AUTOMATION IN THE MUNICIPAL WATER/WASTEWATER SECTOR:
NAVIGATING SCADA DURING A TYPICAL MUNICIPAL CAPITAL PROJECT

PART 1: THE DESIGN PROCESS

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Automation continues to play an increasing role in the provision of critical infrastructure, including our public water supplies. Gone are the days of operators driving from site to site to turn valves at wellhouses or to start/stop pumps as part of normal operations. Instead, we now use sophisticated supervisory control and data acquisition (SCADA) systems to automatically control and monitor the wide range of facilities used to provide drinking water and wastewater services.

Building this critical infrastructure involves a great deal of planning, design, and resources, not to mention a large group of people and a wide variety of skillsets. It is always a team effort. No matter what methodology is used – whether it be traditional design-bid-build, design-build, design-bid-build-operate, etc. – the common element is a wide variety of individuals and skillsets need to come together to execute a successful project. Having a common goal and ensuring that all the parties work together are essential to ensure that a newly built facility will operate as intended and that everyone gets paid as part of the process.

The coordination of these various efforts is usually undertaken by a group of project managers: one acting for the owner, one acting for the design team, and another acting as part of the construction team. The project managers oversee the overall timeline and carry out the important role of controlling the overall schedule, scope, cost and quality aspects of the project. Historically, most project managers in the municipal sector come from a civil engineering/construction background. Civil engineers are not specialists, but instead typically have a good overall grasp of what needs done at each stage of a large infrastructure project. The project managers bring in various specialists as needed during the duration of the project. And if a project involves SCADA in any way – which is pretty much a foregone conclusion these days – SCADA professionals will be needed at every stage of the project.

Scoping the Project

Most municipal water/wastewater projects start with a study to confirm the need and timing for the upgrade. Then, funding will be secured, and a project charter to define the project will be developed.

Once a project charter has been developed, the utility's first task is to develop a detailed scope of what the project will include (and not include) and a desired plan for staging the work. A terms of reference (ToR) document is created for each of the project's major teams. For a traditional design-bid-build project, a ToR consultant provides a task-based overview of what aspects of the project the design team will be handling. (The design team, in turn, develops the builder's scope in the form of the contract drawings and specifications.) From the design team's perspective, the ToR document outlines the owner's design goals and provides a list of the deliverables and services the owner is expecting. A typical design ToR includes task descriptions such as collecting background information, developing a design brief, preliminary design, various detailed design stages (e.g., 50%, 75%, 90%), and then creating a set of ready-for-construction drawings and specifications, followed by tendering the project's construction phase, and then administering the construction contract.

The ToR is accompanied by a copy of any design standards or templates that the owner wants to follow as part of the design. It is essential that the utility include any SCADA design standards, such as guidelines, templates, and worked examples, as part of the ToR. Furthermore, if the project involves upgrading, replacing, or adding onto an existing facility, it is essential that documentation about the existing facility (usually in the form of drawings and other documentation) is included as part of the ToR so that the design team has a clear picture of what they will be working with.

The ISA112 series of SCADA systems standards (currently under active development) provide guidance on how all these various facility-owner SCADA design guidelines, templates and examples can be organized into a set of SCADA design standards. More information about the (freely downloadable) ISA112 SCADA management life cycle, along with a recommended structure for organizing SCADA design standards, can be found at www.isa.org/isa112/.

Once the ToR has been developed, it can be used as the basis of an RFP if an external design consultant is to be used, or it can be used as staffing guide if the design work is being completed in-house.

SCADA's Impact on Municipal W/WW Capital Projects

- In the municipal water/wastewater sector, automation systems are referred to as SCADA systems and are considered to include instrumentation, signal wiring, PLCs, motor starters, actuated valves, the control network, servers, workstations, dashboards, and alarm call-out systems.
- SCADA systems can be implemented in the municipal water/wastewater sector using a variety of technologies including programmable logic controllers (PLCs) with human-machine interface (HMI) software, distributed control systems (DCSs), Industrial Internet of Things (IIoT), and proprietary controllers.
- Once installed, SCADA equipment in the municipal water/wastewater sector is often expected to have a service life of 15 to 30 years, which is considerably longer than many other industries.
- Across Canada there are over 14,000 wastewater facilities and 10,000 drinking water facilities, which will all require upgrades and maintenance during their lifespans and eventual end-of-life replacements.

Background Stage

Once the design team has been selected, the next step is to conduct a detailed survey of the existing conditions and any legacy systems that must be incorporated (or replaced) by the new design. If it is a legacy site, this includes gathering up any historical documentation for the facility. This survey should include, at minimum, a set of up-to-date piping and instrumentation diagrams (P&IDs), site layouts, floor plans, and electrical drawings for the site. Any historical drawings must be verified to ensure they reflect the actual site conditions.

Some utilities choose to pay a third-party engineering firm to make a set of as-found electrical drawings, P&IDs, and floor layouts, so these can be provided to the main project's design team as part of the background information.

Design Brief

Once the design team has a good understanding of the project scope and background information, they develop a short report that outlines their proposed design solution. This is called the *design brief.* Depending on the size and scope of a project, a design brief report may range from a few pages to over a hundred pages. The design brief usually includes some conceptual drawings. Sometimes the design brief is referred to as the *conceptual design phase* or a *10% design*.

From a SCADA perspective, the design brief must also include a section that describes the proposed automation hardware and a high-level description of the planned instrumentation, control devices and process control schemes that will be used for the project.

Preliminary Design

After the design brief has been reviewed by the utility and relevant stakeholders, the next step is to carry out the preliminary design. Often this stage is called the *30% design*. There is usually a considerable amount of design effort at this stage, as this is when the overall project plan is fully developed and the important question of "will it all work" must be sorted out.

The preliminary design stage results in a package of preliminary design drawings, accompanied by a preliminary design report that outlines the features of the proposed design and the rationale behind it. Depending on the type of project, the preliminary design package may also include supplementary information on key pieces of proposed equipment.

From a SCADA perspective, the preliminary design package should include a high-level logical diagram of the automation equipment to be used, process flow diagrams, floor plans, and a list of any hazardous areas that may require equipment with special electrical ratings. Many preliminary design packages also include preliminary lists of electrical loads, pumps, major valves, and instruments.

The preliminary design stage is also when any SCADA "proof of concept" testing should be carried out on proposed automation equipment.

Detailed Design Phases

Once the preliminary design has been reviewed by the utility and feedback gathered, the next step is the detailed design. A commonly used progression of detailed design stages is 50%, 70%, 90%, and construction-ready (or tender-ready). The decision of how many detailed design stages will be used, and if any supporting

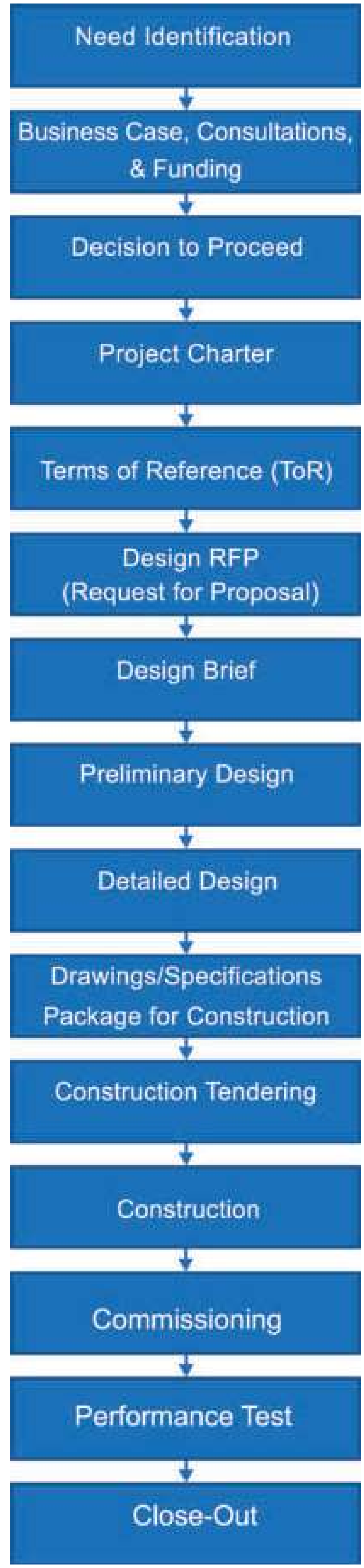

Figure 1. Typical Stages of Municipal Infrastructure Project

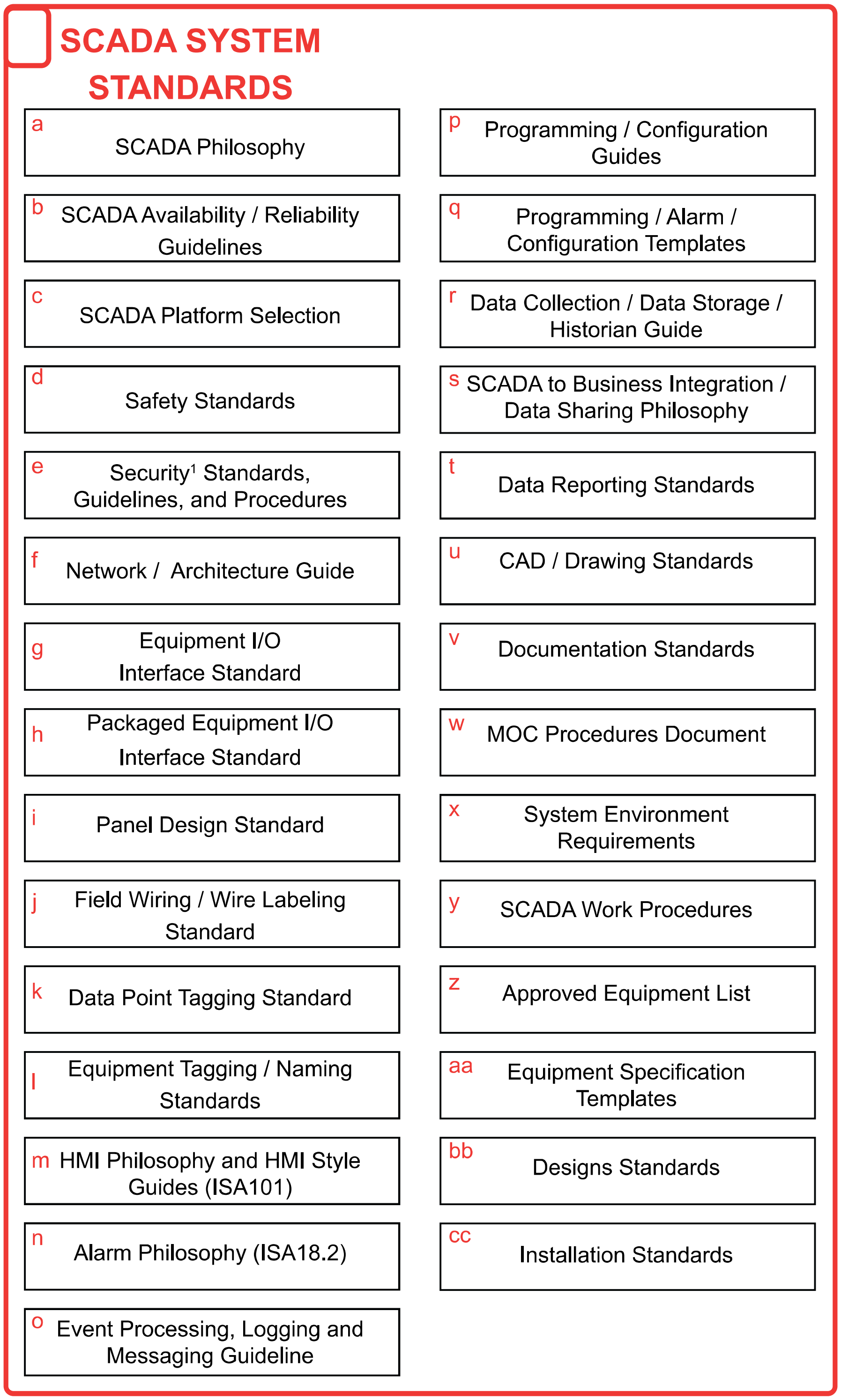

Figure 2. Typical SCADA System Design Standard (Source: ISA112 SCADA Systems Standards Committee)

technical memos are to be developed, will have been defined in the design team's ToR at the start of the project.

At the end of each detailed design stage, an increasingly detailed package of drawings and specifications is provided to the utility for review. As the design stages progress, the number of project drawings and length of the specifications increases as well. For example, at 50% design, the specifications section usually consists only of a table of contents, whereas at 90% it is not uncommon for a specifications section to consist of hundreds, if not thousands, of pages organized into numbered sections.

Additional Resources

- ISA112 SCADA Systems standards committee: SCADA systems management lifecycle, standards and technical reports for SCADA systems – www.isa.org/isa112/
- ANSI/ISA-62381-2011 (IEC 62381 Modified)*, Automation Systems in the Process Industry – Factory Acceptance Test (FAT), Site Acceptance Test (SAT), and Site Integration Test (SIT)*
- ISA101 HMI Design Standard and technical reports – www.isa.org/isa101/
- ISA18 Alarm Management standard and technical reports – www.isa.org/isa18/
- American Water Works Association – www.awwa.org
- ISA Water/Wastewater Industry Division – www.isawaterwastwater.com

The Role of the SCADA Team During Detailed Design

From a SCADA perspective, the main goal during detailed design is to ensure that all aspects of the design have been properly coordinated with one another, and that the utility's SCADA design standards are being followed, so the automatic control system will work effectively. The overall process systems, and the SCADA system that controls and monitors them, will only function correctly if all the aspects have been well-designed, coordinated, and sized properly for all operating modes. Operating modes include start-up, shutdown, online, off-line, normal operation and a wide range of abnormal situations. Thus, both the utility's and the design team's SCADA staff need to carefully review all the drawings and specs together (not just the SCADA-specific sections), so they can check the overall coordination of the design. This review ensures the new SCADA system will effectively monitor, control and log the processes in the newly built facility.

Common Detailed Design SCADA "Watch Outs"

Some SCADA and process design issues are often encountered on municipal water/wastewater infrastructure projects, including:

- **Improperly sized flowmeters:** Flowmeters should be sized based on the expected flow rate, not the pipe size leading to them. If too large a flowmeter is installed, it may read unreliably or suffer from sediment build-up due to flow velocities being too low.

- **Poor locations for instrument taps:** Well-designed tap points are accessible and are clearly shown on drawings. Good practices include having full-port shut-off valves on each port for isolation, having spare ports, and locating tap points so they won't be prone to air-locking, fouling, or sediment.
- **Sample lines that are too long:** Long sample lines, or sample lines that are poorly sized, may result in long deadtimes for the sample to pass from the sampling point to where the analyzer will see it. A long deadtime creates a significant delay before the control system can "see" a process change.
- **Chemical dosing lines that are too long:** Long dosing lines may introduce very long process deadtimes that may make it very difficult (or impossible) for chemical dosage adjustments to affect the process as desired.
- **Non-Identically sized pumps in pump banks:** Having unequally sized pumps in a pump bank makes programming auto-failover conditions in the control system unnecessarily complicated and may lead to erratic operation depending on which pumps fails. Using identically sized pumps in a bank of pumps with variable speed drives provides a wider range of flow control, makes implementing auto-failure for pumps easier, and reduces the number of spare parts needed. Banks of identically sized pumps also avoid the problem of having fire pumps that seize-up because they never run or having the pumping station run erratically because a key pump is out of service.
- **Misplaced or missing air relief valves:** Not having enough air relief valves installed in the high points of piping systems and on pump discharges may cause trapped air in pipes, vapour locking, and erratic flow behaviors. In severe cases, poorly placed air or vacuum reliefs can cause significant health/safety hazards.
- **Inappropriate use of valve types:** Butterfly valves should not be used as control valves, as they do not effectively control flow. Inappropriately sized/selected valves will suffer from poor performance and can rapidly wear out due to cavitation.
- **Improperly sized control valves:** Improperly sized control valves will never

work properly, no matter how sophisticated the software-based control scheme. Control valves should be sized based on an appropriate operating valve coefficient (Cv) rather than just the line-size.

- **Missing pressure testing instructions in contract documents:** When no guidance is provided in the contract documents to the construction team, mistakes can easily happen, including rupturing instrumentation and diaphragm seals, incomplete testing, or missing test documentation.
- **Missing SCADA and/or Network Details:** Incomplete Process Control Narratives, missing programmable logic controller (PLC) hardware details, or no clear I&C wiring guidelines are a recipe for delays and extras during construction. Also, when these details are not included in contract documents, it can result in expensive facilities that are difficult to operate and maintain.

This list is only a sample of the many potential design issues that can happen when the detailed design of a municipal water/wastewater facility is rushed by a design team or is undertaken by a design team with mismatched skills. The important takeaway: Use a team approach to ensure that enough quality assurance/quality control is done on the design package to catch potential problems at the design stage. Resolving issues at the design stage is much cheaper than during construction. When a problem is not corrected during the design phase, it may cost 10 to 20 times more to resolve during construction.

Next Issue: Part 2: From Tendering to Completion

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