Cost-Benefit Analysis for IEC 61850 Implementation

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I. INTRODUCTION

IEC 61850 is a modern communications standard that enables advanced applications to access and process information from substations. This standard defines digital communications protocols and models for application functional information in protective relays and other intelligent electronic devices used in substations. IEC 61850 uses Ethernet networking, fiber optic communications, and IT analytic techniques to:

- Transform P&C deployment from boxes and wiring to a system based on networked intelligent electronic devices (IEDs) with a few fiber-optic connections.
- Transform P&C system engineering from hand-mapping to automated integration.
- Transform P&C system operation & sustainment from manual testing & time-based maintenance to remote monitoring & predictive asset management via data processing.

In today's conventional discrete design, an engineer will select IEDs and discrete devices, study and map the device interconnections, hand-configure interface settings to match the map, configure communications points one-by-one, replicate the exact maps in substation and control center systems, install IEDs and devices; wire every point in the substation and switchyard, configure application settings, and commission-test every wire and point. The utility will also periodically perform complete maintenance testing on every critical function.

Key features of IEC 61850 include (i) data models that exchange standardized information in automatically configured functional groups and (ii) utilization of protocols that run over Ethernet local and wide-area networks. With an IEC 61850 standardized design, an engineer will select IEDs (with HMI and remote servers), perform function-level design integration with software tools and standard archives, install IEDs and connect fibers, download integration files and application settings, commission-test whole functions, respond to failure alarms in service, and turn detailed data into information for the whole organization.

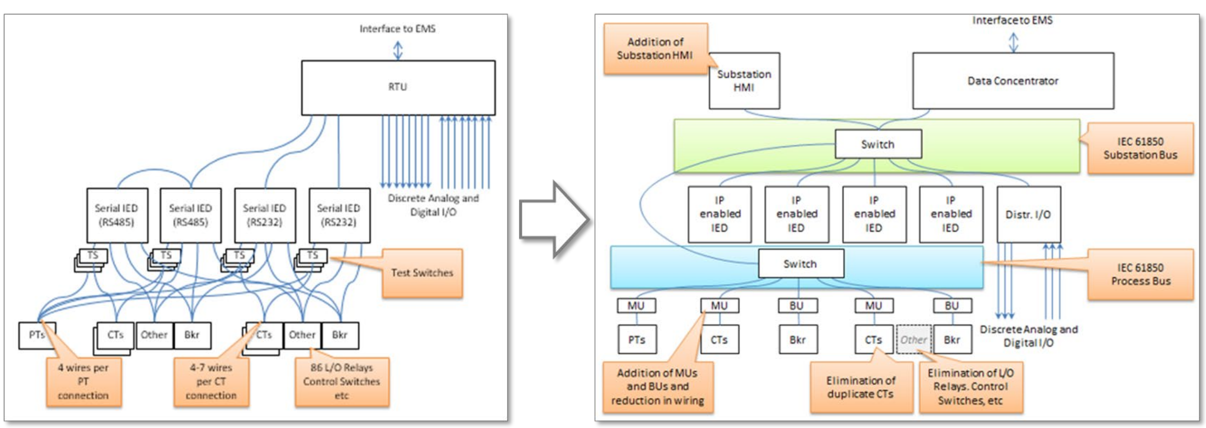

Figure I-1. Comparison of traditional substation P&C design to an IEC 61850 design

This paper will discuss the benefits and costs that will result from retrofitting existing transmission substations with fully digital, IEC 61850-compliant protection and control systems. The cost analysis involves two major components: the initial capital expense (CAPEX) savings and the ongoing operational expense (OPEX) savings. While there are CAPEX savings, the paper will highlight that the communications- and standard-based approach enable higher visibility into and interaction with the substation, improving operational tasks and in turn reducing OPEX expenses.

The key objectives of this paper are:

- To estimate the costs associated with upgrading existing transmission stations to a self-monitoring, fully compliant IEC 61850 environment
- To contrast those costs with conventional upgrade designs
- To estimate the capital and operational expense (CAPEX and OPEX) benefits derived from the use of the new communications-based system at the station level and the system level
- To estimate and incorporate application-based cost benefits of IEC 61850
- To elaborate on the organizational changes needed for full adoption of the new technology and associated transition costs

II. DEVELOPING THE BUSINESS CASE

As old designs become more costly and as the industry faces cost and revenue pressure, potential savings are hard for business leaders to ignore. Senior management at an increasing number of companies now wants their conservative organizations and team members to plow ahead, solve the problems, and work to achieve the benefits of utilizing IEC 61850. They also want to prepare the future and benefit from the digitalization to augment the flexibility of operations and take advantage of more reliable data for maintenance. At the same time, IEC 61850 sees more acceptance at the engineering and first-line management level due to generational change.

To adopt IEC 61850, we have to face the business case question. The electric utility industry ultimately cannot support multiple design paths that are fundamentally incompatible. We are no longer talking about competing vendor-specific protocols; the issue now is cost and the difficulty of maintaining traditional and network-based P&C in the same organization. It is not only that 61850 can be cheaper – although it has cost advantages – but also that the way we have done P&C will become too expensive to sustain in parallel. Adoption of 61850 will also facilitate future upgrades to the P&C.

To develop the business case, a cost-benefit analysis (CBA) needs to be performed. A cost-benefit analysis is used to justify investment for an entire project (e.g., adopting IEC 61850), determining return on investment, and comparing lifecycle cost with time benefits.

The core components of a CBA include:

1. Identify and classify on-going costs
2. Identify and classify new and on-going benefits/savings
3. Look at cost and benefits on an annual basis to determine the break-even point
4. Determine if the CBA supports the investment

III. IEC 61850 COST-BENEFIT ANALYSIS

Major components considered in the IEC 61850 CBA include the following: 1) organizational changes/transition costs, 2) capital expenses (CAPEX) typically for one year, and 3) recurring operating expenses (OPEX) over the lifetime of the project. In addition to hard savings, soft savings are also considered in the analysis. The CBA study covers a 10- to 15-year period to determine the break-even point of the investment. These major components of the CBA are illustrated in the figure below.

Figure III-1. Components of the CBA

A. CBA Approach for Hydro-Québec

The Hydro-Québec/Quanta Technology CBA approach was to estimate the costs associated with upgrading greenfield (new) and brownfield (existing) transmission stations to IEC-61850.These costs were compared to costs with conventional upgrade designs used by Hydro-Québec today. To determine the benefits of the transition to IEC 61850, it was necessary to estimate the CAPEX and OPEX benefits derived from the use of the new communications-based system at the station level and the system level including the application-based cost benefits of IEC 61850. It was also critical to look at the organizational changes needed for the full adoption of the new technology and the associated transition costs. Leveraging the cost and savings for the baseline station, the CBA was expanded to include the substation's upgrades in the capital plan to complete the CBA. This is outlined in the figure below.

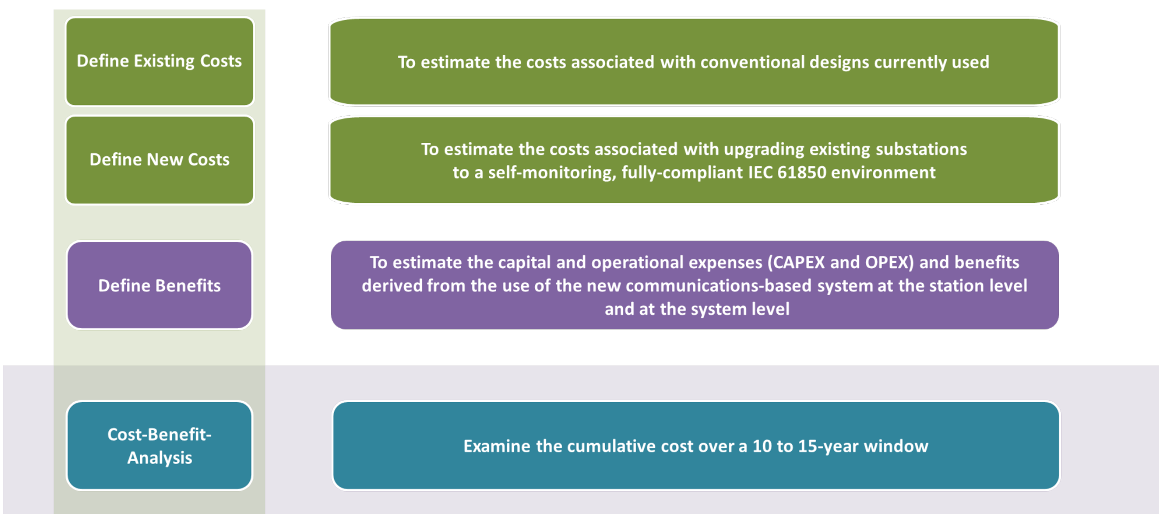

Figure III-2. Cost-Benefit Analysis for a transition to an IEC 61850 design

Each of the subsequent sections outlines some of the major items in each component of the CBA.

B. Capital Expenses

Capital expenditures (CAPEX) are funds used by the utility to purchase, install, and upgrade the physical assets in the substation. Some of the capital expenses considered in the study are outlined below:

- Building Cost: Typically, the building cost for IEC 61850 stations is reduced due to a reduced number of devices and panels.
- Protection, Control, and Communication Equipment: Higher functional integration reduces the number of protection and control devices. However, more communications equipment is required. Also, some existing P&C systems may no longer continue to be deployed due to weak cybersecurity, obsolescence of parts, etc.
- Wiring and Installation of Equipment: Wiring between P&C equipment is replaced by digital messages between devices. Wiring between the control house and yard is replaced with process bus communication.
- Engineering, Testing, and Commissioning: Standardized engineering process, reusable design configuration, and performing more simulation and testing during the lab and factory acceptance test (FAT) reduces the labor and cost. Reduces the time the station is out of service and the project duration significantly.

All the areas outlined above resulted in savings of 5 to 30% when the use of an IEC-61850-based implementation was compared to a traditional P&C approach. One can also include additional CAPEX savings since IEC 61850 provides the ability to extend asset utilization by implementing condition-based monitoring. For example, enhanced equipment monitoring for transformers may be able to defer investment in replacement costs. Transformer monitoring would include temperature, gas pressure, etc. The equipment monitoring application could reside in the IEC 61850 substation controller or pass data through to a centralized asset management system.

C. Operating Expenses

Operating expenditures (OPEX) are funds used by the utility during its normal operations. Some of the operating expenses considered in the study are outlined below:

- Reduced maintenance costs through continuous monitoring
- Maintenance and field-visit cost reductions
- Potential reduction of risks to health and safety by reduction of field visits
- Asset management related cost reductions
- Failure and error monitoring related cost reductions
- Outage and reliability improvement cost avoidance
- Substation inspection cost reductions
- Compliance reporting cost reduction

All the areas outlined above resulted in savings of 5 to 60% when the use of an IEC-61850-based implementation was compared to a traditional P&C approach. It is important to note that IEC 61850 heartbeat communications among processor-based IEDs inherently delivers complete self-monitoring of the P&C system operating integrity, eliminating time-based testing. This supports a condition-based maintenance (CBM) program that can document the monitoring and failure-alarming design through to the maintenance center, validate settings against a managed archive, and respond to alarms from the maintenance center. This improves relaying reliability and eliminates the cost of periodic relay testing and recordkeeping. This also reduces the risk of human error and damage from periodic testing. It is also critical to have systems and applications that can leverage this information to realize the savings.

D. Application Based Cost Benefits of IEC 61850

IEC 61850 is a modern communications standard that enables advanced applications to process information from substations. This standard defines digital communications protocols for protective relays and other IEDs used in substations. To realize many of the OPEX savings, applications are needed to process the data and provide information. A central feature of the Hydro-Québec *Convergence du Réseau et Évolution des Automatismes* (CRÉA) program, or system convergence and evolution of automation program, is the development and deployment of the *Centre d'Exploitation Technologique* (CET), or technological operations and maintenance center.

This center is built around the ITIL standard where four main processes are implemented: 1) Incident management,2) Change management, 3) Access management, and 4) Configuration management. From CET, Hydro-Québec Operations personnel will remotely monitor substation digital assets, deploying on-site maintenance resources when needed with specific skills and equipment when remote alarms or diagnosis indicates the specific need. On-site routine maintenance testing and troubleshooting at substations are mostly eliminated, while physical security and cybersecurity are effectively monitored. This allows for contemporary and consistent solutions in cybersecurity to be implemented. Accumulated cost savings by remote site access and effective monitoring across the large number and vast territorial dispersion of Hydro-Québec substations are substantial.

E. Soft Benefits

Soft benefits are those that cannot be easily assigned a detailed financial value. Soft benefits can be hard to quantify, but they can offer significant cost savings. Examples of soft benefits considered in the analysis include:

- Reduce human error
    - Human error is often due to testing in the substation; it can be largely eliminated with IEC 61850
    - Hard-wired connections can be replaced with fiber optics and pre-configured and pre-tested connections
    - A higher degree of standardization helps eliminate settings errors
- Avoid misoperations and reduce customer interruptions
    - Avoid costs for unserved energy and loss of revenue, penalties
- Avoid major catastrophic equipment failures with better monitoring
- Defer capital investments
- Employee safety with less travel and replacement of electrical cables with fiber optics
- Prepare the future of network operations and maintenance.

There are additional soft benefits that are even more difficult to quantify. These include additional safety benefits, application flexibility, a strong basis for a contemporary cybersecurity solution, and improved talent acquisition by offering a new technology application, etc.

F. Transition Costs

Beyond the economic advantages discussed above, IEC 61850 brings major changes in how the utility designs installations and conducts business. Internationally, manufacturers with IEC 61850 product lines have already fielded multiple generations and thousands of installations of substation P&C systems based on IEC 61850. Many of these are in turnkey substations where a single manufacturer has taken total responsibility for the design, integration, and commissioning; it also supports the purchasing utility through the life of the installation. Experience in North America has already shown that without attention to this transformation, the benefits of IEC 61850 will not be achieved.

Adoption of IEC 61850 impacts the P&C processes and the organization. Some examples include:

- New engineering, design, commissioning, and testing standards
- Engineering tools, systems, and databases
- Pilot P&C design development
- Sustainable laboratory systems
- Workforce education and talent acquisition
- New maintenance and test equipment
- Configuration and Asset Management System for P&C
- Lifecycle management
- Change management process
- Investment in IT infrastructure and new applications

The transition costs are heavily loaded to the beginning of the transition to IEC 61850. Thus, they will have a significant impact on the break-even point for the investment of transitioning to IEC 61850.

G. Cost-Benefit Analysis

As outlined above, several factors affect the CBA. By examining greenfield and brownfield applications, cost and savings can be assigned to the substation capital plan over a 15-year period. Obviously, the benefits increase with the number of deployments as this helps to offset the transitional costs. In the analysis with Hydro-Québec, the savings offset the organization cost over time. The chart below is an example of the output from the overall study. Note that if the soft savings are considered, the break-even point is sooner. However, excluding the soft savings results in a similar break-even point. Based on the analysis, Hydro-Québec has decided to move forward with IEC 61850 in future substation upgrades and new installations.

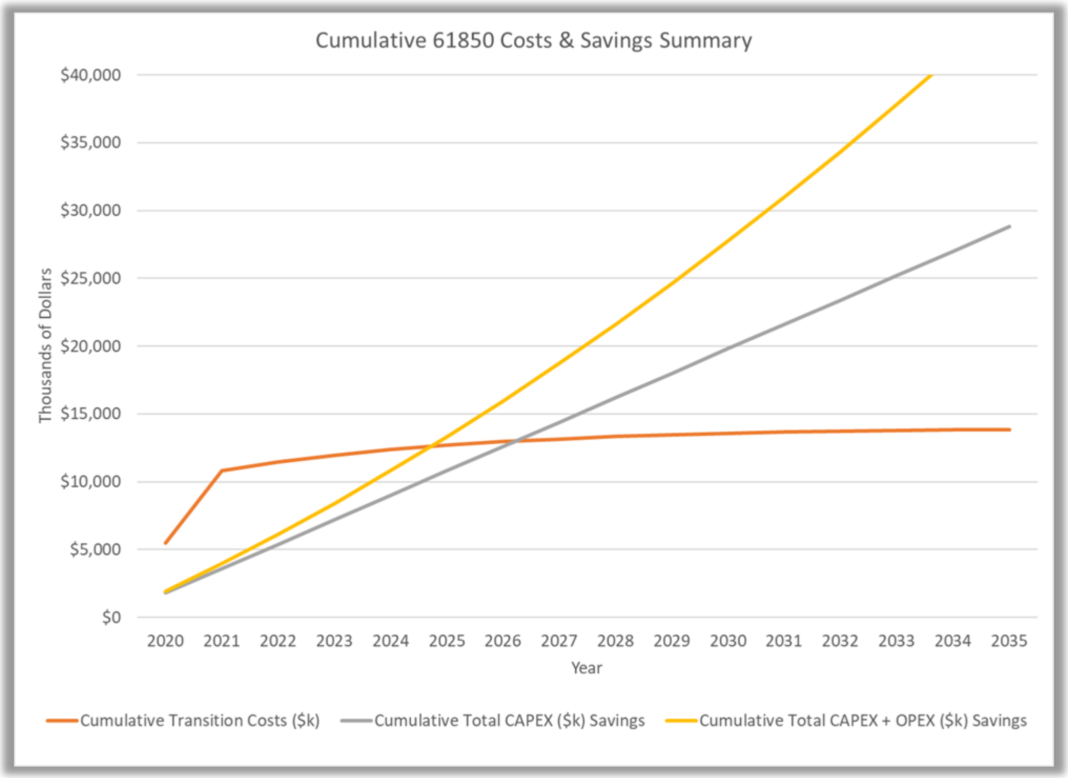

Figure III-3. Example of Cost-Benefit Analysis

IV. BEGINNING THE TRANSITION TO IEC 61850

As mentioned earlier, one of the key aspects of moving to an IEC-61850-based solution is the transition. At Hydro-Québec, a full-time team of managers was created with the objective of setting up the converged technical teams required to start this technical and organizational change. The following issues quickly became apparent:

- The expertise required to execute such an innovative project with new standards, new ways of doing P&C from procurement to engineering to commissioning, new technical fields, etc.
- The human capacity of resources to carry out such an innovative project
- Different organizational silos and collaboration between those silos
- The impact on the tasks of the resources affected by the change (engineers, technicians, IT specialists, cybersecurity specialists, etc.)
- The effort required to make the organization adapt to such changes (change management and adoption curve)
- Greater need for collaboration and a better understanding of other stakeholder issues
- The breadth of the task to "industrialize" this new technological platform
- The justification of the initial costs of developing and integrating the new technological level (before the arrival of the benefits).

In addition, it is important that, at the beginning of such a transformational undertaking, the identification of risks be performed, not only covering the technical aspects of the project but also taking into account the culture of the company. A poor estimate of these risks and the associated mitigation measures have a direct impact on the ability to realize the benefits originally identified.

V. CONCLUSIONS

Utilities in North America have taken a more deliberate approach to IEC 61850 implementation than utilities in other parts of the world. Most are accustomed to designing, integrating, and maintaining their own standard designs. Risks and process change requirements of such a new technology have clashed with inertial challenges of large established organizations. New users of IEC 61850 need new processes: new standard design, new development configuration, new configuration and settings management, CBM-driven repairs, new P&C standards, etc. However, cost-benefit analysis illustrates that moving to IEC 61850 has financial advantages over the traditional approach. The IEC 61850-based design has been shown to have lower CAPEX costs than the conventional approach for distribution and transmission substations. The CAPEX-related annual benefits from the ability to extend asset utilization with condition-based monitoring abilities of IEC 61850 are real but difficult to estimate. However, the reduced maintenance OPEX via a condition-based maintenance (CBM) program is substantial. Deployment of IEC 61850 requires initial investments in transition costs, personnel training, communications infrastructure, and organizational adaptations to be successful. The initial transition costs will exceed initial savings in both CAPEX and OPEX. But over time, cumulative CAPEX and OPEX savings will greatly exceed the transition costs.