SCADA Standardization

Modernization of a Municipal Waterworks with SCADA Standardization:
Past, Present, and Planning for the Future

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ABSTRACT

The need for standardization of its SCADA (Supervisory Control and Data Acquisition) infrastructure led the City of Guelph, Ontario, Canada (population: 132,000) to develop a set of comprehensive SCADA standards to guide the continuing expansion and upgrading of its water facilities. This paper discusses the steps the City of Guelph Water Services Department took during the last eight years to develop a set of comprehensive SCADA standards, the successes/challenges from implementing them, and how the standards were adopted as part of the workflow for all new capital projects. Comments are made on which standards documents (tagging, hardware selection, programming standards, etc.) were most useful in practice and what aspects of the system may be left up to the discretion of the system integrator. Four short case studies illustrate how the city applied the new standards to existing facilities in order to upgrade them in an organized manner while controlling cost and risk. A fifth case study outlines how the new standards were applied to the design and construction of one of the city's brand new waterworks facilities. The paper concludes with recommendations and advice on how to develop and implement a SCADA standardization program.

Introduction

The need for standardization led the City of Guelph's Water Services department embark on a multi-year program to modernize and enhance its SCADA system using a standards-based approach. Starting with a SCADA Master Plan, the city developed a set of standardization documents and code template files that were incorporated into its procurement workflow. Coupled with a continuous improvement program that treated the standards as "living documents", the result was a smooth and orderly transition from an aging feature-poor infrastructure to a standardized SCADA system that is designed to meet both present and future needs.

The Need for Standardization

Supervisory Control and Data Acquisition (SCADA) has become a vitally important tool for the operation, management, and monitoring of public water utilities throughout North America. SCADA now has an ever-present role that includes looking after all automatic control and alarm management, logging of critical process data, and providing operators with remote access to equipment. However, unlike many other fields of engineering, SCADA is a comparatively newer field with many of its current features only becoming available in the last 10-15 years. With SCADA only recently maturing as a technology, most water utilities tend to have wide range of installed SCADA equipment/networks that can vary considerably in terms of age, feature-set, connectivity, and vendor-support. In addition, most systems have been built piecemeal over the years by a wide variety of contractors, vendors, and consultants, each with their own programming approach and hardware preferences. The result: many water utilities now find themselves with complex, varied and comingled systems that are often difficult to manage in terms of operations, maintenance, connectivity and overall system robustness.

In 2003 the City of Guelph realized that a new approach to SCADA was needed for its waterworks. The SCADA equipment they had worked, but it was difficult to maintain in a consistent fashion and it required a large ever-growing investment in terms of staff training, staff time and the use of external consultants. Equipment such as Historians, HMIs, OITs, PLCs, RTUs and SCADA network infrastructure came from a variety of vendors and each individual piece of equipment had its own custom programming, wiring, and support requirements. Additionally, whenever new equipment was brought online by the city, considerable internal resources had to be spent to integrate it into the existing SCADA network. Furthermore, the city staff who had painstakingly built the existing system wanted a change so they could harness new SCADA technology and not be hobbled by the complexity that had plagued them in the past. These considerations, as well as the increasing need for data-logging to meet regulatory requirements, drove the city's need for a more uniform SCADA system.

SCADA Challenges for Waterworks

Municipal waterworks have several unique challenges that have to be taken into account when designing SCADA systems. These challenges include:

- An uncompromising requirement for 100% uptime: Providing drinking water and fire protection water is a critical service.
- Geography: Facilities such as wells, water towers and pumping stations are typically spread out over large distances. This means that the remote monitoring and alarming functions of the SCADA system must take into account an operator's travel time when there is a problem.
- Networking: The spread-out nature of water districts means that SCADA networks must cover large distances and can often require multiple communication mediums such as wireless, radio, fiber optic, microwave, and/or wired links, each with their own technology-specific strengths, weaknesses and costs.
- Staffing patterns: More and more waterworks facilities are typically unmanned these days. Thus there is a heavy reliance on the SCADA system to provide alarm paging and remote HMI interfaces. The 24-hour staffed control rooms, which are often found in other industries, simply do not exist in many municipal water districts.

- Regulatory reporting requirements: The provision of clean drinking water is underpinned by a strict regulatory environment. The SCADA system is increasing being called upon to log critical process data and generate regular reports.

Some Terminology

The terms PLC, HMI, OIT and SCADA are used differently in many industries, so we will first define how we are using these terms these before proceeding any further. The City of Guelph's Water Services department uses the following definitions:

- The PLC (Programmable Logic Controller) is a specialized industrial computer that serves as the interface between instrumentation/devices and the SCADA system itself. The PLC also contains program logic code that looks after automatic control of equipment that is attached to it. In other industries the PLC is often called a PAC, RTU, RPU, Controller, or Solver.

- The HMI (Human Machine Interface) refers to the "screens" that one would find on a personal computer that is part of the SCADA system. The computer screens that are typically found in a centralized control room and/or operations centre are part of the HMI.

- The OIT (Operator Interface Terminal) refers to a touch-screen interface located on the door of a local control panel. When an OIT is installed on a control panel it will typically be directly connected to the PLC that resides in that same panel.

- The SCADA (Supervisory Control And Data Acquisition) system encompasses the following parts of the control system: instrumentation, control panels, field wiring between control panels and instrumentation, control wiring from panels to output devices, PLCs, automatic control programs on the PLCs, OITs, the SCADA network, servers on the SCADA system, HMI screens, the historian and data logging system, and alarm management/paging systems. The SCADA system does not include MCCs (motor control centers), motor starters, safety instrumented systems, or relay-based backup control systems.

The Road to Standardization

Discussions about SCADA standardization for Guelph's waterworks began in 2002. Their SCADA system which they had been developed during the 1980s, and expanded in the '90s, had served the city well but was showing its age. Comprising of a wide range of technologies tied together with 9600-baud modem links, it was becoming increasingly hard to maintain, troubleshoot, and expand.

Seeing the need to develop a plan for the future, the city embarked a comprehensive study of its SCADA needs for the next 20 years. All current and potential stakeholders of the SCADA system were invited to participate. This included operations, maintenance, engineering, and management as well as the regulatory compliance and procurement departments. The result was a draft SCADA Master Plan in 2003, a standardized SCADA hardware platform, and a draft set of standards documents.

The following two years were spent testing out the new standards on a variety of pilot projects. These ranged from the construction of additional UV disinfection systems to complete control system replacements for several remote well outstations. The results were impressive. Total design time for SCADA and controls integration was cut significantly and the process of FAT/SAT testing was simplified by the use of standardized control narrative formats. Based on these successes, the city released its first set of official SCADA standards in 2005 and made them a mandatory component of the contract documents for all City of Guelph waterworks capital projects.

As the city accumulated more experience with applying its SCADA standards, lessons learned were continually merged back into the SCADA Master Plan and into the standards themselves. Rather than acting as static contract specifications, the standards were treated as “living documents” that evolved as the city’s needs changed. Unlike the former approach of always going for the “latest and greatest”, any major shifts in technology were now undertaken only within the long-term outlook of the SCADA Master Plan. Changes were now made strategically to ensure they benefited the city’s entire SCADA system instead of just individual sites.

In addition to providing the framework for the city’s standardization program, the SCADA Master Plan also greatly simplified the process of making strategic automation investments. Instead of rushing to upgrade all of its existing sites at the same time, the master plan prioritized and aligned individual site upgrades in a long-term context. For example, upgrading critical sites that had older technology that was problematic to maintain was made a high priority, while other older sites that were not yet causing significant issues were put on a more long-term replacement schedule. The SCADA Master Plan continues to be an important tool used by the city for planning and scheduling its automation upgrades.

Developing Standards

The key to developing standards is to weigh the time investment required against the potential benefits. Too many standards documents, or too much detail, can consume staff resources and stifle innovation. Too few standards, or standards that lack sufficient detail, can be just as bad as having no standards at all.

Looking to its SCADA Master Plan, Guelph decided to develop the following standards documents: (a) a new system-wide universal tagging standard, (b) standardized control panel and field-wiring designs, (c) a SCADA network equipment/addressing guideline, (d) a list of approved PLC hardware configurations, (e) a single approved OIT with code templates, (f) a PLC programming standard with code templates, (g) a standardized suite of SCADA/HMI software, (h) a SCADA/HMI programming standard with code templates, and (i) a standardized format for process control narratives.

The city was careful to only develop standards that it felt would deliver good return on investment. Each standard was tied to an area in the SCADA Master Plan where the city had identified a need to improve. Some standards were easily formulated by collating specifications from past projects; others were brand new documents and templates that had to be developed from scratch.

One of the key needs identified in the SCADA Master Plan was to develop a new tagging standard that could be used across the city’s entire waterworks. Prior to standardization, tagging had consisted of a patchwork of methods based on P&IDs unique to each site. Using the ISA-5.1 standard as a starting point, the city developed its own customized system-wide tagging system that took into account its numerous facilities and unique equipment types. The new system consists of 12 character alphanumeric tags which are built up from a standardized collection of tag fragments for the site code, equipment code, device code, signal direction, and signal type. For sites with multiple pieces of equipment and/or devices, a system of trailing numbers for the tag fragments is built into the standard. The city was also careful to define tag fragments not just for equipment and I/O signals, but also for such things as operator set points, calculated values, alarm types, and various other control system parameters. Furthermore, for physical equipment labeling an abbreviated version of the tagging is used, with the last two SCADA-specific tag fragments omitted. The standard also includes a clear mechanism for adding new tag fragments, so new codes can be easily added in the future as the city acquires new types of equipment. The city's new universal tagging standard was one of the first standards that was released and put into service.

Standards for control panel design, field wiring, and PLC/OIT hardware were another key area identified in the SCADA master plan. As long as the city could remember, variations in the various control panels across the city's waterworks had been a challenge in terms of troubleshooting and maintaining spare parts inventory. Standardized control panel designs, wiring types/colours, and PLC/OIT configurations were specified using written specifications and CAD template files. The results were easier troubleshooting, reduced design/review time for new projects, streamlined inspections for new construction, and decreased staff training costs.

As part of its standardization effort, the city also looked at how programmers and system-integration firms develop software code. They found that most programmers would rather work with code template files than written specifications. Keeping this in mind, the city made all of its PLC, OIT and HMI programming standards consist of two parts: a written specification and a collection of code template files.

The written specification documents performed their usual roles of providing the scope, overview and explanation of the city's standards, but it was the template files that added the real value. These files consisted of several fully working code examples, empty "base code" programs for programmers to use as starting points, and collections of standardized pre-built widgets/modules. For HMI and OIT programming, this included standardized screen templates, pop-up windows, icons and navigation bars. For the PLCs, the template files included such things as standardized subroutines, add-on instructions, function blocks, and data structures. When put into practice, using both written specifications and template files translated into shorter development timelines and a streamlined QA/QC process.

Selecting the SCADA Hardware, Software and Network Platform

One of the most important parts of the standardization is selecting the SCADA hardware, software, and network platform to use. By reducing variation in the SCADA system, staff training requirements, and the use of external consultants can be significantly reduced. However, it is important to remember that standardization does not necessarily mean sole-sourcing everything from one vendor; sometimes a mix of products from various vendors is the best solution. Whether one standardizes on a vertical solution from a single vendor or a collection of products from various vendors will depend on the specific needs of the individual SCADA system.

Factors that Guelph considered when selecting its SCADA platform included: (a) feature sets vs. needs, (b) connectivity to other systems, (c) cost and availability, (d) impact on current staff in terms of skill sets and training requirements, (e) local vendor support, (f) the vendor's road map for future support and future product releases, (g) availability of local system integrators with the required skill sets, (h) what had worked in the past, and (i) the ease of integrating it with the existing system during the transition period.

Case Studies

The transition from the city's old SCADA system to the new standardized one took careful planning, creativity and hard work. Like most public utilities, the city had a limited annual budget to spend on new infrastructure, and these funds had to be split between capacity upgrades and scheduled equipment replacement. The cost-sensitive and political nature of public utilities also meant that a large rate surcharge could not be applied to finance a short-term upgrades program. To further complicate matters, most of the city's water facilities were in constant use, so downtime had to be minimized. The result was a roadmap to standardization that was planned out as a series of smaller projects over a ten year period. A sampling of some of the upgrade projects that the city undertook as part of its standardization program are discussed here.

Core Infrastructure Upgrade

To start its standardization upgrade program, the city selected two core elements that needed to be addressed immediately: its aging SCADA network and centralized SCADA servers.

Dedicated, fast, and reliable networks are one of the key ingredients to implementing a successful SCADA system. Looking to the future in its SCADA Master Plan, Guelph decided to move from its older serial-based networks to a new dedicated fiber optic Ethernet network. For the new network, the city chose Ethernet because of its speed, wide availability, vendor neutrality, and the availability of a local high-quality fiber optic network provider.

The challenge with the existing SCADA network was that it was vast and would require considerable effort to replace. Rather than trying to replace everything at once, the city decided to upgrade the network backbone that connected in SCADA severs first and then upgrade the rest of the network over a six year period. This translated into core network upgrades taking place in 2005, and the rest of the network being upgraded as a series of staggered smaller projects which were completed on a timeline that stretched into 2011.

The second part of the city's core SCADA infrastructure that needed to be upgraded was the city's centralized waterworks SCADA servers. The servers were nearing end of life and the legacy software they were programmed with was becoming more difficult to support. However, replacing them was no easy task as they were in constant use and they were a central component of the SCADA system. The solution was to adopt a phased approach consisting of smaller projects spread over a longer period of time.

In addition to the installation of the new server hardware and associated new software, there was a significant amount of custom reprogramming required on the servers to effectively harness the capabilities of the new software as envisioned in the city's new standards. To tackle this, the importing and upgrading of the programming was also managed as a series of small projects. The result was a smooth and orderly transition to the new server programming that did not overwhelm available staff resources. In the first project, the new server hardware was installed but the existing HMI, alarming, and data collection applications were only migrated “as is” into the new environment. Then, the detailed process of updating the HMI screens, scripting, tags and alarms to the city’s new HMI programming standard was tackled as a series of smaller projects over the following years.

Facility PLC Upgrade Program

When Guelph embarked on its standardization program the city had a wide variety of PLCs in use throughout its waterworks. The PLCs generally fell into one of three categories: standard hardware with non-standard programming, non-standard hardware that could connect to the new network, and non-standard hardware that could not connect to the new network. All three categories would require upgrading and/or replacement, but it was the third category that was the most problematic.

The city’s non-standard PLC hardware existed primarily as a side-effect of a tendering practice called “performance specification.” Tendering equipment using this method can be very cost-effective but there are many potential pitfalls. Performance specifications tend to be very good at specifying the primary functions of equipment (such as the treatment capacity of a UV filter), but details such as the control system and SCADA connectivity are often overlooked. This is where having an already-developed SCADA standards package is most effective. Performance specifications can be enhanced by simply attaching the SCADA standards to them as an appendix. This enables both the benefits of performance specification as well as the SCADA connectivity that you would normally only get from a “hard specification.”

Using a prioritized approach that started with the older and more exotic PLCs and finishing with the PLCs that only required reprogramming; the city adopted a program where facilities would be upgraded one at a time. At each facility a phased approach was used because taking it offline could only be done for short periods of time. First, new control panels with the new PLCs and field wiring were installed but not connected. Second, new programming code was installed on the new PLCs but only run in simulation mode in order to test the new control philosophy. Once testing was complete, equipment in the plant was then switched over to the new pre-wired field wiring and the old field wiring disconnected. After a verification period, the old field wiring and panels were then removed. As of spring 2011, this facility by facility approach is still ongoing.

Redundant Data Logging for Wells

One of the new features the city included in its SCADA standards was redundant data logging for its Historian. The city had always seen data logging as priority but ongoing connectivity problems with the old SCADA network and dated technology had prevented it from being implemented in a robust manner. Under the city’s new SCADA standards, the remote well sites would use a new standardized OIT to log data redundantly. In the case of a communications outage, the OIT at a well would continue logging data locally and store it in its nonvolatile memory; once communications were restored, the OIT would then automatically forward its logged data to the Historian.

The roll-out of the new redundant datalogging was a two part process. First the network links to the wells had to be upgraded, as the old network did not support the required connectivity. Second, the OITs themselves would have to be installed at the wells and configured to do the redundant data logging. Thus, the roll-out of the OITs was closely tied to the city’s network upgrade program.

Looking to the schedule for the network upgrades, the city adopted a three year program to install the new OITs for its redundant datalogging strategy. However when the city was only about third of the way into the program, a policy shift at the provincial regulator resulted in the city having to install the OITs before the network links were ready. Fortunately, the city was able to accommodate the request because as part of their OIT technology evaluation they had selected an OIT that allowed its data records to be retrieved manually using a software tool. A simple solution was to have a staff member visit the wells on a weekly basis to fetch the data until the new network links were in place.

A Well Field Upgrade

In many ways, using SCADA standardization does not change how capital projects are undertaken. Projects are still envisioned, budgeted, designed and tendered out as projects. The only major difference is that the SCADA standards are attached to the tender documents for any project that involves the SCADA system. In effect, this means all of them, as most capital projects these days always seem involve SCADA in some way.

A typical project where the SCADA standards were used was the addition of two new bedrock wells to the city's Arkell Springs well field. More than half of the city's water comes from this well field, so it was important that the addition of the new wells and the associated control system upgrade went smoothly. It turned out to be a perfect example of how the new SCADA standards contributed to lower design costs, simplified software development, and a quick startup and commissioning process.

"In many ways the Arkell Springs Upgrade was the same as any large capital project, except that the SCADA portion required very little management compared to other parts of the project," says Vincent Suffoletta, Supervisor of Supply for the City of Guelph's Water Services Department, *"The SCADA standards resulted in real time savings for both our in-house and external system integrators when it came to system design, programming and testing. Our operators also liked the consistent HMI screens which made their jobs easier. Furthermore we incorporated the lessons learned from the project back into our standards documents as part of our continuous improvement program."*

New Pumping Station

Realizing that automation hardware/software products do not last forever, the city's SCADA Master Plan considers the entire life-cycle of the SCADA technology they use. The lifecycle planning includes all components of the SCADA system, from initial installation through ongoing maintenance to eventual end-of-life replacement. In 2009, the construction of a new booster pumping station in the city's south end provided an opportunity to test a "next generation" PLC platform that had been identified in the city's SCADA Master Plan.

Using the new PLC platform was a learning experience that yielded valuable lessons about the new technology. These lessons were incorporated into the city's SCADA standards immediately after the project was complete. The city now includes this new "next generation" PLC as one of the options in its standardized PLC hardware specification, and in the PLC programming standard that accompanies it.

Standardization Advice for Others

The first phase of Guelph’s standardization program is now complete, but the city realizes that standardization is an ongoing process as technology and the needs of its stakeholders continue to evolve. Guided by its SCADA Master Plan, the city now continually updates its SCADA standards. That way the standards documents and code templates are always current and play an active role in the city’s procurement, construction, operations and maintenance activities.

Looking back at its SCADA standardization program so far, the city offers the following advice:

- Before undertaking a standardization program you need to develop a SCADA Master Plan. The master plan will help you focus your vision and serve as a guide.

- Select your standardized hardware, software and network SCADA platform using a life-cycle approach. Short term cost savings do not always make sense over the long-term.

- Write your standards documents to suit your individual needs. Tailor the level of detail to what you need to implement your master plan and enforce consistency in your new SCADA platform. The point of the standards documents it to make them work for you, not the other way around.

- Programming standards for HMIs, OITs and PLCs must consist of written specifications accompanied by code template files. Most programmers, whether in-house or part of a system integration outfit, prefer programming to reading. Help yourself by helping them. Provide pre-configured “base load” programs, working code examples, and a large library of pre-built widgets, modules and screen components. If you don’t have the programming resources in-house to do this, consider hiring a system-integration firm to help you develop the standards.

- Use your SCADA Master Plan to help you develop a strategic timeline for updating the older non-standard parts of your SCADA system. Rather than rushing to try to upgrade everything all at once, prioritize potential upgrades in terms of the goals of the SCADA system and schedule accordingly.

- Standardizing does not mean stifling innovation. Use your SCADA Master Plan as a “living document” and review it at least annually. When new technology becomes available look at it in terms of the entire life-cycle of your SCADA system and how it can fit into your SCADA Master Plan. If a technology looks promising, incorporate it into the plan and test it out in a pilot project. Then review and evaluate the results. If it turns out to be the direction you want to go, revise your standards documents accordingly and incorporate it into your workflow.

- Once you have your SCADA standards written, use them for *every* capital project whether it is new construction or upgrades to an existing site. To work effectively, the SCADA standards must be included as part of the contract documents for *every* project that you undertake.

Guelph’s SCADA standardization program was a success because standardization was seen as a strategic investment. Though it did take a fair amount of time and resources to get started, once the standards started being used the real benefits became very apparent. Time and cost savings during the design and construction phases of projects were significant. Integration was easier to control and manage, and the city's waterworks staff found the resulting SCADA system easier to use and troubleshoot. Innovation in the SCADA system is ongoing, but it now moves forward in a controlled and manageable fashion.

Steps from Here

The City of Guelph's Water Services department sees SCADA standardization as a continuing part of their operations, maintenance and capital-improvements workflow. Two years ago, the installation of a new version of their HMI software was identified as a priority in their SCADA Master Plan. A project to complete the upgrade will be proceeding in the summer of 2011. To guide the roll out, the city is updating its HMI standards, so the new functionality of the upgraded HMI software will be effectively harnessed for both the upgrade and all new projects moving forward. The process of SCADA standardization never ends, but neither do its many benefits.

List of Acronyms:

CAD .... Computer Aided Design (electronic technical drawings)
FAT................... Factory Acceptance Test
HMI .... Human Machine Interface (viewable in a central control room and/or operator desk)
MCC .... Motor Control Centre
OIT .... Operator Interface Terminal (mounted on a control panel door)
P&ID................. Piping & Instrumentation Diagram
PAC................... Programmable Automation Controller
PLC .... Programmable Logic Controller
QA/QC.............. Quality Assurance/Quality Control
RPU .... Remote Processing Unit
RTU .... Remote Terminal/Telemetry Unit
SAT................... Site Acceptance Test
SCADA.............. Supervisory Control and Data Acquisition (system)

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