Real-time Modelling of Water Distribution Systems

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INTRODUCTION

The UK water utilities face growing challenges to maintain the water quality and quantity to meet increasing water demand. The challenges include ageing and failing water infrastructure, stricter environmental regulations, growing urban population and water losses (OFWAT, 2005). These challenges raise a serious concern about the current management of Water Distribution System (WDS) and the usage of the Supervisory Control and Data Acquisition (SCADA) system to attain better sustainability of WDS. The key tool to plan and manage the WDS is hydraulic modelling software such as EPAnet (US Environmental Protection Agency). However, majority of hydraulic modelling are done offline which do not represent well the current state of the WDS for operational purposes, especially in emergency events (Machell, et al., 2010). The other disadvantage of offline modelling is unknown parameters are updated by using short term sample of hydraulic data (Preis, et al., 2010). The aim of the initial research work is to improve the modelling of WDS by developing new models for more accurate, online predictions of its state. The future research work will then make use of these models to improve the real-time management of these systems.

METHODOLOGY

The **P**redictor-**C**orrector scheme (PC) (Shang, et al., 2006) is implemented to assimilate the system observations to correct the water demand prediction. The demand forecasting model is based on the **A**uto **R**egressive **M**oving **A**verage (ARMA) (Box & Jenkins, 1976) . Demands are predicted every 15minutes and the **En**semble **K**alman **F**ilter (EnKF) (Evensen, 1994) is used to correct the system hydraulic state.

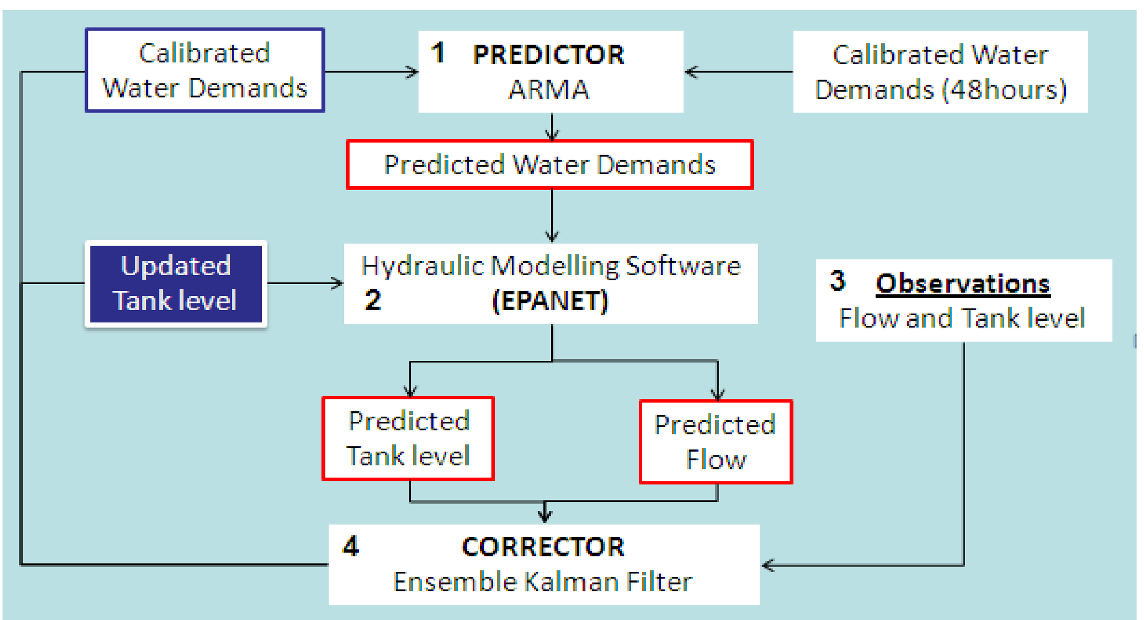

Figure 1: Schematic diagram of predictor-corrector method

The key steps of the PC scheme are as follows (see Figure 1):

1) PREDICTION - The water demands are predicted using the ARMA algorithm based on the 48 hours calibrated water demands.

2) SIMULATION - The predicted water demands are used to drive the selected WDS hydraulic model on EPANET using the steady-state simulation and the outputs are pressure (tank level) and flow rates.

3) INTERGRATION – The measured pressure and flow data are assimilated into the PC scheme.

4) ASSIMILATION – EnKF is used to correct the predicted hydraulic states (water demand and tank level). The corrected water demands are stored in a separate database and used as inputs in prediction model in step 1.

The above is repeated at subsequent time steps.

CASE STUDY

The potential benefits of the online WDS modelling were assessed initially on a real-life system of the Liverpool South (Speke) trunk main. The trunk main model consists of 1 tank, 1 pump, 259 nodes, 213 pipes with no valves (see Figure 2). This trunk main supplies water to 14 DMAs. The hydraulic model is driven by demands from the United Utilities (UU) SCADA database (historical database) over the period of 7days.

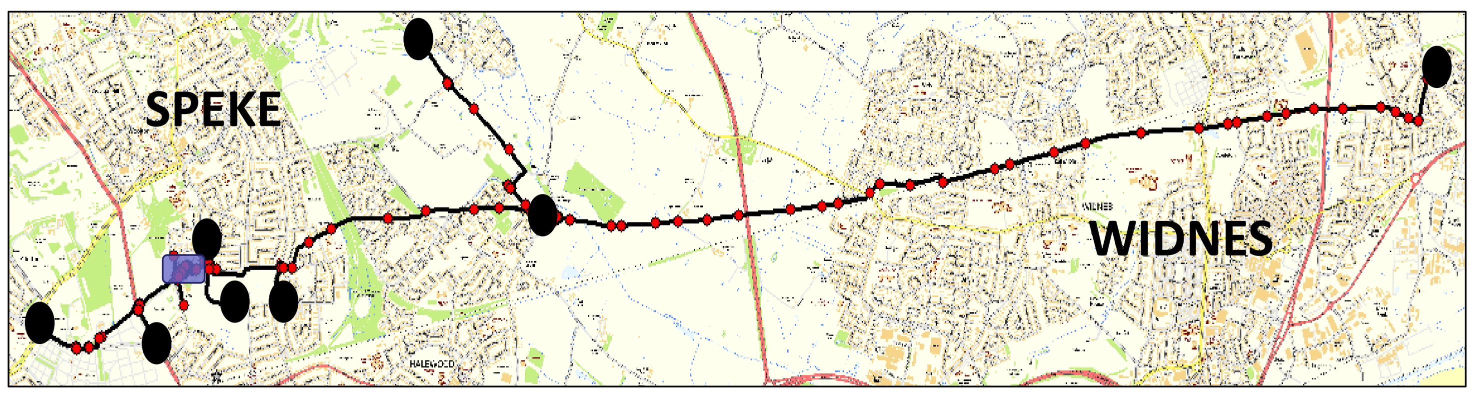

Figure 2: Liverpool South (Speke) Trunk Main Model Showing the location of 9 observations - 8 flow rates (black circles) and 1 tank level (blue square).

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RESULTS AND DISCUSSION

The results obtained show that online hydraulic modelling improves the prediction model performance at the inlet of the trunk main in Widnes (see Figures 3 &4).

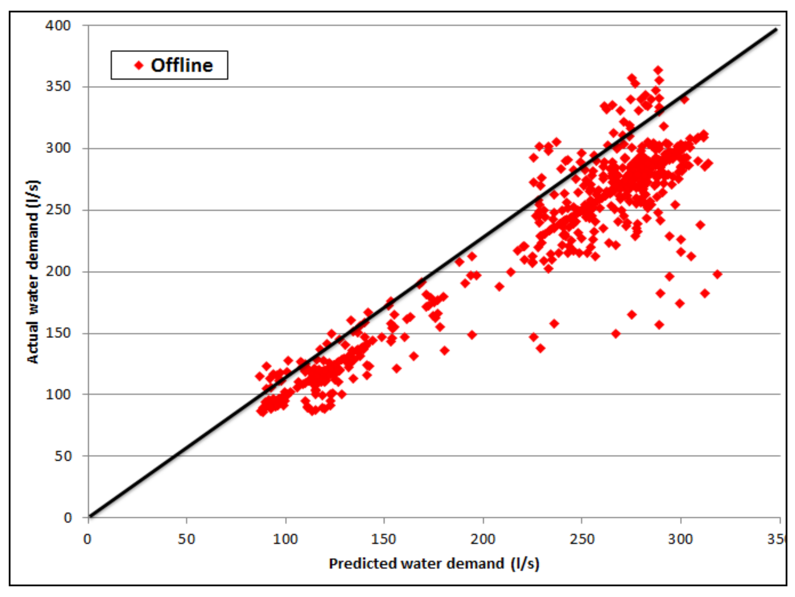

Figure 3: Comparison between actual and predicted offline water demands

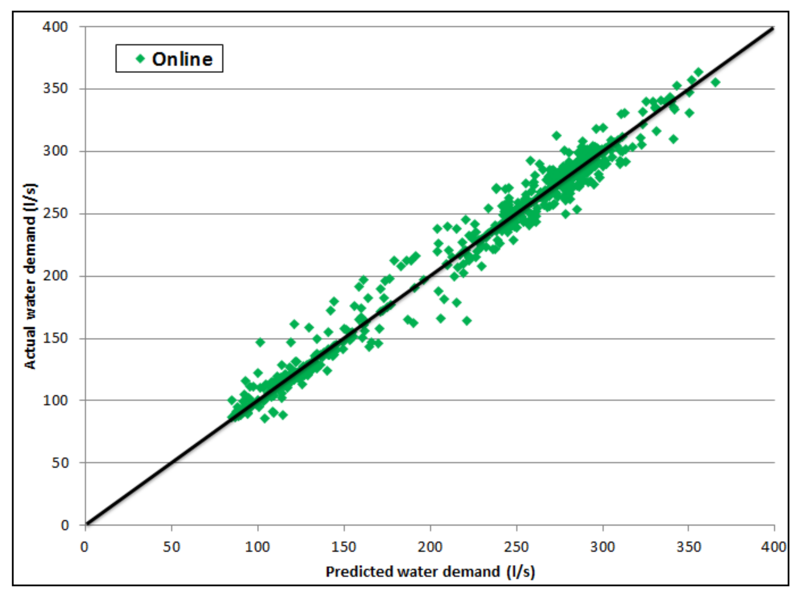

Figure 4: Comparison between actual and predicted online water demands

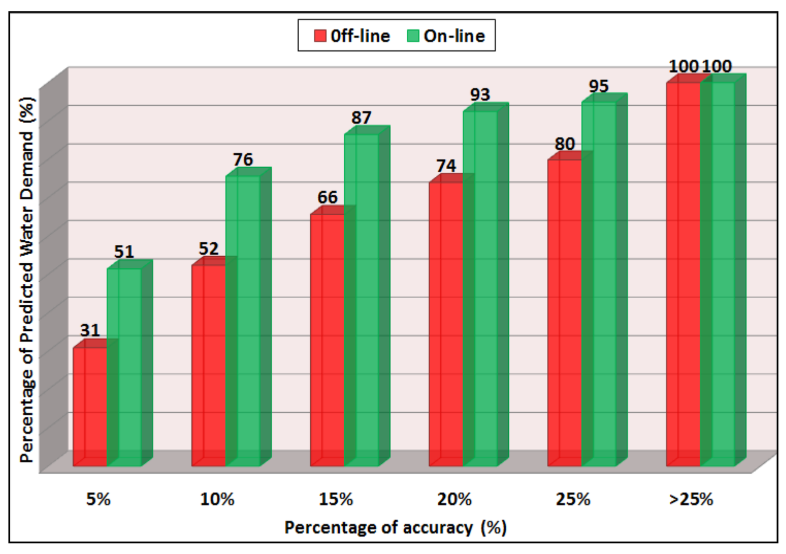

Figure 5: Offline and online water demands

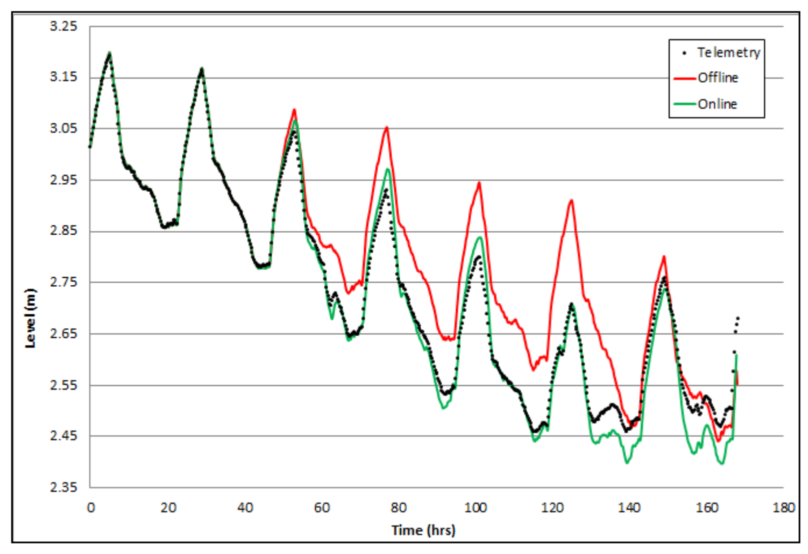

Figure 6: Actual, predicted offline online tank levels

The comparison of predicted water demands (Figure 5) and tank levels (Figure 6) further demonstrates that the online hydraulic model is more accurate than the corresponding off-line model.

CONCLUSIONS

On-line modelling of water distribution system is capable of making prediction that can reflect the WDS state. State update with EnKF minimise the bias in the initial conditions when the hydraulic models are simulated to the next observation time step. The results showed that PC scheme can be a useful tool to predict the hydraulic state of WDS. Further work will look into implementing the PC scheme in UU control room and investigate the practical benefits and limitations.

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