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**Abstract-**

**This paper is concerned with the generation and transmission expansion planning of large-scale energy systems with high penetration of renewable energy sources. Since expansion plans are usually provided for a long-term planning horizon, the system conditions are generally uncertain at the time the expansion plans are decided. In this work, we focus on the uncertainty of thermal power plants production costs, because of the important role they play in the generation and transmission expansion planning by affecting the merit order of thermal plants and the economic viability of renewable generation. To deal with this long-term uncertainty, we consider different scenarios and we define capacity expansion decisions using a two-stage stochastic programming model that aims at minimizing the sum of investment, decommissioning and fixed costs and the expected value of operational costs. To be computationally tractable most of the existing expansion planning models employ a low level of temporal and technical detail. However, this approach is no more an appropriate approximation for power systems analysis, since it does not allow to accurately study all the challenges related to integrating high shares of intermittent energy sources, underestimating the need for flexible resources and the expected costs. To provide more accurate expansion plans for power systems with large penetration of renewables, in our analysis, we consider a high level of temporal detail and we include unit commitment constraints on a plant-by-plant level into the expansion planning framework. To maintain the problem computationally tractable, we use representative days and we implement a multi-cut Benders decomposition algorithm, decomposing the original problem both by year and by scenario. Results obtained with our methodology in the Italian energy system under a 21-year planning horizon show how the proposed model can offer professional guidance and support in strategic decisions to the different actors involved in electricity transmission and generation.**

**Index Terms- Generation and transmission expansion planning; Two-stage stochastic programming; Multi-cut Benders decomposition; Large-scale power systems; Unit commitment; Representative days**

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