ABSTRACT

THE objective of this research project is to develop new software tools capable of operational optimisation of existing, large-scale water distribution networks. Since pumping operations represent the main operating cost of any water supply scheme, the optimisation problem is equivalent to providing a new sequence for pumping operations that makes better use of the different electricity tariff structures available to the operators of distribution systems. The minimisation of pumping costs can be achieved by using an optimal schedule that will allow best use of gravitational flows, and restriction of pumping to low-cost power periods as far as possible.

A secondary objective of the operational optimisation is to maintain the desired level of disinfectant chlorine at the point of delivery to consumers. There is a steady loss of chlorine with residence time in the system. If the level drops too low there is a risk of bacterial activity. Re-dosage points are sometimes provided in the network. Conversely, too high a level produces an unacceptable odour.

The combination of dynamic elements (reservoir volumes and chlorine concentration responses) and discrete elements (pump stati and valve positions) makes this a challenging Model Predictive Control (MPC) and constrained optimisation problem, which was solved using MINLP (Mixed Integer Non-linear Programming). The MINLP algorithm was selected for its ability to handle a large number of integer choices (valves open or shut / pumps on or off in this particular case).

A model is defined on the basis of a standard element, viz. a vessel containing a variable volume, capable of receiving multiple inputs and delivering just two outputs. The physical properties of an element can be defined in such a way as to allow representation of any item in the actual network: pipes (including junctions and splits), reservoirs, and of course, valves or pumps. The overall network is defined by the inter-linking of a number of standard elements. Once the network has been created within the model, the model predictive control algorithm minimises a penalty function on each time-step, over a defined time horizon from the present, with all variables also obeying defined constraints in this horizon. This constrained non-linear optimization requires an estimate of expected consumer demand profile, which is obtained from historical data stored by the SCADA system monitoring the network. Electricity cost patterns, valve positions, pump characteristics, and reservoir properties (volumes, emergency levels, setpoints) are some of the parameters required for the operational optimisation of the system.