IEC 61850 INTEROPERABILITY, THE GOOD … THE BAD … AND THE UGLY

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ABSTRACT

IEC 61850 has rapidly gained popularity since its introduction 12 years ago. It is now a good time to review whether the standard has met its goal of an easy-to-apply standard. The standard has proven to be both easy-to-use and difficult-to-use depending upon the user perspective.

Many new users of IEC 61850 assume that all vendors of products have implemented all parts of the standard in a completely interoperable way; but this is not actually true for two reasons:

- IEC 61850 is a very large standard with many (too many?) sets of options from which the vendor can choose. The marketing departments of each vendor make individual decisions concerning the feature set that their customers will use.
- Some parts of IEC 61850 can be interpreted differently by different vendors.

The good news is that vendors quickly converged upon common feature sets; and the conformance testing program from UCAIug has reduced vendor interpretation errors of the standard. In general, IEC 61850 is easy to apply for those experienced with the standard.

The bad news is that some users perceive the need for features outside of the common feature set. Many of these customers are replacing legacy system and want to operate IEC 61850 in the same way as their legacy system operated. It has been stated many times before "IEC 61850 is not a protocol; it is a way of life." Users may attempt to minimize the risks during the IEC 61850 transition by changing as little as possible; which sometimes leads to strong disagreements between users, implementers, consultants, and manufacturers.

The ugly news is that users must make basic changes to their approach to automation systems when transitioning from legacy systems to IEC 61850. This involves a commitment from all levels of management, engineers, and the front-line workers. These changes involve risks which must be managed at every level. For example, the front-line workers need to understand that their toolkit with voltmeters and current probes will not be sufficient in the IEC 61850 world.

This paper reviews the standard from the viewpoint of the user, with emphasis on first-time users. Experienced users will also learn by observing mistakes of inexperienced users and can thus judge their maturity level in the implementation of IEC 61850.

INTRODUCTION

This paper is focused upon IEC 61850 as viewed by the people who "own" the automation system (i.e. "end-users"). From this viewpoint, vendors exist solely to manufacture appropriate devices for use in the specific (project-oriented) user's automation system. This does not mean that vendors can have no input to the construction of the user's system, but this input must be understood to not always be in the best interest of the user; their job is to sell their own products, not to optimize your automation system.

IEC 61850 consists of many parts; 14 in the core of Edition 1 and over 40 in total. Some parts of the standard are easy to understand while other parts are difficult to understand. In general, the easy parts document the common understanding of users while the more difficult parts involve issues where there is no "right answer for every application".

The standard continues to evolve even after almost 15 years of use. This can be seen by inspecting the number of Technical Issues (TISSUEs) at *http://tissues.iec61850.com*. See Figure 1 below.

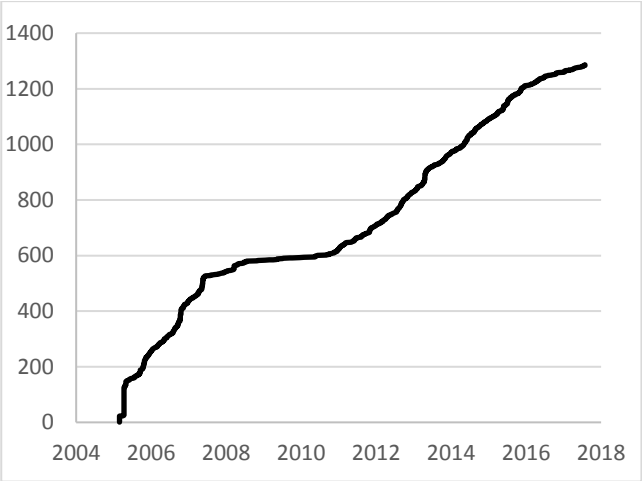

FIGURE 1: Cumulative Technical Issues by year

This graph shows that the present rate of new technical issues is about 10 per month and this rate has been stable since Edition 2 was released across the 2007-2011 time frame.

The UCA International Users Group (UCAIug) has been an active partner with IEC in the development and maintenance of the IEC 61850 standard since the first release in 2005. This group promotes the adoption of the standard by:

- Supporting product demonstrations at various trade shows and standardization meetings
- General promotion of the standard through marketing materials
- Support of Inter-Operability Tests (Paris 2011, Munich 2013, Brussels 2015, and New Orleans USA in 2017)
- Maintenance of the device conformaqnce testing program

WHAT IS IEC 61850

IEC 61850 is very different from previous automation standards. It is not just a protocol; it is a "way of life". The goal of the standard is to provide a design guideline for automation systems incorporating best industry practices as well as existing standards. Seen from this viewpoint, IEC 61850 is all of:

- A management system
- A specification system
- A configuration language
- A definition of automation services
- A precise vocabulary of automation objects
- A conformity assurance system

WHY IS THE INDUSTRY EXCITED ABOUT THE STANDARD

IEC 61850 can view viewed in a number of ways depending upon the user perspective. For a first-time user, the standard is usually approached with both fear and excitement. Experienced users generally view the standard as just part of the normal utility practice.

There are a number of answers to the reason for excitement:

RIGHT ANSWER:

- The standard codifies how to think about substation automation systems
- It ensures a clear path to success
- Has the backing of major automation companies
- It results in clear documentation of most decisions involving the system

ALMOST RIGHT ANSWER:

- It is too big; impossible to learn everything in the standard
- It is intellectually challenging – it requires brains and not muscle
- It encourages young engineers to enter or remain in the power industry

WRONG ANSWER:

- Everyone else is writing about it, it must be good for me
- Nobody else in my country is implementing it (North America)
- Because my manager read an article in a trade magazine about IEC 61850
- A vendor or consultant has a very slick PowerPoint presentation on IEC 61850
- When the project fails then I can blame a standard that nobody else understands

ANATOMY OF IEC 61850

The standard has many parts to it with varying degrees of difficulty. For the purpose of this paper, the parts are subjectively categorized as easy, not-so-easy, and hard.

The easy parts of the standard are both simple to understand and intuitive:

- Services and general data modelling (61850-7-1 and 61850-7-2)
- Common types of data objects (61850-7-3)
- Logical Nodes (data groupings) and the data object names/definitions (61850-7-4)

The not-so-easy parts are more difficult to understand because of the level of detail. Fortunately, most of these parts can be ignored until specific needs arise. These parts include:

- Communication Requirements (61850-5)
- MMS and GOOSE mapping (61850-8-1)
- Sampled Values (61850-9-2 and UCAIug "9-2LE")
- Conformance Testing (61850-10)

The most difficult parts of the standard involve a major change to the thought process for system engineering. The specific parts of IEC 61850 include

- System and Project management (61850-4)
- System Configuration Language (61850-6)

The System Configuration Language is the most difficult part of the standard to learn; but it is also the most important part because it includes the majority of the design artifacts from the automation project. If properly used, the resulting files can be used for:

- Automatic generation of graphical electrical one-line diagrams of both the entire systems and defined subsystems
- Input to simulation tools for testing current and future functions
- Automatic generation of signal flow diagrams and signal analysis
- Automatic generation of data available from every IED
- Ability to determine effects of a failed IED or an IED under maintenance
- Etc.

To repeat, although 61850-6 is the most difficult part of the standard, it is also the most important part to use properly. Some system integrators may attempt to claim completion of a project without delivering these very important files (especially the SSD, System Specification Description and SCD, System Configuration Description files). Without these files, it is extremely difficult to perform system modifications.

HOW TO ACHIEVE SUCCESS WITH YOUR FIRST IEC 61850 IMPLEMENTATION

There are many paths to completing a 61850-based automation project. Some paths lead to success, and other paths lead to failure. The following cookbook is a summary of an ordered set of steps to use to achieve success:

1. Choose a "greenfield" site without any existing legacy automation
2. Assemble a team of experts in communication, protection, and substations. Include in the team the maintenance techs. Early engagement of the maintenance technicians is crucial to success
3. Have the team meet for an initial meeting and stress the importance of success
4. Get upper-management buy-in for the project, stress that low-cost is NOT the objective
5. Set low expectations (first project will have some trade-offs for the sake of simplicity)
6. Use Edition 2+ of the standard. It more clearly defines critical maintenance aspects.
7. Don't implement Merging Units (this has subtle issues which are only discovered late in the project as deadlines loom)
8. Ensure entire team learns the "big picture" of 61850 (parts 1 and 4 and 5 and 7-1)
9. Invite a trainer to perform a 1-2 day training session for the entire team. Focus on details of the standard such as services and objects and MMS and basic networking, etc.
10. Use the top-down engineering approach to the project development
11. Create a hand-written high-level design of the system that fits on one (A0-sized) page
12. Purchase the best SCL tools that you can afford
13. Document the one-page design in an SSD file
14. Decide whether inter-device communication will use backup copper wiring. Although 61850 GOOSE has proven reliability, some people are uncomfortable using only GOOSE to perform some critical functions. For interlocking, do NOT use copper wiring.
15. Engage a consultant to review the high-level design (1-2 days). Remember that the design belongs to you and NOT the consultant!
16. Engage a system integrator with proven experience with the standard. Ask for references.
17. Choose devices based upon functionality, 61850 requirements, and conformance tests
18. Work with the integrator (your team, not the integrator, will need to live with the results)
19. Create a small test lab to play with new ideas and become comfortable with technology. Ensure that the test lab is equipped with signal generators, signal analyzers, and timing devices. Purchase additional IEDs which can remain in the lab AFTER the project

completion. Use this lab to train project people on the test equipment

20. Test everything in isolation; note every issue found. Resolve these while in the lab.
21. Engage the consultant again for a design review (2-5 days)
22. Consider redundancy. But carefully justify redundancy needs. Redundancy = complexity.
23. Create a detailed commissioning plan including communication tests
24. Carefully plan post-commissioning maintenance tasks. How to test an in-service automation system. The legacy "air-gap" method will NOT work with IEC 61850!
25. Document everything. SCD file is a great place to put documentation.
26. Perform a post-project audit. Write down all issues found and possible solutions. Keep this for the next project.

HOW TO FAIL WITH YOUR FIRST IEC 61850 IMPLEMENTATION

There are far too many paths to failure with IEC 61850. For a first implementation, there is often an incentive to "try everything in the standard, but choose what works in the end". This is not the best approach.

Another clear path to failure is to "build before designing". This sometimes works with legacy protocols, but IEC 61850 demands a coordinated approach to the problem. The description below shows many ways to ensure that a satisfactory automation system will NOT be created:

1. Assemble a team of only protection and protocol engineers. Tell them that IEC 61850 is difficult to use and there is a backup plan in case 61850 "does not work".
2. Allocate no resources to the project. Do not purchase special test equipment and only use only free software tools found on the Internet (and Microsoft Notepad/Excel)
3. Ensure that the time allocated for completion is as short as with existing legacy system
4. Use the bottom-up engineering approach to IED configuration. This ensures that "something will work" early in the project. Ensure that nobody on the team coordinates changes with others.
5. Choose brownfield site where IEC 61850 equipment must co-exist with the existing automation system
6. Set high expectations. Assume that every magazine article explains all pitfalls.
7. Assume that the new automation system will work exactly like the existing system
8. Assume corporate-wide procedural changes will not been needed
9. Engage a consultant before learning anything about the standard
10. Have every team member attend a 2-week seminar on all aspects of the standard.
    If possible, force the maintenance technicians attend a 3-week course.
11. Try to use every part of the standard. Insist on only purchasing equipment which has every feature of IEC 61850.
12. Select the equipment to be used before any design takes place
13. Hire the consultant just after the equipment is purchased and before the high-level design is complete. This ensures that the consultant "has work to do".
14. Install the equipment immediately upon arrival. Assume equipment is functional without any testing.
15. Save money by not building a test lab. This money can be your bonus.
16. Send all status messages generated by each IED to the substation computer (cannot be sure which messages are needed, so just send everything)
17. Allocate zero time for debugging and commissioning. Because IEC 61850 is a great protocol it does not need testing.
18. Ignore all maintenance issues; assume "air-gap" IED isolation works with IEC 61850

This is only a partial list of approaches to the automation problem which have proven to be problems in the first implementation. The most basic cause of failure is the lack of recognition that IEC 61850 systems are truly different from legacy systems; to repeat "it is not just a protocol, it is a way of life". An attempt to create a IEC 61850-based

system which works identically to existing systems is doomed to failure.

This list is mostly correct for every implementation of the standard but is needs to be changed somewhat for subsequent projects. For example, the use of Merging Units, although not recommended for a first implementation, should be considered for every system. This allows for a vast reduction in the amount of point-to-point copper wiring in the system. However, the complexities of the design (especially the communication redundancy aspects), can easily overwhelm the team during first implementation,

THE GOOD, THE BAD, AND THE UGLY

The standard is very comprehensive in the desired outcome for an interoperable system. However, proper application of IEC 61850 standard requires a careful plan.

The good part about IEC 61850 is that it can result in a system which is well planned, well documented, easily altered, and easily maintained. The standard promotes a clean structured approach to the design of automation systems. The number of highly-qualified engineers with experience in the standard is growing and it has attracted many new young engineers into the field of power engineering.

The bad part about the standard is that is requires designers to “think out-of-the-box”. In other words, there is much more creative thought involved with an IEC 61850 system than with previous systems. The entire organization needs to become involved with consideration of new ways to accomplish tasks which could have never been done before without using IEC 61850.

The ugly part about the standard is that the first experience is always painful. The “learning curve” for the standard can be very steep; and training costs are typically under-estimated. This will cause many people to doubt whether the transition to the new standard is worth the effort; and there may be pressure to return to “business-as-usual”. Implementation of IEC 61850 technology will require a large degree of risk management.

IEC 61850 has many advantages over legacy system. The advantages will eventually drive all power automation systems toward this standard. Upon recognition by upper management that implementation efforts can be dramatically reduced compared to legacy protocols, there will be pressure to use even more parts of the standard in subsequent projects and move away from the paradigm of “business-as-usual”. In the words of a science-fiction television program “resistance is futile”.

SUMMARY FOR FIRST-TIME IMPLEMENTERS

The decision to adopt IEC 61850 cannot be taken lightly. It will change the course of the company in unexpected ways. As you think about process of implementations, many new ways of operating an automation system will become apparent.

First-time implementation of the standard will be costly in term of labor. Most of this cost is due to learning about new ways to think about automation (and 61850 in particular). As a starting point, the amount of engineer-hours can be expected to be 200-300% for the secondary system (the primary system costs remain mostly unaffected). The second implementation may also not result in cost savings. However, the third implementation will result in cost reductions. The design time required for the first project will also be longer than with legacy system; management must understand this.

The implementation group must learn to work together as a team. This requires commitment from upper-level managers down to the maintenance technicians. The team needs to able to handle the inevitable tensions from individual team members.

The implementation team must be dedicated to “getting it right” rather than just “getting it working”. Shortcuts in the present implementation almost always cause problems in the future.

Training is essential to the adoption of the standard. Without a clear map of the proper processes and capabilities of the standard, many of the advantages of using the standard will not be realized. This is very similar to moving a foreign country but only learning a few phrases in the new language.

A test and simulation laboratory must be created. This environment can be used to train engineers, managers, and technicians on how to use the equipment which will be found in the “real” environment. This is also the location where automation schemes can be developed without the hazards of “live equipment”. This laboratory should be equipped with equipment that closely mimics the actual automation system and should be maintained after the project has been commissioned. This test area can be used when planning substation upgrades or expansions.

Ensure that the implementation schedule allows time for mistakes. Most of these mistakes should happen in the test lab but some can happen late in the design process or even be discovered during commissioning. Use of high-quality consultants can minimize these mistakes.

Use only well-proven devices for the automation system; UCAIug conformance-tested products are a strong indication of mature products. For the second implementation, the team should be able to

use more exotic devices because the pitfalls will be more well-known. The same is true for test equipment and software tools; select these more for ease-of-use rather than full features. The team will have enough work without the worry of using faulty devices or hard-to-use testing tools.

Carefully select the best consultants and system integrators. On a per-hour basis, these will probably be the most expensive. But the number of required hours will be far less than with inexperienced people. Use these consultants to help finds better ways to accomplish your goals. Ask specifically how GOOSE and reports should be used as well as whether Merging Units make sense for your specific project.

Use the experience of your equipment vendors. They often know more ways to apply their equipment than you have considered. But be careful with vendor advice; their interest is to sell products while your interest is to optimize the automation system.

Create a highly visible sign in the project area “The second project will be easier”

Have fun, enjoy the learning process. Be sure to take time to plan the work. Stress to the team the importance of the project from the view of upper management.

CONCLUSIONS

IEC 61850 is the future standard to which most automation systems will be built. The sooner you begin down the path, the more savings your company will enjoy. However, this first step will be difficult.

The standard has many subtleties which only become apparent during implementation. Allow time to consider some small changes in direction after the basic project pre-planning is complete. You might find surprising ways to perform tasks which could only be done by 61850.

Plan for the maintenance of the automation system. IEC 61850 is different from traditional systems in that everything becomes inter-connected. This is a very hard lesson to learn. For example, in traditional systems the “action” outputs of a protective relay can be simply disconnected from other equipment; but with 61850, all of the outputs are multiplexed together in a single communication path. “Air gaps”, used during maintenance of traditional systems simply cannot work with IEC 61850. There are solutions, but this needs to be designed into the system.