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Parameterization of offline and online hydraulic simulation models

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Abstract

The proper estimation and regular update of model parameters is crucial for the actuality of a mathematical simulation model representing the hydraulics and water quality of a real physical water distribution system. Especially, when the model is running online, uncertainties in model parameters can result in large discrepancies between model predictions and behavior of the real system. Therefore, adequate techniques for data acquisition, maintenance and update of model parameters have to be developed. In what follows the "parameterization" of a hydraulic online simulation model is described including the classification of parameters regarding data source, update cycles and function in the model. The parameterization framework was developed to benefit the modeling of water critical infrastructure systems.

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Keywords: Hydraulic online simulation, parameterization, calibration, SCADA-System, GIS, data acquisition, model update

1. Introduction

Driving online hydraulic simulations of water distribution systems in real-time or in replay mode requires within the simulator the integration of measurements and operational data that are continuously collected in the real physical system and transferred to a central SCADA (Supervisory Control And Data Acquisition) system [1]. Hydraulic simulation is especially important in the context of monitoring and modeling of critical infrastructure systems [2]. In the following document real-time measurements and operational data are denoted by "online data". In addition, the term "model parameters" refers to values of the hydraulic simulation model that are assumed to be known for the calculation and serve as boundary conditions for the system of differential algebraic equations or

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describe the (constant) physical properties of the components of the model. Consequently, the model parameters can be subdivided into “physical parameters“ such as pipe diameter, roughness and elevation of nodes and “operational parameters”, for instance valve states, pump speeds and, of course, the water demand representing the timely changing load of the system. The following table shows the different classes of parameters and the associated rate of change:

Table 1. Classification of model parameters

Parameter class	Change rate	Description	Examples
Physical network parameters	Slow (month to years)	Describe the physical properties of the network elements such as pipes, pumps, valves and control devices. These properties normally change slowly in time. Some of them cannot be directly identified and need to be calibrated. For example, dependent on the pipe material and water quality, deterioration of pipes results in increased roughness values and reduced inner diameters caused by growing incrustations. However, these changes develop over years. In the online use case it is assumed that the model has been calibrated in advance and that slowly changing parameters have been properly identified and remain constant during the entire simulation period.	network topology, diameter, roughness and length of pipes, elevations, physical properties of valves and control devices
Remote controlled operational state parameters	Fast (multiple changes per day)	Operational parameters, like the previously described physical parameters, are assumed to be known in the hydraulic network calculations (boundary conditions). However, they are not constant but continuously updated. Their states are continuously monitored in the SCADA system.	operational states of valves, pump status (on/off) and speed, set values and state of remote controlled control devices, tank water level as initial conditions
Not remote controlled operational state parameters	Medium (weeks to month)	The values of non-remote controlled operational state parameters are more difficult to estimate since their current state is not transferred to the SCADA system and must be sometimes updated in the model by hand. Often this information is not available.	state of gate valves that are closed for rehabilitation works
Load parameters	Continuous	In general, the actual demand distribution is not known. The nodal demands in the model are based on meter readings that are carried out from time to time (months to year). The proper estimation of nodal demands is crucial for the results of the online simulations. For the hydraulic calculations the demand is normally assumed to be known. However, in dependency of the kind of modelling the demand can be used as fixed parameter (DDM: Demand Driven Modelling) or as an upper threshold (PDM: Pressure-Dependent Modelling).	Domestic demands, Industrial demands

In what follows the process of choosing the parameters of the mathematical model is called “parameterization”. This consists of two steps. In the first (offline) step the components that are important for drawing a reliable picture of the real system are identified including: pipes and their characteristics, network topology, elevations, control devices and pumps with their corresponding physical properties and operational modes, valves and hydrants location and the customer repartition and behavior including average consumption. Measurement data of the past are typically used for a first offline calibration of model parameters. In the second (online) step the model is confronted with “online” data from the SCADA system (SCADA: Supervisory Control and Data Acquisition). In this context, the measurements and operational data of devices are subdivided into three groups. The first group includes operational states of devices (valves states, rotational speed of pumps) that can be directly transferred to the corresponding parameter of the model. The second group concerns measurements that are used as boundary conditions in the model like tank inflows and water levels. Group one and two are the driving parameters of the model (actuators). The third group consists of measurements that can be used only indirectly for the online