THE SEARCH FOR THE WORST CASE TRANSIENT LOADINGS IN WATER DISTRIBUTION SYSTEMS

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The water demand is the main driving force of the hydraulic dynamics occurring in a water distribution system; unfortunately, determining design demands is not as straightforward as it is sometimes assumed. In essence, estimating demands is related to two simple questions: (i) How much water will be used? and (ii) How will usage change as a function of time? However, the associated answers are often uncertain and complex and the number of possible combinations of loadings is almost overwhelming. The randomness of water demand arises from many factors including the uncertainty of fire flow, the variations in local climate, and the partially random nature of population growth, all of which cause demand variations on an annual, seasonal, daily, hourly, and momentary basis. The implications of these random behaviors on system performance are often difficult to estimate accurately and unexpected variations in demand may degrade system performance, or may require unplanned and costly upgrades. For example, a fire flow loading might occur with a peak-hour demand loading in a deteriorated system to depress residual pressures below acceptable levels, and thereby necessitate costly capital investments, or at least operating the system at a higher level of risk.

Optimization methods have been widely applied to many problems associated with water distribution system design, management and operation; however, no approach has been developed to search for the worst case loadings in a system. In this paper, transient analysis is applied to simulate a variety of loadings in the quest for the worst-case scenarios during distribution system design. Evolutionary computation algorithms (ECAs), in particular genetic algorithms (GAs) and particle swarm optimization (PSO), are combined with transient analysis to identify the worst-case loadings in example systems. Fig. 1 depicts a procedure for searching worse case loading in WDS. First, GA and PSO, as optimization methods, initialize the decision variables like baseline demands, time-varying demands and tank levels, and their operation times. With selected decision variables by GA and PSO, the mathematical models to solve the governing transient equations, momentum equation and mass conservation with initial and boundary conditions for transient flow, calculate the maximum and minimum heads. Based on the objective functions value (H_{max} or H_{min}), GA and PSO evaluate the fitness of the individual in the population and create a new population for next generation.

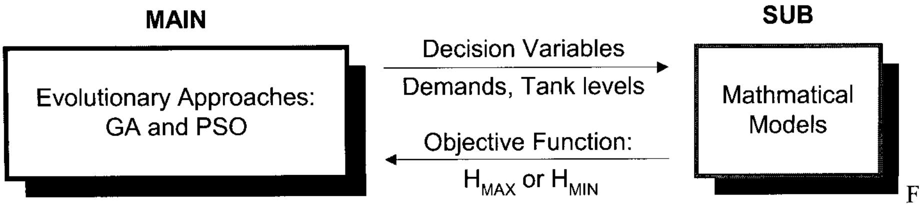

Fig. 1 The search for worst case loading

The transient responses of the worst-case loadings selected by ECAs assist in designing mitigation measures and help to train operators and designers as to how to avoid the identified the worst-case conditions. This approach shows that not only are the loading conditions sensitive when searching the worst case in pipeline network, but also the selection of the system characteristics such as system topography, pipe size, material and thickness are crucially important to prevent or mitigate the worst case events in the system. Systematic surge protections using transient analysis, therefore, are crucially important for system integrity, safety and performance.