Developing In-House Sewage Pumping Station Design Standards: Streamlining Integration of Pump Stations in Niagara Region


1 Provectus Systems, Inc., 206 Main Street West #2A, Hamilton, Ontario, Canada, L8P1J3
(*correspondence: mpresti@provectussystems.ca)

2 Water and Wastewater Technical Services, Regional Municipality of Niagara - Public Works, 980 Major Street, Welland, Ontario, Canada, L3B 6J2
(*correspondence: ed.vanvliet@niagararegion.ca)

KEYWORDS
SPS, SCADA, PLC, HMI, MOE, OIT, PCN

ABSTRACT
From the early onset of engineering practices there has been the focus to create processes which reduce learning curves, inconsistency and human error. The goal has been and still is the ability to complete tasks in a more consistent, efficient and standardized routine.

The Wastewater Collection Process is comprised of several remote Sewage Pumping Stations (SPS’s) that functionally perform the same task; the collection and pumping of wastewater to a centralized plant for treatment. With the challenges of workforce attrition and financial restraints the undertaking of upgrading aging infrastructure in a standardized fashion can be laborious, resource intensive and result in inconsistent variances from the original intended method unless rigid, detailed standards are put in place. Aside from the physical installation, the methods of control philosophy can also be vulnerable to variation depending on several influential factors such as having no adopted philosophy in place and the development being left to various retained subject matter experts.

Based on the need for a standard that contained physical control architecture and a documented process philosophy but still had the opportunity for minor customization, new innovative technologies and uniqueness the 85% SPS Design Standard was developed. This standard was developed through the combined efforts of the Operations, Process, Electrical, SCADA, Maintenance and Engineering groups to ensure that all interests were accounted for. This collaboration of efforts enabled internal ownership, a benchmark of accountability as well as reduced drawing and process control narrative review time, accelerated SCADA design sign off and increased the overall PLC, SCADA, Data Collection and Reporting commissioning phases of Sewage Pump Station control system upgrades.
Introduction

The Niagara Region, located in Ontario, Canada owns, operates and maintains 6 water treatment facilities, approximately 40 remote water sites along with 8 wastewater treatment facilities and approximately 140 remote sewage pumping stations. Each of the systems are fully automated and are capable of view only or view and control capability to the main treatment plants through a Supervisory Control and Data Acquisition (SCADA) System. With most of the design focus being put into the hands of the third-party consultants, the network was standardized and stable for the technology of its time. In 2005 the Niagara Region Water and Wastewater Services Division recognized that the platform for the SCADA system was at its end of life cycle and required upgrading. As opposed to invoking the previous model of using third party consultants they made the conscious decision to execute a plan that allowed them to bring more of their contracted business to in-house expertise.

With that movement a team of SCADA professionals was hired to provide the Niagara Region with internal ownership and begin looking at not just the SCADA system but all the components that integrate into a SCADA system, such as instrumentation, process control and engineering design. One of the goals was to become proactive with respect to implementations and an effective way to do that was to develop a design standard that could be handed to consulting engineers and contractors that dictated how things were to be built and operated. Going above and beyond typical SCADA tagging standards which were already in place, the Niagara Region developed an 85% Sewage Pumping Station (SPS) Design Standard.

The Engineering Review Process

As part of any capital project, once the design consultant has been awarded the role, a kick off meeting is initiated followed by 40% and 90% design meetings. During this process there are an abundance of hours attributed to the control system development followed by a series of back and forth correspondence with the design consultant. It became apparent in the first few years of the SCADA team’s involvement that the deliverables required by the Region were the same for each Sewage Pump Station whether it was an upgrade to a facility or a new construction project. Some of the deliverables that were inconsistent were the physical operating performance of the individual stations. SPS’s had various control philosophies which made it difficult from an operational and maintenance perspective. There were various secondary strategies that were implemented and often times it was not clear in the tender documents or it was left in the hand of the programming firm who was typically retained by the general contractor. From an electrical perspective the wiring diagrams, wire colors, field input and output locations were different. In principle, although the Niagara Region has identified a standard design, the sewage pump stations that were being upgraded or newly constructed still had a great deal of inconsistencies from an operational, maintenance and engineering viewpoint. Based on the number of hours that both internal and external resources were committing it was apparent that a new method would need to be invoked that would deliver a consistent solution.
The Conceptualization Process

The main objectives of a Sewage Pumping Station are to pump sewage to the downstream process without violating any Ministry of the Environment (MOE) regulations, following safety protocols and maintaining the protection of the environment. Everything else is secondary. In many locations the designs seemed over-complicated and had become clouded with what-if scenarios losing focus of the primary objective of a pump station. In some locations, secondary devices such as HVAC controllers were integrated into the design which became a risk causing potential station failure. Having a team of technical professionals with backgrounds not just in water and wastewater, the Niagara Region was able to leverage prior industry experiences and take an Original Equipment Manufacturers (OEM) approach to the development of a specification for design of Sewage Pumping Stations. Taking an OEM approach but with the focus being on regulatory compliance and not cycle times and throughput as in manufacturing, food and other automated disciplines.

As in many industries there are engineers, operators and maintainers as stakeholders. To provide a holistic solution, all three disciplines would need to be involved to ensure that their requirements were met and the solution was comprehensive. It was determined that rather than starting the process from new each of the team members was required to submit and present characteristics of what they wanted implemented. It was a blank canvas approach to a design but allowed for the team to leverage existing concepts that were appealing and combine them with solutions and innovative technologies from other industries.

Developing SPS Design Standards

The SPS Design Standards is a compilation of six items:

1. A Process Control Narrative
2. A set of AutoCAD P&ID, Electrical, and I&C drawings
3. PLC Code
4. A Station HMI Application
5. A SCADA System
6. A Historian Tag Assignment

A reference to the Niagara Region SCADA Standards and the Niagara Region Approved Product and Equipment List was also a mandatory component.

The physical development of the standards involved a further breakdown of the three main disciplines. From the Operation side all the wastewater treatment plant managers along with the Associate Director of Wastewater Operations were involved; from the maintenance side, the Manager of Technical Trades, Electrical Managers, Maintenance Managers and SCADA/Instrumentation Technicians (who were the main facilitators); and from the Engineering side, Project Managers and the Associate Director of Engineering.

Understanding that in any design project there is going to be unique elements the Region decided to label the standard as 85% complete. This gave any retained design consultant some flexibility with
respect to providing any innovative technology, tailoring the control system to meet the needs of the application and still remain completely responsible for the delivery of a functional system.

The Process Control Narrative

The Process Control Narrative (PCN) document was the first deliverable item. Important attention was given to the Operations group for the development of this document for several reasons; they are the certified operators of the facilities and the Region needed to ensure consistent operation, training, call out procedures, and a method of doing business. Before any PLC code development, direction from the Operations group on how they wanted their stations to operate was established. Topics such as alarms priorities, trending information, paging details, SCADA screen information, units of measure, pictorial representations, and so forth was discussed, agreed upon and detailed into the Process Control Narrative.

The PCN became the basis for the PLC program design. It is a comprehensive document that contains every field input and output (I/O) device, every tag of PLC and HMI/SCADA memory that was considered that would give the user the ability to control the station operation. Given today’s level of expectations with respect to usability and visibility, graphics were proposed and implemented that fully articulated the physical representation of a station. The PCN was developed for a maximum of a four-pump station using both Variable Frequency Drives (VFD) and/or Soft Starters (SS). It was decided that regardless of the number of pumps the fundamental operating principle of the station should remain the same.

Electrical design and automation input was solicited from the Maintenance section. Although pump stations are designed with pump redundancy in the event of single pump failure, a common backup strategy was introduced that was fundamental enough that it gave the operations team confidence that the stations would operate outside of any PLC or automation failure. Historically, typical backup strategies involved using the ultrasonic or radar level sensing devices on board contacts to act as a second level of redundancy. In this case, the start/stop levels required programming into the level sensing controller and had a high probability over time of being changed by on-site users and conflicting with the setpoints entered in the PLC as part of the automated control of the station. These solutions did not resolve the issue of a redundant system or reduce any risk as the level sensing device was now another single point of failure. Some would consider a solution to mitigate that risk would be the addition of a second wet well level sensing device. As the number of instruments grew, so did the complexity in both engineering, operability and maintainability and the focus became more of an over-engineered solution to a rudimentary process.

This redundancy strategy was solved by designing it around a single electromechanical float schema that decoupled itself from the PLC and any level sensing electronic technology. As long as the station has electrical power the pumps will be triggered to operate below the station overflow levels. This entire schema was fully detailed in the PCN with a table outlining elevations of where the start triggers are along with how long the start command is held for. The tipping of the float is not dependent on the PLC for pump control but is used as an alarm point. This provides indication to the operator that the station is running on float control which could mean a series of other systems have failed such as the level sensing device or PLC input cards. In the event of a communication loss to the SCADA system the
operator now has confidence that the station will consistently run on a backup float system regardless if the failure was caused by PLC, modem or level sensing device malfunction. This system is designed to provide the response team the required time to attend to the facility, assess the situation and execute a remediation plan without the concern of not fulfilling the main objectives of a sewage pumping station.

As a final and common use of PCN’s, details involving the various scenarios of control, the information to be alarmed, historically logged and trended and the security levels for control capability were also explicitly defined.

**Electrical and I&C Design**

The second deliverable of the overall specification was a comprehensive set of Electrical and Instrumentation and Control design drawings. Further to the operation of the station now involved the Electrical design. Utilizing the same concept followed regarding the operation of a two-pump or four-pump, VFD or SS station the electrical and control panel design followed the same guidelines. Starting with the design of the PLC rack, a processor and I/O assignment was built such that regardless of the number of pumps used in a station the PLC control panel would be built exactly the same way with same I/O wired to the same terminal block assignment. The thought process which invoked this solution was that during a troubleshooting instance there would be no requirement for someone to familiarize themselves with the layout or wiring assignment based on the type of station they were in. It was designed to eliminate the additional time for problem solving based on non-standardization.

Following the PLC control panel was the design of the interface to the standby power systems (if equipped) and the main incoming power of the station. Specific details such as transformer, breaker and standby power sizing were not considered part of the scope as these particulars were specific to each location. One main consideration that was implemented was the location of Surge Protection Devices (SPD). SPD’s are notorious for creating internal surges and absorbing surges from outside sources causing issues with electronic devices within VFD’s, instrumentation equipment, PLC’s and HVAC equipment. Since most surges are internally generated and are quite problematic in the operation of a SPS and the SPD strategy is not normally given much thought, it was decided that the technology needed to be carefully considered and implemented. After an in-depth review of SPD’s a design was implemented to protect all critical equipment with a manufacturer verification process during installation.

The Heating Ventilation and Air Conditioning (HVAC) design was something else that varied per site installation. The louver control strategy for bringing in fresh air and exhausting air was often outfitted with numerous sensors and electronic components that over the course of a lifetime of 20 or more years would at some point fail. Since the requirement to use outside air for cooling was considered a safety item, the louver operation was considered an interlock condition internal to the generator start command. This condition added a level of risk to the design of a station and again was an opportunity where the main objectives of an SPS would not be fulfilled. Again, not being able to design HVAC systems as the engineering specifications were very detailed, the PCN and design drawings required that the control of specific electromechanical louvers would be “fail open” on power loss. Furthermore, sensitive electronic equipment was kept to a minimum.
PLC Program Design

Prior to the development of the SPS Design Standards, the PLC program would be written by the firm retained for PLC/SCADA programming. In many cases they would use either a code structure that they had developed in-house or they would request one from the Region which they were to follow. Without a defined PLC programming standard to hand over to the retained firm the Region was often left with very inconsistent versions of PLC code across the network of SPS’s.

Using the PCN as a basis for PLC code development the shell code and auto logic was developed in accordance with the Region’s SCADA standards, which is the third component of the SPS Design Standard. During this process a defined standards PLC code framework was also designed which has detailed User Defined Data Types (UDT), assignment and allocation of code and Add on Instruction (AOI) blocks for specific equipment types. The components of building the correct tag names associated with the particular station and equipment used still has to be manually assembled but the development time to build the PLC logic is now drastically reduced. With this program in place the Factory Acceptance Test (FAT) process is also greatly reduced.

Station HMI Application

The Station HMI application is the fourth deliverable of the SPS Design Standard. Although not a regulatory requirement the Region perceived value in data logging information in the event of communication failure to the SCADA system at the main plant. As outlined in the PCN the local HMI has very little capability to control the station, so more emphasis was put on functionality than physical size of the HMI. The selection of HMI was around the performance with respect to the plant’s data Historian. Again, a standard set of graphics were developed with more emphasis put on visualization, trending and data logging and less emphasis put on capability of control. Allowing control at a SPS local HMI broached the issue of having changes made in the field without the Operator in Charge (OIT) knowing. Again, these issue could be solved with further PLC code development and handshaking between the station PLC, OIT and plant SCADA system but this contained a level of complexity that could add a level of risk of not fulfilling the main objective of a SPS.

Plant SCADA System

The plant SCADA display is what the operators of the SCADA system interface with and is used to fully comprehend what is happening at the SPS without, in fact, attending the site. Prior to the development of this standard, the tag database driving the screen visuals had inconsistencies, but more importantly from a user perspective, the displays were rudimentary, inaccurate and inconsistent in functionality and performance.

The development of a standard set of displays and trend requirements created a common look and feel for users which improved the overall understanding of what is happening at the station and are intuitive to use.
Historian Tag Assignment

Historian tag assignments in past projects was given the lowest priority. However, from an Engineering standpoint, it is a very high priority where historical data is needed for performance studies. Although there is no regulatory requirement to maintain a historical data log of pump run, flow or station level information, it is very critical to know this information to understand the performance of the system. As part of the SPS Design Standard, which is also detailed in the PCN, it was identified what information was to be logged and at what frequency; all of which could be served up to the common reporting interface the Region used to evaluate their systems.

Summary

The Niagara Region has had this standard in place for four years. This standard has since been implemented at several other municipalities proving that it is an innovative and accepted approach to designing SPS’s. The Niagara Region has seen significant improvement in the consistency of control systems and related deliverables when reconstructing or building an SPS by utilizing these standards. It has also enabled an internal approach of providing SPS control system upgrading services to where capital projects have not been initiated but the requirement exists. As any design package, this remains as a living document which requires maintaining and, most importantly diligence to ensure that it is being followed and utilized to deliver its highest value.

List of Acronyms:

- PLC: Programmable Logic Controller
- SCADA: Supervisory Control & Data Acquisition
- HMI: Human Machine Interface
- SPS: Sewage Pumping Station
- MOE: Ministry of the Environment
- OEM: Original Equipment Manufacturer
- PCN: Process Control Narrative
- VFD: Variable Frequency Drive
- SS: Soft Starter
- SPD: Surge Protection Device
- HVAC: Heat Ventilation & Air Conditioning
- UDT: User Defined Data Type
- AOI: Add On Instruction
- FAT: Factory Acceptance Test
- OIT: Operator In Charge
- I/O: Input/Output

About the Authors

---
Mark Presti, M. Eng. D., P. Eng. is the President of Provectus Systems, Inc. He has over 15 years of experience in automation ranging from food processing, printing and water & wastewater treatment. Prior to establishing Provectus Systems he was a Sr. Automation consultant with Gray Matter Systems, Inc. and further proceeded by a career with the Niagara Region Water and Wastewater Division. He spent seven years at Niagara; 2 yrs. as SCADA Engineer and 5 yrs. as Manager of Technical Trades. In that time frame he accomplished several milestones some of which included building a team of professionals that allowed the Region to implement state of the art technologies in all of their 12 treatment facilities along with wide area solutions for management and information distribution. He has extensive experience with both SCADA and Computerized Maintenance Management Systems (CMMS). Mr. Presti has a diploma in Electronics Engineering Technology from Mohawk College, as well as a Bachelor of Electrical Engineering and Master of Engineering Design from McMaster University. Mr. Presti is also a licensed professional engineer in the province of Ontario, Canada.

Contact mpresti@provectussystems.ca

Ed Van Vliet, C.E.T. is a SCADA Technician with the Water and Wastewater Technical Services section of the Regional Municipality of Niagara Public Work Department (Welland, Ontario, Canada). He has over 15 years of experience in automation in semiconductor testing, steel industry and water & wastewater treatment. Prior to working at the Regional Municipality of Niagara, he worked for Procon Niagara as a SCADA Project Manager where he was contracted to work on many municipal water & wastewater projects throughout Southern Ontario.

Contact: ed.vanvliet@niagararegion.ca