Operational decision support in the presence of uncertainties - Water Distribution Systems

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This book addresses the scientific domains of operations research, information science and statistics with a focus on engineering applications. The purpose of this book is to report on the implications of the loop equations formulation of the state estimation procedure of the network systems, for the purpose of the implementation of Decision Support (DS) systems for the operational control of the network systems. In general an operational DS comprises a series of standalone applications from which the mathematical modeling and simulation of the distribution systems and the managing of the uncertainty in the decision-making process are essential in order to obtain efficient control and monitoring of the distribution systems. The mathematical modeling and simulation forms the basis for detailed optimization of the network operations and the second one uses uncertainty based reasoning in order to reduce the complexity of the network system and to increase the credibility of its model. This book reports on the integration of the two aspects of operational DS into a single computational framework of loop network equations. The proposed DS system will be validated using case studies taken from the water industry. The optimal control of water distribution systems is an important problem because the models are non-linear and large-scale and measurements are prone to errors and very often they are incomplete. The problem of steady state analysis of water distribution systems is studied in the context of a co-tree flows simulator algorithm that is derived from the basic loop corrective flows algorithm. It is shown that the co-tree formulation has several inherent advantages over the original formulation due to the use of the spanning trees. This allows a rapid determination of the necessary input data for the simulator (the loop and the topological incidence matrices and the initial flows) as well as the fast calculus of the nodal heads at the end of the simulation. A novel Least Square (LS) state estimator that is suitable for on-line monitoring of the water distribution systems is presented. The state variables are both the loop corrective flows and the variation of nodal demands. It is shown that the input data necessary to build the network equations can be derived from the spanning tree obtained for the co-tree flows simulator and so there is a natural connection between the novel state estimator and the simulator algorithm. In spite of the increased size of the state vector, a satisfactory convergence is obtained through an enhancement in the Jacobian matrix. Furthermore a fine-tuning of the inverse of the tree incidence matrix is carried out in order to avoid the lack of numerical stability characteristic to the nodal heads state estimators. A very efficient and effective loop flows LS state estimator is developed that is tested successfully on realistic water networks. Based on the novel state estimation technique, new algorithms for quantifying the measurement uncertainty impact on the state estimates are developed. The Confidence Limit Analysis (CLA) algorithms include a formulation of an Experimental Sensitivity Matrix (ESM) method, a sensitivity matrix method within the loop equations framework and an Error Maximization technique (EM). The performances of these algorithms are assessed in terms of their computational complexity and the accuracy of the results that they produce. It is shown that the computational efficiency and the accuracy of results of the EM method renders it suitable for online DS applications.

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