Abstract ID 1165

A BRANCH AND BOUND METHOD FOR GLOBALLY OPTIMISING VALVE LOCATIONS IN WATER DISTRIBUTION NETWORKS

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Keywords: Global optimisation; valve placement; pressure management; water distribution networks

Abstract: The optimal control of pressure is critical for the management of water distribution networks (WDNs). In fact, significant leakage reductions can be realised by continuously operating pressure control valves to maintain average zone pressure (AZP), under stochastic changes in demand, close to a minimum level defined by regulations [1]. This work investigates the problem of optimal placement of control valves in WDNs, where the objective is to minimise AZP. The problem formulation results in a nonconvex mixed integer nonlinear program (MINLP). Due to its complex mathematical structure, in previous literature, this nonconvex MINLP has been solved by heuristics [2] or local optimisation methods [3]. However, such approaches do not provide theoretical guarantee on the global optimality of the computed valve configurations. Here, we implement a branch and bound method to obtain certified bounds on the optimality gap of the solutions. The algorithm generates a sequence of lower and upper bounds to the optimal value. The lower bounds are computed solving mixed integer linear programs whose formulations include linear relaxations of the nonconvex constraints. Such polyhedral relaxations are defined by extending the derivation in [4] to the nonconvex terms considered here. In addition, a tailored domain reduction procedure is implemented to tighten the relaxations. The developed methods are numerically evaluated using case studies, including an operational WDN from the UK. The branch and bound algorithm converged to good quality feasible solutions in all instances, with bounds on the optimality gap comparable to the level of uncertainty usually experienced in water network models. Future work should investigate the inclusion of valid linear inequalities within the formulation of the relaxed MILPs, to further reduce the optimality bounds.

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