Topology Planning of Gas Transportation Networks by solving MINLP Programs

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The topic of this talk is topology planning of large-scale, real-world gas distribution networks. We are given a set of nominations which each define a balanced allocation of source and sink flows. The goal is to decide which combination of network extensions such as pipelines, compressors, or valves should be added to the gas network such that every nomination is feasible which means that the specified amount of gas can be transported.

The gas transportation network is modeled by a directed graph. Each arc corresponds to a pipeline or to an active element such as compressors or control valves. In addition to flow conservation a pressure value must be assigned to each node and the gas flow on a pipe is induced by the pressure difference of the endnodes of the arc. This relation is described by a nonlinear function and implies a unique flow for a nomination in a gas network that does only consist of pipelines. Typically the number of possible extensions is much bigger than the number of arcs of the gas network.

Our approach decomposes into three steps. First, we introduce slacks on the flow conservation to locate bottlenecks in the network. In the second step, a set of extension candidates is produced using the information from the solved slack models together with a Delaunay triangulation, a Min Cost Flow Problem and utility considerations. This part of the talk will be given by Robert Schwarz. At last, topology planning will select the cost optimal subset of the fixed candidates. This part will be hold by Jesco Humpola. To solve large-scale topology extension instances, we present a framework which in principle computes a global optimal solution for this problem. We formulate a nonlinear mixed-integer model in which discrete decisions correspond to active elements. In the beginning of the solution process every nonlinearity is substituted by linear outer approximations. The possibility to build a new pipeline is modeled by big-M formulations. At the time when all integer variables are fixed, we replace the approximations by their corresponding exact formulas. The resulting local problem is convex and thus can be solved to global optimality. This interconnection of a mixed-integer linear program and a nonlinear program is implemented using the solvers SCIP and IPOPT. We will present computational results on real-world instances with hundreds of nodes and about 3000 arcs. The data are provided by Open Grid Europe GmbH (OGE), a subsidiary company of E.ON Ruhrgas AG.