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An Efficient Algorithm for Solving the Transmission Network Expansion Planning Problem Integrating Machine Learning with Mathematical Decomposition

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Abstract : To effectively combat climate change, many countries around the world have committed to a decarbonisation of their electricity, along with promoting a large-scale integration of renewable energy sources (RES). While this trend represents a unique opportunity to effectively combat climate change, achieving a sound and cost-efficient energy transition towards low-carbon power systems poses significant challenges for the multi-year Transmission Network Expansion Planning (TNEP) problem. The objective of the multi-year TNEP is to determine the necessary network infrastructure to supply the projected demand in a cost-efficient way, considering the evolution of the new generation mix, including the integration of RES. The rapid integration of large-scale RES increases the variability and uncertainty in the power system operation, which in turn increases short-term flexibility requirements. To meet these requirements, flexible generating technologies such as energy storage systems must be considered within the TNEP as well, along with proper models for capturing the operational challenges of future power systems. As a consequence, TNEP formulations are becoming more complex and difficult to solve, especially for its application in realistic-sized power system models. To meet these challenges, there is an increasing need for developing efficient algorithms capable of solving the TNEP problem with reasonable computational time and resources. In this regard, a promising research area is the use of artificial intelligence (AI) techniques for solving large-scale mixed-integer optimization problems, such as the TNEP. In particular, the use of AI along with mathematical optimization strategies based on decomposition has shown great potential. In this context, this paper presents an efficient algorithm for solving the multi-year TNEP problem. The algorithm combines AI techniques with Column Generation, a traditional decomposition-based mathematical optimization method. One of the challenges of using Column Generation for solving the TNEP problem is that the subproblems are of mixed-integer nature, and therefore solving them requires significant amounts of time and resources. Hence, in this proposal we solve a linearly relaxed version of the subproblems, and trained a binary classifier that determines the value of the binary variables, based on the results obtained from the linearized version. A key feature of the proposal is that we integrate the binary classifier into the optimization algorithm in such a way that the optimality of the solution can be guaranteed. The results of a study case based on the HRP 38-bus test system shows that the binary classifier has an accuracy above 97% for estimating the value of the binary variables. Since the linearly relaxed version of the subproblems can be solved with significantly less time than the integer programming counterpart, the integration of the binary classifier into the Column Generation algorithm allowed us to reduce the computational time required for solving the problem by 50%. The final version of this paper will contain a detailed description of the proposed algorithm, the AI-based binary classifier technique and its integration into the CG algorithm. To demonstrate the capabilities of the proposal, we evaluate the algorithm in case studies with different scenarios, as well as in other power system models.

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