CASE STUDY: LINKING BRISTOL BABCOCK'S SCADA SYSTEMS TO WATERCAD, A WATER DISTRIBUTION MODELING TOOL

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ABSTRACT:

Water Distribution Modeling and SCADA (Supervisory Control and Data Acquisition) technology has evolved immensely in recent decades. A few years ago, integrating SCADA with WaterCAD[2] would have been a formidable task because of technological limitations. However, now, because of advances in the software, integration for the two technologies has become a realistic target.

Bristol Babcock offers a commercial SCADA system called OpenEnterprise and Haestad Methods produces the water distribution modeling software solutions WaterCAD and WaterGEMS. These programs offer the programming-level customization technology known as WaterObjects, which can be used to extend the functionality of WaterCAD and WaterGEMS. In this joint effort project between the City of Bethlehem, Bristol Babcock Inc., and Haestad Methods Inc, Haestad Methods used WaterObjects to develop integration with Bristol Babcock's OpenEnterprise for the City of Bethlehem (Pa.). An application called "SCADAConnect" was developed to facilitate communication between OpenEnterprise and WaterCAD Software. Using SCADAConnect, the Engineers at the City of Bethlehem Public Works Department can calibrate and initialize a water distribution model using SCADA data to provide for better operator training, real-time system control, energy cost reductions, emergency response planning, and forensic analyses. This paper describes the technical issues, complexities, and benefits of this integration. It also presents a case study of SCADA-model integration for Calibration & Validation purposes.

INTRODUCTION

Advances in computer hardware and software have changed the way we think and work. The water industry was not spared in these changes. Today, computers are present at every engineer's desk, and are used to mange and operate facilities, collect and organize information, as well as many other tasks. Over recent years, enterprise data sharing and integration has become the buzz-word in the water industry. However, integration of modeling software with real-time data is a goal yet to be achieved. The benefits of the integration of real-time data with modeling applications are twofold. On one side, models developed from current, accurate data is able to accurately predict current and future behavior of the system. On the other side, model prediction can be use to interpolate SCADA observation between collection points as well as to extrapolate SCADA observation in future.

The case study begins with a simplistic idea of model calibration and validation. This is an important goal for the link between real-time SCADA and the modeling package. However, this objective is just a stepping-stone. Once this goal is achieved, there will be numerous possible benefits to the User/Operator.

Historically, the modeling software package is used by an advanced user for Design and Planning purposes. It aids an offline theoretical study of the Water Distribution system. On the other hand, a real-time SCADA package, deals with real-time monitoring and control requirements of the distribution system. Both packages serve their intended yet traditional purposes. The real question is how does one achieve 1+1=3 where the real-time SCADA system feeds into the model, the information it needs to sharpen the tool (modeling) and then gets back the (predictive) information in return to empower the operator with the intelligence built in through the model? How does the model provide a "systemic view" beyond the actual measured points and guide the operations? Some modest yet realizable objectives are narrated within this paper. Once you have a model that can be kept current, it is likely to be put to use.

A Supervisory Control and Data Acquisition (SCADA) system is a widely distributed computerized system primarily used to remotely control and monitor the condition of field-based assets from a central location. Field-based assets in water systems include wells, pump stations, valves, treatment plants, tanks, and reservoirs.

For a water distribution network, the common objectives of a SCADA system are to [1]:

- Monitor the system for Water inventory management, throughput, or demand and quality control.
- Obtain control over the system and ensure that required performance is always achieved for management, throughput and quality in a Water Distribution System.
- Streamline operational procedures and efficiency through automation
- Achieve top down view of the entire system by operating a system from a single, central location
- Store data on the behavior of a system to achieve full compliance with the mandatory reporting requirements of regulatory agencies
- Establish efficient operation of the system by minimizing the need for routine visits to remote sites and potentially reduce power consumption through optimization of pumping operations
- Provide the ability to monitor and control remote facilities
- Provide an alarm system that will enable problems to be diagnosed from a central point, thereby allowing suitably qualified staff to be sent to the field which will avoid incidents that may be damaging to the environment.

Computerized modeling of water distribution systems has been in existence since as early as the 1960s. Like SCADA systems, these models have evolved with available technology. WaterCAD and WaterGEMS are the water distribution modeling software solutions developed and promoted by Haestad Methods, Inc. Haestad's WaterObjects is an object-oriented Software Development Kit (SDK) that allows users to customize the software to meet their specific needs. It provides programmatic access to the features of the modeling software, enabling end users and third-party developers to build, access, and modify model databases to suit application-specific needs.

The City of Bethlehem Water & Sewer Resources Department uses OpenEnterprise for their SCADA system Human Machine Interface (HMI) and the Public Works Department uses WaterCAD for hydraulic modeling of their distribution system. In order to quickly obtain relevant SCADA data, especially during emergencies when time is critical and operators are at their busiest, city engineers felt it necessary to automate the process of transferring data. They also wanted to be able to simulate past events based on historic data, as well as predict future conditions based on current SCADA parameters.

This paper discusses the SCADA and water distribution modeling technology implemented by the City of Bethlehem and the integration of the two technologies that has made it possible to bring about the operational benefits to the user that goes beyond each of the technology.

CITY OF BETHLEHEM SCADA SYSTEM

SCADA technology typically consists of the following, as in case of the City of Bethlehem:

- RTU (Remote Termination Units): Remote field devices (e.g., pressure flow or level transmitters, pumps, chemical parameters) collect and transmit field data to a local RTU (Remote Termination Unit). RTU is also capable of controlling the field devices with commands such as valve open/close or position or pump start/stop and its speed. As in a typical SCADA system, the RTUs are distributed at critical hydraulic nodes (such as pressure points, storage points, pumping stations, and flow measurement sites) within the city wide system, serving vital information to run the Water Distribution Operation.

- CFE (Communication Front End): The distributed RTUs report data through a communication network into a SCADA Central which can consist of a variety of communication media. A CFE manages communication between RTU and SCADA Central through secured protocol and traffic management. CFE ensures that each RTU is polled at a known frequency. Smart RTUs are capable of local data scanning, management and computations, local control, alarm detection, message handling with time stamping, and report by exception. CFE can be configured as a traffic manager to support transactions between SCADA Central and RTUs. The CFE may also serve as a data concentrator to poll, collect, and retransmit data.

- SCADA Server: SCADA Server serves as a depository of the real-time and historical data. It handles dispatching of commands or managing and processing the alarms. Operators and managers can view field data through their Workstations by running Human Machine Interface (HMI) software. The Human-Machine Interface (HMI) creates a representation of the system and visually displays the data collected by field devices. The Server is capable of letting a third party software package access its real-time and historical data. This is where integration link begins. OpenEnterprise is Bristol Babcock's SCADA and Process Control package. OpenEnterprise enables other applications to query the real-time and historical database through the driver Polyhedra (http://www.polyhedra.com/). Polyhedra is a Windows-based driver that can understand regular Structured Query Language (SQL), queries such as those used by SCADAConnect to request data, translate these for OpenEnterprise, and retrieve the information from OpenEnterprise's database. Any software that has a capability to connect using ODBC (Open Data Base Connectivity) protocols can connect to the real-time and historical data of OpenEnterprise using the Polyhedra driver, which is installed within OpenEnterprise. To exchange data with WaterCAD, Polyhedra must also be installed locally on the computer running WaterCAD and SCADAConnect if different from the OpenEnterprise machine.

In the City of Bethlehem, the OpenEnterprise HMI provides operators with a good control tool. However, because of operational considerations, access to this software was limited to operations personnel only; so whenever SCADA data was needed, engineers and modelers would have to contact an operator who would then retrieve and transfer the information manually. Although this process provides a working solution, it is cumbersome and leaves much room for human error. Assuring an automatic transfer of a coincidental data set from a historical or real-time SCADA database into the modeling package on demand was a formulated objective in this integration effort.

For security reasons, most utilities do not have SCADA machines connected to their LAN (Local Area Network); such was the case with the City of Bethlehem. However, for an integration project to succeed, a physical connection must exist between the computer running WaterCAD with computer hosting the SCADA data, or WaterCAD needs to be installed on the SCADA computer. To address this need, the City of Bethlehem put together a special computer system physically located in the Department of Public Works Engineering Bureau and connected to the SCADA system through a LAN. In order to ensure system security, this computer was not connected to the internet or to other computers.

Integration of OpenEnterprise Server & WaterCAD/GEMS:

Earlier versions of SCADA systems and associated data were proprietary; thus, only the SCADA system supplied by the vendor could extract distribution system data. Current technology, such as that of OpenEnterprise, makes it possible for external applications to connect to the SCADA database and retrieve information. This technology eliminates the need for an operator to manually retrieve data from the HMI or export spreadsheets or other data files with the required SCADA data, and the need for the modeler or engineer to manually feed this data into the model. The original, manual process is illustrated in Figure 1.

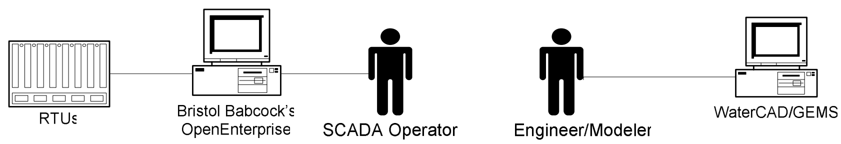

Fig 1: Schematics of Data transfer without a hard wire connection between the computer having modeling software and the computer having SCADA data

With the advanced tools for database connections available in WaterCAD, it is relatively easy to set up database connections between the SCADA data with model and import the data. However, this procedure requires the operator to first extract the data from the HMI and place it in a common data file. Then, the modeler must import the data into the model. This procedure is illustrated in Figure 2.

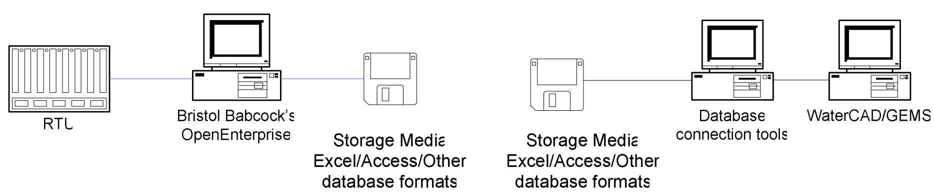

Fig 2: Schematics of Data transfer from SCADA system to WaterCAD/GEMS through Database connections

With the new open database structures, it is possible to establish database/SQL connections and retrieve data through import routines. However, this option is still very time consuming, as the user must create and validate SQL queries and connections, require special permissions in some cases (like access or user rights to the database machine and database), and ensure that the correct data is imported. Due to the large time requirements, importing real-time data is not practical with this approach.

For the City of Bethlehem, SCADAConnect software was used to establish a seamless connection between WaterCAD and the SCADA system. SCADAConnect works by establishing ODBC connections directly to the data storage of OpenEnterprise, thereby removing all human intervention steps and simplifying the process to just a one click process. Figure 3 is a schematic of this approach.

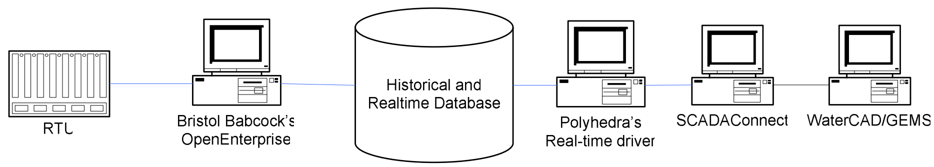

Fig 3: Schematics of automated implementation in SCADAConnect

OpenEnterprise stores two types of tables:

1. Real-time data tables

2. Historical data tables

There is an inherent difference in the setup of these two table types. Real-time tables contain the most recent set of data from the RTUs. The built-in historical system within OpenEnterprise allows for generating the historical data tables from the real-time database at a defined rate or on exception basis (when change is detected) and further aided with a variety of data compression routines. Because the SCADA system was not set up with the model in mind, and vice versa, the SCADA signal locations and model elements had different names.

For example, a signal name might be "Macada&Thomaston@presdn.up.di" for the observed pressure location corresponding to junction J-3406 in the WaterCAD model. A mapping procedure that correlates SCADA signals with WaterCAD attributes and elements was used (and is provided as a Graphical User Interface) to resolve these inherent naming differences. SCADAConnect utilizes this mapping to retrieve SCADA signal values from OpenEnterprise and populate WaterCAD. Mapping is a one-time activity because SCADAConnect is able to preserve this information for later use. The data source and driver for the data exchange are specified with a connection string. In

Bethlehem's case, Polyhedra drivers handle the real-time connection. SCADAConnect is used to relate specific historical and real-time tables to WaterCAD elements and calibration field data sets.

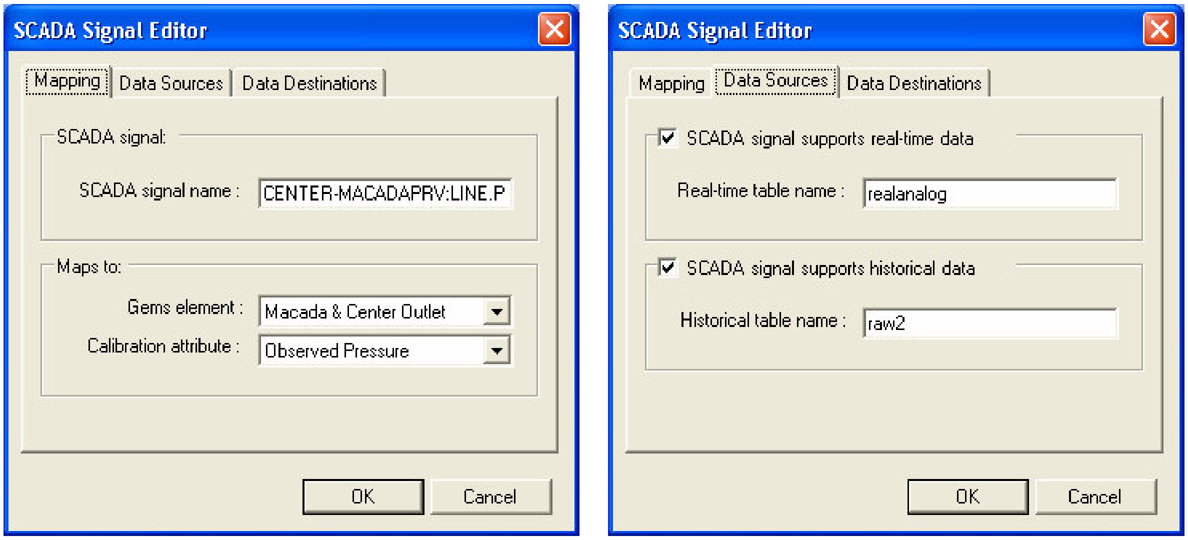

Figure 4: SCADAConnect Signal Editor

The SCADAConnect Signal Editor used in mapping is shown in Figure 4. In these screens, the signal name "CENTER-MACADAPRV:LINE.PRESDN.DI" refers to the Observed Pressure calibration attribute for the "Macada & Center Outlet" junction in the WaterCAD (GEMS) model. The real-time and historical tables in OpenEnterprise where SCADA data are stored are called "realanalog" and "raw2," respectively.

IMPORTING KEY DATA FROM THE SCADA SYSTEM TO THE WATER DISTRIBUTION MODEL

Several types of information can be obtained from SCADA data. As stated previously, SCADA data are broadly classified as either real-time or historical. Real-time data is instantaneous data (usually most current data) available from the SCADA system. It can be used to initialize water distribution models for real-time modeling and calibration.

Historical data is data that is recorded and preserved for later use in, for instance, calibrating the model or simulating past events.

With the Bethlehem project, a total of fifty one signals were mapped to attributes of WaterCAD. Pressure signals at junctions were mainly used as observed values for calibration purposes. Tank levels were imported as both initial conditions for model runs and boundary conditions for use in automated calibration runs with WaterCAD's Darwin Calibrator module. Pump status data was used in establishing initial conditions for model runs. Pressure readings downstream of PRVs (Pressure Reducing Valves) were used to check model PRV settings. Pipe flow values were imported for calibration purposes.

SCADA DATA APPLICATION AT CITY OF BETHLEHEM

This section describes various model applications and the specific ways in which SCADAConnect can aid modeling efforts.

Validating the Model Using Historical and Real-time Data

Calibration is a very important aspect of water distribution modeling. It builds confidence in model results and their application in strategic decision-making.

The City of Bethlehem uses SCADAConnect to provide the following types of observed conditions for use in calibration:

- Field data
  - Pressures
  - Flows
- Boundary conditions
  - Tank levels
  - Pump status
  - Valve settings

Boundary condition data is used to establish the initial conditions for a water distribution system model run. The model run estimates system pressures and flows for a particular set of boundary conditions. These computed values can then be compared with values from field observations to validate the model or to predict the future state of the system given current conditions. SCADAConnect enables the user to quickly import both field observations and boundary conditions into Darwin Calibrator.

With SCADAConnect, data sets for both historic and real-time conditions can be developed. Using a predefined setup in Darwin Calibrator, a calibration run can be performed at any time to validate the model against real-time or historical data.

Estimating Parameters at Unmonitored Locations

In general, water distribution hydraulic models contain many more pipes and nodes than the SCADA system has RTU's. Therefore, the model can report predicted pressures and flows at points that are unmonitored. In this capacity, the model can serve as a source of virtual RTU's. This capability can help the utility managers to estimate what is occurring at certain unmonitored locations based on available SCADA data. A calibrated model is an excellent tool for providing insight into what is happening at unmonitored locations. To obtain results for current system conditions, real-time data is imported as model boundary conditions, and the model is executed.

Making Decisions in Emergencies

One of the primary uses of a water distribution model is to predict the effect that an emergency will have on the system and quickly develop appropriate corrective actions. For example, the water model can be used to select the hydrant with the most capacity for use in fighting a fire, and also to determine if water service will be negatively affected in other locations. Thus, using real time modeling will allow utilities to optimize their operations to save time and money while providing better service.

Developing Demands Based on Flows

An important part of the calibration process is validating the demands used in the model. SCADAConnect can be used with Darwin Calibrator to quickly and easily validate demands for real-time and historical conditions, and also adjust these demands if needed.

Training Operators

After receiving some rudimentary training, operators typically learn most skills on the job. Because they occur infrequently, it is difficult to train operators to handle emergencies such as fires, pipe breaks, terrorist attacks, and power outages. WaterCAD can be used as a simulator to show the operator how the system would react in various emergencies and how actions taken by the operator can correct or degrade a situation.

Model conditions similar to current conditions can be created by initializing the model with a SCADAConnect real-time data import. Operators can then attempt remedies within the model and perform simulations to see the repercussions throughout the modeled system.

Future Potentials

Once the model is calibrated and validated with SCADA supplied data, its usage is far reaching. Some examples of such enhanced concepts for future potentials are noted in here.

- Energy Conservation and Cost Effective Operational Planning: The model could guide the operational staff how to minimize pumping during the daytime. The model could also review valve positions, pump status, and tank levels in a state matrix that could minimize adding energy beyond needs while adding and throttling energy at the same time

- Optimize chemical usage: Ensure that the chemical dozing is optimized (e.g. by adding more than what is required of the two neutralizing chemicals, the end results may be achieved, but at a higher cost.).

- Disaster recovery scenario: At all times let the model provide "FLOW DIRECTIONS" in major pipeline arteries (that could be isolated) to the operator and actions required (open valve A, turn off pump B, start pump C, define “affected area” for notifications) to “isolate” or “contain” water in a segment of the Distribution System in the fastest way possible. In case of a need for isolation arises, the operator has a ready made action plan. The model could also aid in guiding certain actions in terms of additional pumps or valve actions required (in case of need arises due to fire or main break.)

- Supervisory Functions: The model could deal with weather conditions, events, holidays, time of day, while continually defining the hours of on hand supply to prompt operation for boosting productions.
- Distribution System Planning and Evaluation Functions: The model that is calibrated and validated could aid in rezoning requests and their effects on the distribution system, determining the need for and the results of abandoning mains/service lines.

Summary

Linking the SCADA system with a hydraulic and water quality model can greatly simplify data transfer and open up possibilities for the application of modeling in system operations.

The reasons for establishing the data link between a SCADA System and a computerized water distribution model are far too many and go beyond those noted above. This paper establishes viability of such a link as well as scratches the surface of power that such a link can unleash. Once you have this link established, it is difficult to imagine how else to keep the model continually calibrated and validated with the actual field data set from SCADA. In days to come, use and application of a reliable Water Distribution System Model will go far beyond planning and design.

Reference:

[1] Walski, T., D. Chase, D Savic, W. Grayman, S. Beckwith, E. Koelle. 2003. *Advanced Water Distribution Modeling and Management*. Waterbury, CT: Haestad Press.

[2] Haestad Methods, WaterCAD™ Users Manual, Waterbury, CT: Haestad Press.

[3] Bristol Babcock Inc., OpenEnterprise Users Manual, Watertown, CT.