Theoretical and Practical Aspects of Optimal Loop Extensions in Gas Networks

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Abstract: Gas transportation companies often need to extend their networks, in order to enable feasible operations. This is known as Expansion Planning and can be modeled as a nonconvex MINLP, where discrete decisions correspond to the operation of active network elements and nonlinearities are due to the flow-pressure relationship in pipes. An appreciated extension method of the gas transmission companies in practice is to build new pipes in parallel to existing ones, called looping. Compared to the original pipe, a loop provides the possibility of transporting more gas and leads to a reduction of the pressure loss.

The decisions to be taken comprise the selection of the pipes to be looped, the continuous loop lengths as well as the appropriate choice of loop diameters out of a discrete set. Since we are able to determine the best looping diameters a priori, we can efficiently reduce the problem size of the resulting MINLP. This model is still nonconvex but we solve it to global optimality using outer approximation and spatial branching.

In this presentation, we focus on theoretical and practical aspects of loop extensions. We show how to strengthen our model formulation by analytically deriving the convex envelope of the constraint function $\Phi(q, y) = yq|q|$, that describes the pressure loss in a looped pipe over the amount of transported flow q and the impact of variable diameters and loop lengths being represented by y. Finally we present computational results and show how a solution can be transformed into a concrete loop extension in practice.

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