

Contents

1	Introduction: Gas Network Optimization	1
1.1	Optimization Tasks	2
1.2	Previous Work	4
1.3	Solution Approach	8
1.4	Computational Study	10
1.5	Outline of the Thesis	11
2	Solving Mixed-Integer Nonlinear Optimization Problems	13
2.1	Definition of MINLP	13
2.2	Details on SCIP for Solving MINLP	14
2.3	Convex and Non-Convex MINLP	17
2.4	Necessary Conditions for Local Optimality	19
2.5	A Specially Tailored Adaptation of SCIP	20
3	An MINLP Model for Gas Network Topology Optimization	23
3.1	Technical Background	23
3.2	An MINLP Model	30
3.3	Complexity Analysis	35
3.4	The Passive and Active Transmission Problem	41
3.5	Computational Setup	43
4	Efficiently Solving the Passive Transmission Problem	51
4.1	Notation	52
4.2	Relaxation of Domains	53
4.2.1	Existence of a Solution	54
4.2.2	Characterization of the Feasible Region	58
4.2.3	Interpretation of Lagrange Multipliers	64
4.3	Relaxation of Flow Conservation Constraints	71
4.3.1	Preprocessing	72
4.3.2	Existence of a Solution	73
4.3.3	Characterization of the Feasible Region	78

4.3.4	Interpretation of Lagrange Multipliers	85
4.4	Relaxation of Potential-Flow-Coupling Constraints	88
4.4.1	Conditions of the KKT System	88
4.4.2	Different KKT Points	90
4.5	Solving the Passive Transmission Problem	91
4.6	Integration and Computational Results	95
5	An Improved Benders Cut for the Topology Optimization Problem	103
5.1	Valid Inequalities for the Passive Transmission Problem	104
5.1.1	A Nonlinear Inequality	106
5.1.2	A Linear Inequality	111
5.1.3	Feasibility Characterization by a Linear Inequality	114
5.1.4	A Linear Inequality derived from the Lagrange Function of the Domain Relaxation	124
5.2	A Valid Inequality for the Topology Optimization Problem	126
5.3	Integration and Computational Results	133
6	Sufficient Conditions for Infeasibility of the Active Transmission Problem	141
6.1	Non-Convex Relaxations for the Active Transmission Problem	142
6.1.1	Relaxation of Domains	143
6.1.2	Relaxation of Flow Conservation Constraints	150
6.2	Detecting Infeasibility of the Active Transmission Problem by MILP	155
6.3	Interpretation of the Infeasibility Detection MILP	170
6.4	Integration and Computational Results	175
7	A Primal Heuristic based on Dual Information	181
7.1	A Relaxation of the MINLP	182
7.2	A Primal Heuristic for MINLP with Indicator Constraints	184
7.2.1	Theoretical Motivation	184
7.2.2	The Basic Dual Value MINLP Heuristic	187
7.2.3	Embedding the Heuristic in a Branch-and-Prune Search	188
7.3	A Specialization to the Topology Optimization Problem	188
7.3.1	The Relaxation	189
7.3.2	Handling Different Modes of Active Devices	190
7.3.3	Handling Loop Extensions	194
7.4	Implementation Details	196
7.5	Computational Results	198

8 Conclusions	203
A Tables	207
Bibliography	227