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DEVELOPMENT OF OFF-LINE AND ON-LINE STRATEGIC MODEL OF BELO HORIZONTE, BRAZIL

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Abstract

The strategic hydraulic model of the water supply and water distribution system of Belo Horizonte, 3rd largest city in Brazil, was developed based on the various data sources including ArcGIS, ESRI (Geographical Information System), CAD, elevation data, operation data, consumer information and billing information data, and telemetry SCADA (Supervisory Control and Data Acquisition) data. The strategic model consists of app. 13 200 pipes, 126 tanks, 145 pumps, and 387 control valves. Junction node demands were distributed based on the population polygons, measured flows at macro-measurement points, large water users; multiple demand categories were used including residential, commercial, industry, other, and leakage. Macro-calibration of the model was done based on the historical data and based on the selected data from the telemetry data. The macro-calibrated model was linked with OaSys, Telvent SCADA system in order to be prepared for automatic and periodic model update and for the forecasting simulations. Tailored demand forecasting module was developed for estimating water demands for the predictive extended period simulations based on the historical and current demand and meteorological data. The experience from developing off-line and on-line strategic model of Belo Horizonte including GIS and SCADA link is discussed in this paper.

1. INTRODUCTION

The water supply and water distribution system of Belo Horizonte (see Figure 1) consists of app. 34 municipalities with 31 operated by COPASA on the area of 6 000km^2. The integrated water supply system includes water sources from rivers and reservoirs has the production supply of 17.5m^3/second actual supply of 14.3m^3/sec. The system consists of 30 pumps, 50 reservoirs, 550 control valves, and it serves 4 500 000 people by water, with 2 500 000 inhabitants in Belo Horizonte.

The development of the hydraulic strategic model of the water supply and water distribution system of Belo Horizonte is a part of the Project 3T. The hydraulic model will be used in both off-line and on-line operating modes. Off-line model is linked with the GIS system, which is the primary data source for the model geometry. On-line model is linked with SCADA system and it is periodically updated based on the actual operation of the system.

Figure 1. Belo Horizonte is the 3rd largest city in Brazil with approximately 2.5 million of inhabitants

2. PROJECT 3T

Reduction of the water losses, energy consumption and operation and maintenance costs are the main benefits foreseen with the implantation of the Project 3T - system of automation of the assets of water supply and treatment of sewers. The project is coordinated by the Division of Services of Support of Metropolitana (DVAP), Copasa, Belo Horizonte. The project has been initiated in December of 2005. “Something similar in Latin America does not exist, and this is a great challenge for all. We wait to reach the objectives”, disclosed João Andrade, coordinator of the project. The return of the investment, about R$ 28 million, will be given in three years, after the implantation of the project, that has a maximum stated period of four hundred and eighty days. 3T-Telemetering, Telesupervison, and Telecommand will provide real-time control of the reservoirs, storage tanks, water treatment and water supply, energy costs, water quality, flows and pressures, PH.

3. PIPE NETWORK

GIS data is available for app. 70% of the network. This includes pipes with the following main attributes to be used by the model: GIS-ID, diameter, length, material. All network pipes are available in CAD drawings and there are no attributes to be used for the model. CAD pipes do however have a label corresponding to the diameter and this label was used to substitute the attribute for the model. Automatic procedure was developed to import both GIS and CAD data into the model (see Figure 2), update the model attributes, generate the corresponding junction nodes automatically, and build up the network topology. Data checking tools were used to report missing or out of range values. The total number of pipes in the strategic model is app. 13 200 pipes; these pipes were selected from the all pipe model by selecting all pipes above 350 mm and by including pipes, which make important loops in the system.

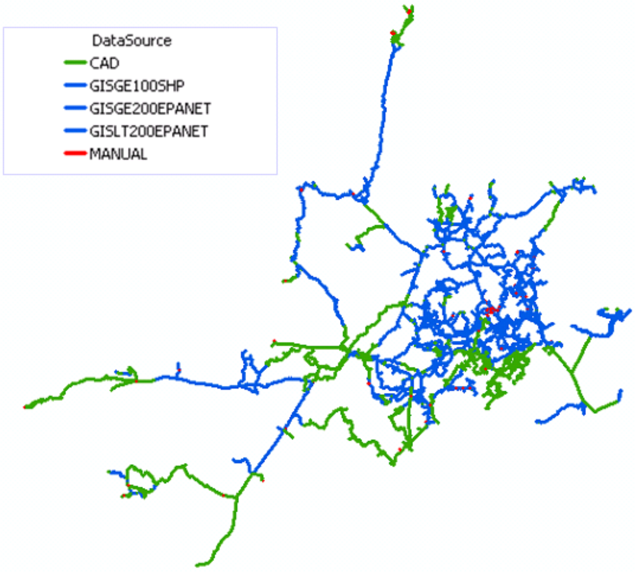

Figure 2. The pipe network was developed based on various data sources including GIS data (ArcGIS) and CAD files (AutoCAD). The strategic model has app. 13 200 pipes

4. NODE ELEVATIONS

Node elevation (surface elevation) needs to be defined for each junction node in the model. This was done by combining data from different sources such as contour lines from GIS, manual entry of the node elevation in AutoCAD. These data sources were merged together in ArcGIS, TIN model was developed **(**see Figure 3), and MIKE URBAN junction node elevation was interpolated from the TIN model. This process also helped to identify errors in the input data. TIN model was repeatedly used during the model building every time new junctions were inserted. Tank bottom elevation and elevation of pressure or level meters was obtained from technical drawings and from dedicated observations.

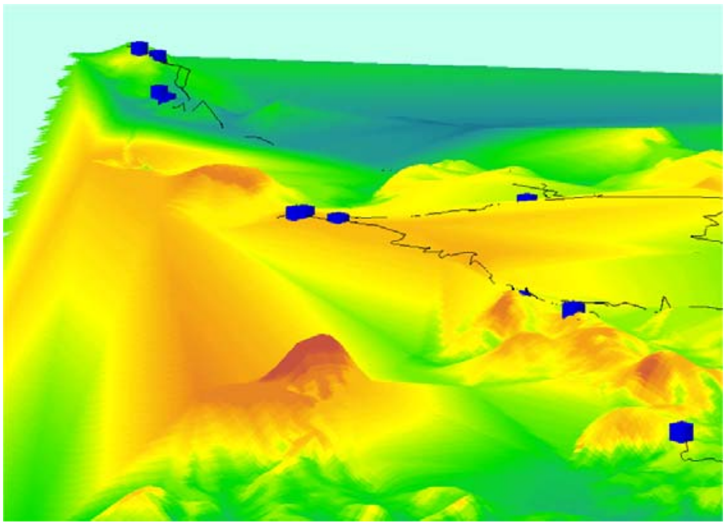

Figure 3. Node elevations were developed based on the digital model of terrain

5. HYDRAULIC STRUCTURES

The strategic model contains 126 storage tanks, 145 pumps, and 387 control valves. These elements were properly schematized and inserted into the model; their attributes such as tank levels, pump Q-H curves, valve settings were verified based on the technical documentation as well as field observations. Pump Q-H curves were also verified based on the telemetry data later on during the on-line model development and calibration. Collecting and verifying data for hydraulic structures (see Figure 4) was the most time consuming part of the model building. Schematic drawing were developed in AutoCAD prior to the input of data into the hydraulic model, naming convention was carefully kept in order to maintain the link of these elements to GIS and SCADA system (based on the asset and model ID).

Figure 4. Hydraulic structures i.e. storage tanks, pumping stations, water sources, control valves were properly schematized

6. DEMAND PROCESSING

Water consumption is defined as node demands; there can be multiple demand categories per each junction node. The following demand categories were used: residential and commercial, leakage, large water user. Automatic demand distribution methods were used to distribute the corresponding water consumption into each junction node demand category; demand distribution of residential, commercial, and leakage was based on the length of a pipe and the diameter of a pipe. Large water users were individually connected to the appropriate nodes of the model. There are app. 160 macro-meters throughout the model area, where the flow is recorded and there are app. 45 zone areas, which average water consumption is calculated based on the corresponding macro-meters. We have used all this information for the demand distribution.

7. MODEL CALIBRATION

The model calibration was done first for selected demand and operating conditions for the steady state conditions. The model was checked for errors such as wrongly closed valves, topological problems, wrong node elevations, incorrect PSV (pressure sustaining) and PRV (pressure reduction) valve settings. Pump Q-H curves were verified based on the telemetry data. Once the model was macro-calibrated, the model verification was done using the On-Line model, which was running every 10 minutes and simulated pressures and flows were compared with the telemetry data.

Macro-calibration for the extended period conditions shown indicated that we had to focus on the control-rules, which are very complex for some of the pumping stations, and we still need to work more on the development of control rules by talking to system operators and by learning all difference control strategies from them (see Figure 5). The sensitivity analysis for pipe roughness and node demand was performed as a part of the model calibration.

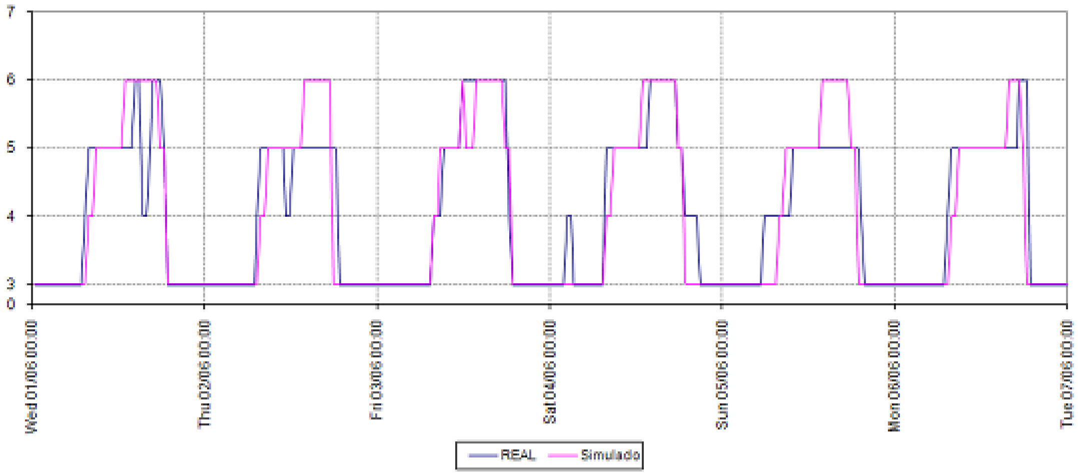

Figure 5. Validation of the control rules and their development based on the SCADA data (history of control). Blue series shows the history of the pump operation (in terms of number of running pumps within selected pumping station) while red one shows how the same pumps would be operated based on the hydraulic model control rules

8. GIS INTEGRATION

The integration of the hydraulic model into GIS system was developed in several levels. Once the hydraulic model was developed based on the data from the existing GIS model, automatic data import, append, and update procedure were established. At the same time, experience from this primary data import was used for adjusting the data structure of the new GIS system in order to make the correspondence between the hydraulic model and asset data more direct. This was particularly true in case of representing valves and pumps (point to link conversion) as well as for the proper schematization of storage tank chambers. GIS database was also extended by pump and valve settings, dimension of storage tank chambers etc. The second level of the model and GIS integration allows for using the model components e.g. run simulation, load results, and others, directly from within the ArcGIS environment. This is level of integration is developed using MIKE Objects, which are COM components of MIKE URBAN model.

9. SCADA INTEGRATION

The hydraulic model is linked to the SCADA system in order to perform automatic and periodic model update and to run hydraulic simulations for the current conditions as well as to predict the future system behavior under extended period conditions. The link between the hydraulic model and SCADA system (Telvent OaSys) is done using the OPC data communication provided by the OPC server of the SCADA system and DIMS (DHI) middleware. The automatic data transfer allows for transferring actual water levels at storage tanks, status of regulating valves and pumps, flows and pressures through macro-meters from the SCADA to DIMS and then to the hydraulic model. Selected simulation results are then transferred from the hydraulic model back to DIMS and to SCADA system. This is used for displaying the simulation results on the SCADA screens used by operators (see Figure 6), to compare measured and simulated data, to alarm for difference above certain threshold and so on.

Figure 6. The new telemetry system was installed by Telvent. The link between SCADA and hydraulic mode was developed

10. ON-LINE MODELLING

On-Line module of MIKE URBAN receives real time data from the SCADA system via DIMS and performs an on-line analysis of the system status and response to changing conditions. Based on the state of the system sent on real-time from the SCADA, the use of the pipeline simulation model in real time and under steady state conditions allows computing flows and pressures, for example, even at locations where there are no measurements. This virtual sensor mode is used for better understanding of the system hydraulics, for micro-calibration of the model, and for automatic comparison of the measured and calculated flows and pressures. Alarming is set setup in case that those differences are significant. The hydraulic, water quality or cost energy model results may be downloaded back into the SCADA database for real time display on the HMI screen (see Figure 7).

Another operating mode is predictive mode, in which the hydraulic model performs a predictive simulation of the system behavior for the next 6, 12, 24 hours. This operating mode requires proper estimate of the network demand (water consumption); dedicated demand forecasting module was developed taking into account historical trends in demand consumption in specific zone areas including large water consumers as well as the impact of the current meteorological parameters i.e. weather forecast.

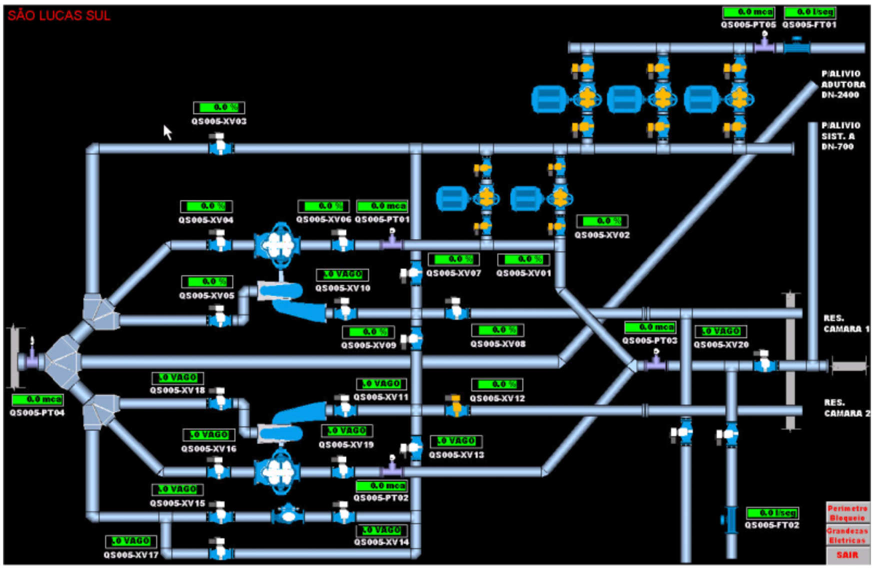

Figure 7. The link between each control location and the hydraulic model was developed. The hydraulic model operating in the on-line mode is periodically and automatically synchronized with the SCADA system

11. CONCLUSION

The strategic hydraulic model of the water supply and water distribution system of Belo Horizonte has been developed and it is now in operation as a part of the Project 3T, which integrates SCADA technology, GIS, and hydraulic modeling into one complex environment. The modern digital technology for acquiring data, modeling approach and updated tools made this integration possible. The developed models running in off-line and on-line modes have a great potential for planning purposes, optimization of the operation of the system and an important decision support tool by the system operators themselves for solving and supporting their daily work. The solutions reported are designed to satisfy all the project objectives however, some of the components are currently still under development and need to be evaluated during the verification and trial period. To make this possible, not only technical capacity is important but also it is crucial to incorporate the use of this technology, hydraulic models, and experience into a daily practice of the client organization and allocate the necessary resources for the model update and use.

12. ACKNOWLEDGEMENT

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