Solving Nonconvex MIQCP Arising in Gas Network Extension Planning

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Abstract: The topic of this talk is topology extension planning of large-scale, real-world gas transmission networks. Gas networks are complex structures which consist of passive elements like pipelines between sources and sinks, and active elements such as valves and compressors. We are given a set of nominations, which are balanced allocations of source and sink flows, and have a suitable setting for all network components such that the nominated amount of gas can be transmitted through the network, without violating physical or operational constraints. In this case, every nomination is feasible. If the specified amount of gas cannot be transported through the network, the goal is to decide which combination of given network extensions such as pipelines, compressors or control valves should be added to the gas network, so that every nomination is feasible.

The gas transmission network is modeled by a directed graph. Each arc corresponds to a pipeline or to an active element. In addition to flow conservation, a pressure range is assigned to each node, and the gas flow on a pipe is induced by a nonlinear pressure difference relationship between end nodes of the arc. Every extension is a series of pipelines and active elements, and the state of each active element is necessary in order to minimize the construction cost.

To solve large-scale topology extension planning instances, we present a framework which computes a global optimal solution for this problem. We present a mixed-integer quadratically constrained (MIQCP) model, where discrete decisions correspond to active network elements. The solution process starts with the substitution of every nonlinearity by linear outer approximations. As soon as all integer variables are fixed, we replace the approximations by their corresponding exact formulas. The resulting local problem has at most one solution and thus can be solved efficiently to global optimality. The interconnection of the mixed-integer linear program and the nonlinear program is implemented using the solvers SCIP and IPOPT. The local problem has equivalent formulations which enable the computation of nonlinear cuts for the network extensions. It also enables the measurement of unfeasibility level of the nominated flow and pressure.

We present preliminary computational results on real-world instances with several hundred nodes and about 3000 arcs. The data for this study is provided by Open Grid Europe GmbH (OGE), the leading German gas transportation company.

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