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Remplacement des systèmes de conduite du réseau de transport d'électricité

Assessment Report

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Assessment Report on Hydro-Québec TransÉnergie's Project for the Replacement of its Supervisory Control and Data Acquisition System, Energy Management System and Generation Management System

Submitted to:

Hydro-Québec TransÉnergie (HQT)

By:

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1 Introduction

1.1 Purpose of this Report

The purpose of this report is to provide an independent assessment of Hydro-Québec TransÉnergie (HQT)'s existing SCADA/EMS/GMS systems, as well as HQT's project to replace these systems, for the Régie de l'énergie du Québec.

1.2 Methodology

The methodology that was followed to perform this assessment included the following steps:

1. Present information on the past and current state of the SCADA/EMS/GMS Industry
2. Conduct a current state assessment of the existing HQT systems that monitor and control HQT's power system network. Provide a detailed questionnaire to HQT to gather information and use it to assess the existing systems and develop our opinion. Clarify responses as required with follow-up discussions.
3. Compare how HQT's needs align with the current state of the SCADA/EMS/GMS industry and specific issues with the current HQT SCADA/EMS/GMS technologies
4. Provide our assessment of the components of the project including the functional components, project oversight, procurement strategy, solution providers, evolution strategy, and risk mitigation strategies.

This report concludes with a summary of the key assessment findings.

1.3 Terminology Used

The following terms are used throughout this report:

- **SCADA – Supervisory Control and Data Acquisition** – These applications collect real-time information from field equipment (for example, currents, voltages, circuit breaker states) and allow HQT operators to remotely control field equipment without the need to send a crew to the substation. SCADA applications communicate with field equipment via **Remote Terminal Units (RTUs).**
- **GMS – Generation Management System** – These applications control power generation, raising or lowering it in order to maintain the frequency of the power system at 60 Hertz. They maintain the balance between the system load (demand) and production of generation.
- **EMS – Energy Management System** – These applications support Operators with assessing the reliability of the power system. Two of the key EMS applications are **State Estimator and Contingency Analysis**. **State Estimator** analyzes the field data and the network model to produce a coherent and complete picture of the real-time network. **Contingency Analysis**, starts from the result of State Estimator and automatically runs a series of "what if" scenarios (e.g. what if Transmission Line X has a fault? What if Transformer Y fails?) in order to get advance warning of the impact (for example overloads) so that operators can take corrective actions.
- **OEM – Original Equipment Manufacturer** – These entities provide standard off-the-shelf components for hardware (e.g., Dell, Hewlett Packard, Lenovo) and operating systems such as Microsoft Windows.
- **"Evergreening"** – The practice of using periodic updates to ensure that systems do not become obsolete and will not require a full system replacement. It requires a commitment to keep these technologies up-to-date with the chosen vendor's products.

- **SCR-T** or **SCR-T project** – The project to replace HQT's existing SCADA/EMS/GMS systems with a new integrated product.

1.4 About ESTA

ESTA International LLC is a specialized consulting firm providing Intelligence, Strategy, and Technology Advisory Services to the Electric Energy industry worldwide with a focus on Smart Grid and Control Center Technologies including Supervisory Control and Data Acquisition (SCADA), Energy Management Systems (EMS), Generation Management Systems (GMS), Distribution Management Systems (DMS), Outage Management Systems (OMS) and their integration/ interoperation with other utility/non-utility systems.

ESTA International, LLC was established in 2009 and has been serving the electric energy industry worldwide in areas of Smart Grid, Control Center Technologies, and other related areas. ESTA's individual staff members average over 25 years of experience with these related technologies.

ESTA International, LLC is a US company registered in the Commonwealth of Virginia. Its headquarters are located in Herndon, Virginia, a suburb of Washington D.C.

The personnel that have participated in preparing this report are working with HQT on the replacement project but also have extensive experience assisting other entities with similar types of projects. We have called on that expertise to assess the project as completed thus far as well as the plans for the entire project. Participants include:

Mr. Nader Farah

- President of ESTA International, LLC
- Over 35 years of related experience working with utilities throughout the world

Mr. Joseph Moran

- Executive Consultant
- Over 30 years' experience primarily in North America including Investor Owned Utilities, US Federal Government Entities, Municipal Utilities, and Independent System Operators with the strategy, planning, procurement, implementation and testing of SCADA, EMS, GMS, DMS, MMS, and OMS

Ms. Catherine Murphy

- Executive Consultant
- Over 25 years' experience developing, integrating, delivering and deploying SCADA, EMS, GMS, DMS and OMS software systems to utilities worldwide

2 Evolution of the SCADA/EMS/GMS Industry

This section describes the evolution of the industry over the years in response to changes in the power system, utility needs, regulatory requirements and technology. This is intended to provide the context for the assessment of the existing HQT systems presented in Section 3 of this report.

2.1 Level 0

During the 1960s, most utilities had limited remote monitoring and control capabilities. The SCADA/GMS systems that were available on the market were hardwired analog systems providing basic monitoring and control as well as managing frequency. Utilities had to buy their RTUs and their SCADA software from the same vendor because the communication protocols were specific to the vendor. There were no commercially available EMS systems.

2.2 Level 1 Evolution

During the period from the early 1970s to the late 1980s, utilities significantly expanded remote monitoring and control and the first EMS applications were developed. The technology moved from analog systems to digital computers. As a result of the blackout of 1977, vendors developed applications that assisted Operators with understanding the current state of the power system from a reliability standpoint. The first versions of the EMS State Estimator and Contingency Analysis applications were developed to increase operator awareness of the current state of the network and to alert them to potential risks to network security. The early versions of these applications were very slow and often could not produce a solution due to the lack of adequate data measurements or inaccurate model data.

The Level 1 systems remained very proprietary and closed (that is, the systems did not incorporate any standards for communications and the vendors all used their own hardware and developed their own operating system).

Each project was highly customized and built specifically for each utility. Vendors would typically select one of their previous project systems that most resembled the current project in terms of functionality and started from there.

2.3 Level 2 Evolution

During the 1990s, utilities and vendors embraced OEM hardware and operating systems, open system concepts, and embarked on the process of defining and implementing standards to promote interoperability between systems from different vendors. Significant changes in the architecture and hardware used by SCADA/EMS/GMS vendors began with the introduction of OEM-provided servers and workstations from IBM and Digital Equipment Corporation. System vendors exited the hardware business (no longer manufacturing their own computers) and leveraged the use of OEM servers and workstations. The concept of “open systems” was adopted by the industry and reflected in system architectures that moved away from proprietary systems and toward communication protocols facilitating the use of third party software, hardware, and components.

The systems were limited from a performance, scalability, expansion capability, and storage perspective. Communication bandwidths were also a limiting factor, affecting the volume of data that could be collected from the field and the rate at which that data could be collected.

Standard RTU communication protocols were defined during this period, through a joint effort by utilities and vendors, and adopted by both SCADA vendors and RTU vendors. Through a similar process, a standard protocol for communication between SCADA systems was developed in order to enable interconnected utilities to exchange data in real time. Both the standard RTU protocols and the standard inter-SCADA protocol are in operation at the vast majority of utilities worldwide and are supported by all SCADA vendors.

EMS applications became more reliable, performance improved, and more sophisticated algorithms were introduced.

The typical pattern, up to the end of the 90s (and partway into the 2000s) was for utilities to procure and implement a system, and after a period of about 10 years, when the hardware became obsolete, replace the entire system through the same process of procurement and implementation; this was referred to as the "forklift" approach. The concept of "evergreening" the system began to emerge but was not yet a reality due to the lack of vendor "baseline" systems. By the end of the 90s, however, vendors created the first "baselines" of their system functionality with the aim of offering a product that would address the needs of a broad range of utilities, increasingly replacing hard-coded features with configuration as a means of addressing individual utility requirements. Each new vendor project implementation would start from the baseline system and add customizations to meet specific utility needs.

2.4 Level 3 Evolution

During the 2000s, vendors continued to evolve their baseline systems as a means of reducing the amount of customization needed to comply with utility requirements. Vendor baseline systems expanded their use of open system components as a means of providing utilities with added flexibility, and enhancing interoperability with third-party software and with different hardware platforms (moving towards hardware independence). Computing hardware and memory size limitations were reduced. One of the principal drivers behind this change was a new focus by utilities on the Total Cost of Ownership: these changes resulted in lower maintenance and support costs once the systems were in operation.

EMS applications became more robust; in particular, vendors improved their State Estimator application so that it could better tolerate inconsistent data and to provide tools that made it easier to identify and correct data problems. This decade also saw improvements in the reliability and effectiveness of certain EMS functions which had, in principle, been offered for several years, but had not, thus far, worked reliably or delivered on their promised benefits.

During this same period, compliance with reliability standards in North America, which had, up to this point, been voluntary, became mandatory. A major blackout in August of 2003, affecting the Northeast US and parts of Canada, brought about the need for better tools in assisting operators with monitoring the reliability of the power grid and creating more situational awareness in the control rooms. The North American Electric Reliability Corporation (NERC) had defined a set of operating guides and procedures that utilities only had to file on a voluntary basis. After the blackout, the NERC standards were made mandatory and enforceable with financial penalties for non-compliance. Vendors included functionality in their systems to assist utilities with meeting the applicable reliability standards and providing reports to show as evidence of compliance.

As technology continued to advance, the use of less specialized commercial servers and workstations from OEMs and the increasingly common practice of connecting to the internet raised concerns about cybersecurity attacks against the control centers; this in turn created the need for more diligent cybersecurity technologies to protect against and detect cyber-attacks. NERC created new Critical Infrastructure Protection (CIP) standards that directly impacted the SCADA/EMS/GMS systems. The CIP standards were included as part of the NERC Reliability Standards and became enforceable as well as being subject to penalties. Complying to CIP standards increased the level of cybersecurity in SCADA/EMS/GMS. In addition to complying with CIP, utilities adopted much stronger cybersecurity technologies and architectures to significantly deter a cybersecurity attack from impacting the grid.

2.5 Level 4 Evolution

The current decade has seen significant enhancements in SCADA/EMS/GMS systems in terms of the situational awareness they provide in the control room, leading to better overall system reliability. This is due to a combination of functional improvements, advances in visualization technologies, the ability to solve ever-larger power system networks, and significant advances in processing resources and storage.

Improvements in technology have allowed utilities to move towards common technology and to consolidate their real-time systems. The limitations of the past that might have required multiple systems, each covering a different set of functions or a subset of the transmission network, no longer exist as a result of technology improvements in performance. The architecture whereby the solution is deployed at 2 Data Centers (main and back-up or main-main), providing 99.95-99.98% availability, has become the norm in the industry.

The technology advances in computing power, computer memory, and communications throughput have allowed for development and implementation of more advanced software solutions. For example, where once an RTU could access data once every 2 seconds, now phasor measurement units can sample data at a rate of 120 samples per second providing the operators with a wealth of information. The increase in computing power has enabled technology providers to employ new algorithms in EMS applications such as State Estimator, where the use of synchro-phasor measurements can be included and hence enable more precise system analytics. Other applications such as Dynamic Stability Analysis are now able to run (execute) in timely manner providing system Operators with more insights into network stability.

This has been accompanied by an increased emphasis on cyber-security. For example, utilities architect the SCADA/EMS/GMS that direct connections to the internet are not allowed. The SCADA/EMS/GMS pushes its data to other corporate systems via firewalls that are established with rules that only let the data flow out without allowing access back into the secure zone of the system. The architectures incorporate mainstream cybersecurity technologies to detect and deter cyberattacks.

Vendors continue to enhance their baseline products to add functionality to keep up with external factors, such as distributed energy resources (for example solar panels and electric vehicles), that impact the stability of the power grid.

NERC continues to adopt new standards such as TOP-010, Real-time Reliability Monitoring and Analysis Capabilities, that established requirements for Real-time monitoring and analysis capabilities to support reliable System operations. Vendors, in response, have included corresponding changes to SCADA/EMS/GMS system functionality in order to support utility compliance with the standard.

Utilities are actively adopting the "evergreen" approach in order to lower maintenance and support costs. "Evergreening" is finally becoming a reality and utilities have started to make periodic incremental updates to their systems software in order to stay current with their vendor's baseline solutions and benefit from advances in functionality.

3 Assessment of HQT Systems

This section presents our assessment of the existing HQT SCADA/EMS/GMS systems as compared to the current state of the industry and in terms of their ability to meet the current and future needs of HQT to maintain the reliability of HQT's power network.

HQT distinguishes between the so-called "main" transmission network, which extends from the generating stations to cover the portion of the transmission network that is deemed most critical by HQT's planning group, and the regional network, which is less critical and is typically more radial.

Currently, at HQT, the SCADA, EMS and GMS functions are performed by a combination of systems:

1) The Spectrum SCADA/GMS, procured from Siemens, provides SCADA monitoring only (no control) for the main transmission network, and provides GMS applications for controlling frequency.
2) The LASER EMS, procured from GE (originally SNC-Lavalin), provides EMS applications to help improve reliability; it runs on the main transmission network.
3) The GEN4 SCADAs, procured from GE (originally SNC-Lavalin), provide SCADA control and monitoring for the entire transmission network (i.e., main and regional networks).

There are no real-time EMS applications running on HQT's regional transmission network.

Note that LASER also includes certain SCADA functionality; however, it does not include key functions such as Data Acquisition from field devices or Supervisory Control so for the purposes of this report, it is referred to as the LASER EMS.

There are currently three (3) instances of the GEN4 SCADA systems, each of which covers about one third of HQT's transmission network. Originally, there were seven (7) instances, but these were consolidated in 2008.

3.1 LASER EMS

The following highlights the salient points of our assessment of the existing GE LASER EMS system running the network reliability applications.

1) Major Issues include the following:
   a) End of Life – This system was commissioned in 2005 after a multi-year project procurement and implementation - this means the technology used during the development may have been from the early 2000's. The LASER system is no longer in the vendor's product line as they have 2 other EMS products that provide the functionality included in this system. No new or upgraded functionality is ever provided to address new demands on the power system (e.g., distributed energy resources, new regulations).
   b) Technology Obsolescence
      i) [redacted]

ii) The hardware used is no longer available from the OEM. In the event of hardware failure, the only option is to deplete HQT's stock of spare parts; once this is fully depleted, HQT will need to procure used hardware.

c) Declining Performance – As the hardware continues to age, the frequency of failures (in particular hard disk drives) has increased.
d) Minimal Support available – The vendor is still supporting LASER but at a minimal level (i.e., the vendor never offers functional upgrades because it is no longer in the vendor's product line).
e) Limited Expertise in Product - Vendor expertise in the LASER technology is limited since the vendor is focused on its other products. Experienced staff who previously supported LASER have retired or moved on to other ventures.
f) [redacted]
g) [redacted]
h) Incomplete coverage – the LASER EMS applications run only on the main transmission network; they should be running on the entire transmission network.
i) No Operator Training Simulator – LASER does not include an Operator Training Simulator to support the training of new operators nor does it support training of more experienced operators on potential power system scenarios that better prepare the operators for potential real-time events that occur on the power system.

2) Recommendations:
   a) In our opinion, while the LASER EMS has served the needs of HQT well since it was implemented, it must be replaced due to major issues identified above which threaten HQT's ability to adequately monitor the reliability of the power system and understand potential issues, and which, in turn, increase the risk of significant power outages.
   b) Projects to replace systems of this type have significant lead times (several years) so HQT needs to continue on its current path for replacement.
   c) HQT needs to continue to build up its stock of spare servers in order to respond to hardware failures since the incidence of failure will continue to rise over time and HQT will need to keep LASER running until a replacement system can be purchased, implemented, tested, and commissioned.

3.2 GEN4 SCADA

The following highlights the salient points of our assessment of the existing GE GEN4 SCADA systems used for remote monitoring and control of power system devices.

1) Major Issues include the following:
   a) End of Life – This system was commissioned in 2004 after a multi-year project procurement and implementation. These SCADA systems are based on the same vendor technology as the LASER

system. It is no longer in the vendor's product line as they have other SCADA products that provide the functionality included in this system.

b) Technology Obsolescence – While most of the Operating Systems and hardware were upgraded as a result of the consolidation project, and again in 2015, the data communication processors used to communicate with the field RTUs are still the original highly specialized computers. Replacement data communication processors of that make and model cannot be found in the market, so HQT is going through its inventory of spare parts. As the hardware ages, the failure rate will increase.

c) [redacted]

d) Limited Expertise in Product - Vendor expertise in the GEN4 technology is limited since the vendor is focused on its other products.

e) [redacted]

f) [redacted]

g) Operator Training Simulator – Compared to what is available from off-the-shelf systems, the GEN4 Operating Training Simulator is very primitive. Setting up a training session requires a significant amount of manual effort and results in a training experience that is not very realistic so that it provides limited value in preparing the operators for potential real-time events that occur on the power system. Any changes to field data, for example in response to trainee actions, require that an Instructor be standing by to manually enter those changes.

h) Limited Expansion – Currently, HQT uses 3 SCADA systems to cover the province. Off-the-shelf systems are designed to handle significantly more data while meeting stringent performance requirements.

i) [redacted]

2) Recommendations:

a) In our opinion, replacing the existing GEN4 SCADA Systems is the only viable option due to major issues identified above, which threaten HQT's ability to adequately monitor the reliability of the power system and understand potential issues, and which, in turn, increase the risk of significant power outages.

b) In the interest of simplifying system maintenance and due to the improvements in performance, reliability and scalability of the systems currently available on the market, the 3 GEN4 SCADA Systems should be consolidated into a single SCADA.

c) Projects to replace systems of this type have significant lead times (several years) so HQT needs to continue on its current path.
d) HQT needs to continue to build up its stock of spare parts in order to handle the failure of the data acquisition computers since the incidence of failure will continue to rise over time and HQT will need to keep the existing SCADA systems running until a replacement system can be purchased, implemented, tested, and commissioned.

3.3 Spectrum SCADA/GMS

The following highlights the salient points of our assessment of the existing Siemens Spectrum system used for remote monitoring and control of production plant generators:

1) Major Issues include the following:
   a) End of Life – This system was commissioned in 2001 after a multi-year project procurement and implementation. It is the oldest of the three systems. Its supported functionality has been updated via development by HQT, but it has not followed the evolution of the Spectrum baseline since its initial installation.
   b) Technology Obsolescence – While HQT has taken steps to keep its server operating systems and hardware up-to-date, some of the field communication servers cannot be upgraded because the newer models do not support the cards that are required to communicate with the RTUs. Neither the field communication servers nor the cards are manufactured anymore and so can only be purchased used.
   c) [redacted]
   d) [redacted]
   e) No Operator Training Simulator – The Spectrum system does not include an Operator Training Simulator to support the training of new operators nor does it support training of more experienced operators on potential power system scenarios that better prepare the operators for potential real-time events that occur on the power system. A given training session typically requires three instructors: one to lead the training, one to manually enter data and the third to enter changes into a copy of LASER in order to see the result and manually enter data in the training environment.
   f) Critical missing functionality: One of the areas where GMS and EMS need to overlap is related to the selection of which of the generating units should have their MW output increased or decreased by the GMS. The configuration of the HQT network is such most generation is in the North and East and most power consumption is in the South. The power flows from the North/East to the South via a limited set of transmission lines, which can act as a bottleneck. Transmission Constrained Dispatch is an application that proposes unit MW setpoints while taking into consideration transmission line loading limits. It was not available when the LASER system was first commissioned but is currently available from all SCADA/EMS/GMS vendors.
2) Recommendations:

a) In our opinion, replacing the existing Spectrum system is the only viable option due to major issues identified above. The functionality in this system is critical to being able to manage the balancing of the generation with the demand as well as maintaining the frequency at 60 Hertz.
b) Replacing systems of this type have significant lead times (several years) so HQT needs to continue on its current path.

3.4 Overall

The current HQT systems can be characterized as Level 2-3 Evolution systems as defined in the previous section. The expected life span of these systems is typically in the 10-year range from commissioning. By the time the replacement system is commissioned, some of the existing systems will have been in operation for as long as 20 years.

The end-of-life and obsolescence issues described above represent a threat to the reliability and security of HQT's transmission network. This lower level of reliability may take the form of some data not being acquired or of advanced power system network applications failing to solve, leaving operators blind to the state of the power system. In particular, with regard to field communications, the limited set of spare parts gives some urgency to the need to replace the systems.

As the industry pushes forward with significantly improving the power network applications, the current EMS (LASER) is still derived from much earlier versions available when the system was purchased. Replacing the current EMS provides the opportunity not only to implement more robust algorithms for the current applications but also to extend the coverage of those applications so that they analyze HQT's entire transmission network.

Vendors spend significant time understanding the trends and external factors impacting utility operations to identify areas where new applications can be developed to support utilities' needs to maintain system reliability. Two important areas to note include the move towards enhanced situational awareness using advanced visualization techniques and the need for more robust algorithms required to solve today's modern grids. Applications such as Optimal Power Flow, Voltage Stability Analysis, and Transient Stability Analysis, just to name a few are becoming more mainstream in larger utility and ISO/RTO control centers.

Similarly, separate systems for the regional network vs the main transmission network, or for GMS, EMS and SCADA, are not needed, given that what is currently available on the market off-the-shelf is integrated SCADA/EMS/GMS systems, and these are in operation at a growing number of utilities in North America and around the world. Moving to a common platform will eliminate the need to reproduce the highly customized interfaces between the existing systems, reduce duplicate work, reduce the amount of hardware needed, provide more resource flexibility by eliminating the need for multiple teams supporting different systems, and will avoid the need to coordinate complex changes across multiple systems.

4 Evaluation of the Project

4.1 Introduction

Based on the evidence presented in section 3, HQT's project to replace its SCADA/EMS/GMS is necessary due to the obsolescence of the systems and lack of adequate vendor support. Alternatives such as migrating to newer operating systems and hardware to extend the life of the system do not resolve the problem with the field communications hardware nor address the issue of minimal support from the vendor. In our opinion, home-grown solutions (i.e., built from scratch internally by the utility) are really not worth considering given the extensive standard functionality that is currently available and the substantial development and financial risks a utility would thus have to undertake. We do not know of any utility that tries to build a home-grown solution nowadays given the maturity of the current SCADA/EMS/GMS commercial marketplace. The major vendors have annual user group meetings where their client utilities can review upcoming product roadmaps and share experiences using the products. The feedback provided by the vendor's customers drives the enhancement their products. Vendors use a percentage of their revenues for research and development to enhance their products.

In light of this, the replacement of these complex systems requires a detailed approach in order to increase the likelihood of meeting the goals of migrating to the new system in the most effective manner.

Projects leading to the full replacement of SCADA/EMS/GMS require long lead times. The complexity of these systems requires utilities to take the time to define their requirements in a detailed specification. This can take a year or more in some cases. The total time for larger utilities to procure, implement, test, and migrate from the old system to the new system can take 4 to 5 years. In the case of HQT, the replacement project needs to proceed now in order to manage the risks associated with the aging hardware of the existing systems.

While this industry is mature, external forces impacting utilities and the continued enhancement in underlying technologies drive utilities to ensure that their mission critical SCADA/EMS/GMS system is kept up to date so that the Operators have the tools required for managing the reliability of power system. The major vendors continually invest in their products to keep them up to date with technology changes and to meet new needs.

4.2 Preparation

Among the first activities HQT initiated in the context of the replacement project was to survey other utilities who had undergone similar types of projects.

The survey was led by ESTA with HQT's participation and conducted during the first half of 2017. It involved utilities from North America, Europe and Australia. Among the utilities who had conducted replacement projects, the main conclusions were the following:

1) With the exception of utilities who only had one system to begin with, all utilities moved toward a consolidation of their systems, moving from 2 to 1, 3 to 1, …etc. with the most extensive being a utility that consolidated 44 systems down to 6.
2) The principal drivers behind the projects were obsolescence of software and hardware and lack of support from the vendor, coupled with increasing maintenance costs.

3) The architecture trend was just as consistent, with utilities choosing to implement two data centers in a Main and Back-up configuration, with the Back-up able to take over from the Master within minutes or, in some cases, with no delay.

One of the principal keys to success for the utilities surveyed, in terms of the initial phases of the project, was taking the time to clearly document requirements, and involving all of the stakeholders in the process.

Another focus of the market survey was related to the functionality currently in operation at those utilities. The net result was that in terms of basic SCADA, historian, GMS and EMS applications, those utilities had the same needs as HQT, and there was generally a high level of consistency. All had some level of customization in their systems and all were actively working to limit it.

In parallel with the utility survey, ESTA also conducted a survey of vendors most commonly selected by utilities on HQT's behalf to collect general information about baseline vendor capability.

4.3 Detailed Evaluation

Our opinions stated in the following sections are based on working with HQT in the Planning and Requirements Development phase of the replacement project.

Our opinion includes the following key project areas:

1. Requirements Definition
2. Functional Scope
3. Project Oversight
4. Procurement Strategy
5. Evolution Strategy

4.3.1 Requirements Definition

An important key to success in trying to define requirements in the context of existing off-the-shelf systems is to understand what is available in those off-the-shelf systems.

In mid-2017, HQT and HQD jointly issued an invitation to vendors to pre-qualify for the SCR-T and SCR-D projects; this included vendors having to respond to a brief questionnaire. The four vendors who pre-qualified then gave a two-day demonstration of their standard, off-the-shelf products, with the aim of helping HQT get a clearer and more concrete understanding of the level of advancement of vendor products. The demonstrations were very well attended by HQT, with audience members from transmission system operations, system maintenance and solution architecture.

The writing of requirements for the SCR-T began in earnest following the pre-qualification demonstrations. Participants have included:

- Representatives from transmission operations, including operators, engineers working from both the Control Center ("CCR") and regional operations centers ("CTs");
- Data and software maintenance personnel who work with each of the systems (the Spectrum SCADA/GMS, the LASER EMS and the GEN4 SCADAs)
- Solution architects

The resulting requirements were published into a formal Request for Proposal released in May 2018.

4.3.2 Functional Scope

In 2018, the standard offering available from vendors covers much more of HQT's needs than when the existing systems were initially procured. Moreover, the significant increases in processing power and performance and improvements in reliability combined with near-standard two (2) data center architecture and the fact that all of the vendors in the SCADA/EMS/GMS space offer complete SCADA, GMS and EMS functionality as part of a single integrated package, make the procurement of a single integrated system the obvious choice. This is overwhelmingly the trend among electric utilities (including very large utilities) and independent system operators (ISOs) and Regional Transmission Organizations (RTOs).

The proposed functional scope of the SCADA/EMS/GMS replacement project includes not only the replacement of the existing functionality but also functionality which is part of the standard off-the-shelf offering of all vendors and which would benefit HQT without any extra investment.

The following table compares the existing systems' functionality with the requirements for the replacement system (items for this system are in off-the-shelf products):

Table 4-1 List of standard SCADA, GMS and EMS functions

Functionality	LASER EMS	GEN 4 SCADA	Spectrum SCADA/GMS	Replacement System
Data Acquisition	X	√	√	Part of standard products
Data Processing	X	√	√	Part of standard products
Supervisory Control	X	√	X	Part of standard products
User Interface	√	√	√	Part of standard products
Generation Management	X	X	√	Part of standard products
Power Network Analysis	√	X	X	Part of standard products
Historian	X	√	√	Part of standard products
Switching Management	X	X	X	Part of standard products
Operator Training Simulator	No	√ (limited)	X	Part of standard products
Model Manager	X	X	X	Part of standard products

As indicated in Table 4-1, the core functional components of the replacement SCADA/EMS/GMS system include the following:

- Supervisory Control and Data Acquisition (SCADA) – the new system will still need to communicate with RTUs and other field devices using the existing communication protocols. The vendors also provide, as part of their baseline, newer standard protocols so that if and when HQT chooses to migrate its field communications to a newer standard protocol (as most utilities do), the protocol will not need to be developed.

- User Interface – the new SCADA/EMS/GMS will come with a more modern user interface that should significantly enhance the user experience. In an effort to enhance Situational Awareness for Operators and other users, they have incorporated the use of advanced visualization techniques to take raw data and transform it into more usable information that provides for quicker recognition of system conditions. The use of dashboards that synthesize the results of advanced power network applications summarizes the areas of concern. For example, the new systems can execute 2500 different contingencies in less than 2 minutes (or even faster) and then present a dashboard summarizing the number of potential line overloads and voltage violations.
- Generation Management – the new system will include standard GMS functions including Automatic Generation Control/Load Frequency Control to replace the functions in the older Spectrum system. In addition, it will also include a Security Constrained Dispatch (which takes into consideration transmission line limits), Operational Reserves Monitoring, and functionality to enhance the Operator's situational awareness.
- Power Network Analysis – the new system will include standard EMS functions such as Network Topology, State Estimation, Contingency Analysis, and Dispatcher Power Flow to replace the functions in the older LASER system. These functions in the new systems have significantly improved robustness and performance compared to the versions available when the existing system was purchased. Algorithmic enhancements and the ability to solve much larger networks will mean that HQT will be able to run the EMS applications on the entire transmission network, with the resulting ability to detect and alert the operators to potential problems in the regional network. Standard functions available with today's EMS products also include functions and features to assist in identifying inaccurate metering, which has been the cause of many of the LASER system failures over the years. In addition, the vendors have incorporated new features for real-time Stability Analysis, Network Sensitivity, and Volt/Var Scheduling into their suite of network applications, all of which enhance the operator's ability to monitor the reliability of the power system.
- Operator Training Simulator (OTS) – the new SCADA/EMS/GMS will include an OTS that will provide environments for HQT to perform cycle training (training done on a periodic basis), training of new Operators that replace Operators that retire or move to other positions, training on the simulation of power system scenarios, and training of Operators on new functionality that impacts business processes. The OTS can also be used as an environment to test new software prior to installing the changes in Production.
- Historian – the new SCADA/EMS/GMS will come with an enhanced Historian. The previous generation of Historian functionality had limitations on the amount of data that could be stored and the duration. The newer versions of Historians available from the vendors include a data recording capability similar to a flight data recorder in that they can store the SCADA data at the rate in which it is received from the field. The capability to play back the data for a previous period greatly enhances after-the-fact analysis. The new Historian will also result in a significant simplification in overall architecture, and improved system security since it will allow for the elimination of a large number of direct interfaces to external software systems (i.e., non-SCR-T systems inside the company).
- Switching Management – the new SCADA/EMS/GMS will include the standard capability to prepare, validate and approve switching orders which are used to manage the network during maintenance activities.

- Model Manager –The industry movement towards data exchange using the Common Information Model drove the need for software that manages the creation and maintenance of different network models. Vendors have enhanced these tools to be the basis for managing all of the SCADA/EMS/GMS models within a single integrated tool. The additional capabilities to work on different models reflecting current and future points in time will provide the opportunity to study the effect of power system changes on the reliability of the network prior to their being commissioned; this will also reduce the risk of introducing erroneous data changes that would negatively impact real-time operation.

It should be noted that while the vendors' off-the-shelf products can be expected to meet most of HQT's requirements, some customizations and configurations will be required to meet HQT's unique needs. This is typical in similar types of replacement projects. However, unlike previous generations of SCADA, GMS and EMS systems, where customizations were hardcoded into the system, the advent of the Common Information Model (CIM) and Application Programming Interface (API) concepts has meant that customizations can increasingly be implemented in standalone modules that can interface with the rest of the system through standard interfaces. The result is that, once the new system is in operation, subsequent upgrades to keep it current with the vendor's off-the-shelf software can be done without requiring a significant effort to port the customizations.

4.3.3 Project Oversight

The implementation of the SCR-T project requires a strong project oversight model adapted to the size and scope of the project including many participants of HQT. Within Hydro-Québec, HQT and IT have implemented a structured oversight framework, including a Program Management Office which facilitates project information sharing, issue escalation, addressing risks and decision-making.

Based on ESTA's extensive experience with these types of projects, it is our opinion that the proposed Project Oversight Structure is appropriate given the size and complexity of the solution being procured.

HQT has established a Risk Identification and Management approach that identifies key risks based on their experience with similar types of projects to the SCR-T project and based on the results of the Market Survey conducted in 2017. HQT has quantified the probability of each risk event occurring, the potential impact on the schedule, budget, and quality of the solution. HQT has defined several key issues and appropriate mitigation strategies. A detailed risk matrix is currently being monitored.

4.3.4 Procurement Strategy

HQT has a well thought-out and well-planned procurement strategy for its replacement system. The replacement of the SCADA/EMS/GMS will be done using a competitive bidding process. This approach is typical when a full replacement is needed. As a large, major transmission utility, HQT can expect to receive very competitive pricing from the prequalified solution providers.

HQT has developed detailed specifications for the technical, commercial, and service requirements that are required to successfully implement and commission these complex, mission critical systems. HQT has used generic baseline specifications which reflect the features and functions available in the current SCADA/EMS/GMS products and most commonly used by other utilities. HQT enlisted teams that included business and IT personnel to adapt those specifications to the way in which it operates its power grid. HQT has issued the Request for Proposals (RFP) to a pre-qualified set of SCADA/EMS/GMS vendors with the requisite experience and system solutions to meet its requirements. The Vendors will be provided sufficient time to prepare their proposals in response to the RFP.

HQT has also developed an evaluation approach that will facilitate selecting the vendor that is best positioned to meet its needs. Since all of the vendors have baseline systems that will meet most of HQT's requirements, it is important to establish an evaluation methodology that allows HQT to focus on the differences between the different vendor offerings. The evaluation will consider both the level of compliance (what is in the products as it relates to the requirements) and how the vendor has implemented the requirement. In the case of features or functions where the vendor has complied but does not currently support the feature/function, the specification requires that the vendor indicate whether the resulting capability will be developed as a customization or as part of their product; the latter offers the clear advantage that subsequent software updates would not require re-integration of these new features, and will be ranked accordingly. This will include reviews of the written proposals as well as detailed demonstrations of each vendor's features.

The RFP requests pricing not only for the project itself but also the cost of maintenance, this will allow HQT to estimate the long-term cost of the solution.

4.3.5 Evolution Strategy

HQT plans to adopt an "evergreen" strategy once the new SCADA/EMS/GMS has been deployed in order to avoid the need to perform a complete system replacement in the future. This is consistent with the approach that many other utilities have adopted.

The current HQT systems can be classified as being Level 2-3 in the evolution of the industry. The concept of "evergreening" offers utilities the opportunity of keeping the new system up to date with the vendor product, which provides the following incremental benefits:

- On-going patching;
- Periodic upgrade of OEM software to avoid software obsolescence issues and enable periodic migration to new software;
- Periodic injection of new functionality such as application features and user interface enhancements.

The most significant benefit, however, is that utilities can avoid having to undergo costly, disruptive, and higher risk full-scale replacement of the system in 10-15 years.

5 Conclusions and Recommendations

ESTA's conclusions and recommendations regarding our assessment of the existing HQT SCADA/EMS/GMS are as follows:

1. The existing systems have reached their end-of-life and need to be replaced. Given the significant lead time of several years, HQT needs to continue down its current path of replacement.
2. The existing systems should be replaced with commercial off-the-shelf solutions available from major vendors of these products.
3. HQT has defined a detailed set of requirements in which it clearly identifies any requirements that will need to be added to meet its needs.
4. HQT has established a project oversight structure that aligns with similar projects of this size and scope.
5. HQT has developed an evaluation methodology that will facilitate an "apples-to-apples" and unbiased evaluation between the different pre-qualified vendors' total offerings.
6. HQT has a plan, as noted in Section 3, to ensure that the existing systems can be used while the replacement system is procured, designed, built, tested, and commissioned.
7. HQT needs to move to an evergreen model for evolution to keep up to date on changes impacting its power system and technologies.
8. Where possible, through its training and change management, HQT should adjust some of its practices to align more with industry approaches to similar issues (as is being done at other utilities). This will allow HQT to to reduce the level of customization of the selected vendor systems and especially the amount of custom code that needs to be developed and maintained.