Introducing Protocol Converter In a Sub-Station Communication Environment for IEC 61850 Compatibility

A White Paper

Prasanth Gopalakrishnan
prasanth@kalkitech.com

Jose Thomas
jose@kalkitech.com

Fahid KA
fahid@kalkitech.com

Kalki Communication Technologies Private Limited
#147, 2nd Floor, 5th Main Road
Sector 7, HSR Layout
Bangalore 560034
Karnataka
INDIA

Phone: 91-80-25721263/4
Fax: 91-80-25725473
E-mail: info@kalkitech.com
Web: http://www.kalkitech.com

Introduction

The communication protocol standardization in general in sub-station equipments as well as the adoption of IEC 61850 standard in particular as the uniform standard in IED's and sub-station controllers for communication and engineering, there is a an ever increasing requirement to look at current migration strategies and options to these newer communication standards while retaining the current investments in sub-station equipment. This calls for utilities to identify their current, near-term and far-term sub-station migration strategies together with sub-station communication and engineering requirements for local and remote communications.

This article describes some of the impacts of introducing communication gateways or protocol converters in a sub-station environment to achieve the migration requirements of utilities and the drawbacks and benefits for the utilities in investing in such gateway equipment. This paper also looks at how OEM's and end customers may use protocol gateways for meeting specification conformity and better pricing regime, and its overall impact on the utilities.

Current Sub-Station Architectures for local and remote communications

Current sub-station architectures are highly focused on increased automation and communication capability for local and remote monitoring and data acquisition. The key objectives of the current sub-station architectures [CIGRE2002] tend to be addressed towards meeting objectives for adapting to energy trading scenario's, increased operational efficiency to meet the newer and more competitive environment, reduced operational costs and greater flexibility in adapting to newer technological and operational requirements of the evolving energy trading environment.

An automated sub-station is a sub-station, where all secondary equipment within a sub-station is interlinked with communication buses. Serial communication buses or proprietary communication media with associated protocols almost entirely linked the conventional automated sub-stations. These sub-stations used serial dedicated links for local HMI as well as for remote communication to remote Network Control Center.

With the standardization effort brought about by the IEC 60870-5 series of communication protocols and the DNP3 there has been a marked shift improvement in the inter-operability scenario in new sub-stations. These protocols brought about some semblance of conformity and inter-operability within a sub-station and for remote telemetry between multi-vendor systems. However these efforts addressed mainly the communication part of sub-station standardization.

The IEC 61850 approach Advantages in modern substations

As has been evident in the sub-station scenario, the utilities problems with inter-operability has soon transcended the boundaries of having sub-station equipments talk to each other or having sub-stations talk to multi vendor control centers, but also to have common understanding between the naming conventions, object naming and addressing, formats for engineering, which is critical for continuous maintenance of the sub-station and future enhancements.

This process was started by the UCA initiative by EPRI, which brought about a well defined set of object naming conventions, employed XML to bring about uniformity in data and context using meta-data and an overall object oriented approach. This approach later co-opted into the IEC 61850 standard thus provides a basis for sub-station communication as well as sub-station engineering, thereby bringing not only the communication into the purview of inter-operability, but the entire sub-station engineering and sub-station solutions into the purview of standardization.

The IEC 61850 defines two high-speed Ethernet network buses, the station bus and process bus. The process bus implementation requires high network speed of 100 Mbps or 1000 Mbps. Optical CT's and PT's with high speed processing and accuracy on an Optical Ethernet will bring about very high speed sampling data on the network, and thus makes it possible for IED's to have sampled values from the network rather than from hardwired interfaces. At the station bus also Optical Ethernet is preferred at 100 Mbps speed. This conceptually takes away the entire field wiring at the Process level to IEDs out and thereby making your overall sub-station wiring simpler. The bus architecture at high speeds enables multi-casting, thereby enabling multiple IEDs to process the same data if required.

At the station level, the bus architecture enables peer-to-peer communication and distributed decision-making. Also the IEC 61850 engineering conceptualizes a common XML based object driven configuration mechanism, a layered communication architecture on top of MMS services and well defined conformance specifications. These definitions thus enable the IEC 61850 standard to achieve long term cost benefits to utilities in terms of lowered engineering and commissioning costs and simpler architecture makes maintenance costs that much lower.

The utility migration paradox

The Electric Utilities migration paradox exemplifies the general trend whereby the new technology provides great advantages and benefits while the current investments has not fully completed their operational life. Together with this is the increasing maintenance costs of old equipments with time and the learning curve associated with the transition phase to a new technology.

Standards always bring about a great change in the competitive scenario creating low cost and high quality products in a very short time. Standards also try to cover a lot of ground from utilities and OEMs experiences with pre-existing equipment and systems. However the standards also force on the utilities a wide variety of options with regard to retrofit and expansion of existing infrastructure, which are very difficult to choose from. Also there exist an interregnum, where Utility, the OEM and the System Integrators will have to grapple with the old and new architectures and system at the same time. This situation shall be very prevalent in the first 3-5 years of the new standard's operational adoption life.

So also is the case with IEC 61850. A Utility has to ponder on questions like; What should be the best migration alternative for IEC 61850?. Should the Utility shift completely to a IEC 61850 environment? Should the Utility stagger the investment on new technology till the technology is proven?. Should the Utility mix new technology with old technology?. Should the Utility continue with the old technology in existing infrastructure, until their complete upgrade to the new technology in a phased manner?. Should the Utility do an impact analysis on the risks of migration with intermediate components being introduced?.

These questions are not unique for IEC 61850. But are also relevant for the other standardization efforts in all areas where new technology brings about an order of magnitude or more change in the way current things are done, for eg: with CIM, IEC 61970, IEC 61968 etc., which tries to bring abount a common Model driven API, thereby brining more standardization and integration at the power system level and in the overall energy market.

These are vague as well as difficult questions. However the answer to these depends more on the Utility and its plans in participating in a deregulated and market driven energy market.

Using IEC 61850 Protocol Gateways in Sub-Station Migration

One of the options that is available to the Utility is to mix old investment with new technology. This would mean modernization or up gradation of existing investment in sub-stations by employing intermediate gateways for IEDs, RTU and SCADA Systems, which will provide inter-operability between their new IEC 61850 based systems as well as old proprietary or other IEC standard based systems.

Such a migration option always throws up an intermediate gateway or protocol converter into the Utilities solution. The intermediate gateways normally provide the following capabilities:

a. Provides protocol conversion from IEC 60870-5, DNP3 or Proprietary to IEC 61850 and vice-versa

b. Provides configuration and diagnostic tools
c. Provides multiple communication interfaces and data storage capability thereby providing concentration capability
d. Provides Interface to old and new systems simultaneously
e. Provides inter-operability to a great extent from the IEC 61850 communication perspective

Depending on the use, IEC61850 protocol converter covers two scenarios:

1. In the automation system where the data has to be monitored/controlled on SCADA, which supports IEC61850,but there are some devices in bay/process levels, which do not support IEC61850. In this case it is required to put a protocol converter, which will take the data from bay/process devices in specific protocol format & convert it to IEC61850 server format.
2. The data transfer has to be made between bay/process devices, which supports IEC61850 & DCS/SCADA, which does not support IEC61850. In this case protocol converter will acquire the IEC61850 data by acting as client and send these data to the specific external master protocol.

IEC61850 Protocol Converter Configuration Requirements

The first and most important part of protocol converter is its configuration functionality. The configuration utility used for this should be highly reliable and user friendly. It should have facility to give online diagnostics of the protocol converter. There will be standard input file as per IEC61850 standards, which will define all the IEC61850 logical nodes, data objects, data attributes etc. from which the SCL file can be generated. The configuration utility should generate three major output files.

a) SCL File: - Configuration file should be generated for IEC61850 part as per substation configuration language [IEC61850-6]. This will contain details of data model as per the IEC61850 standard.
b) There should be configuration files for the other protocols.
c) There should be a procedure to map the data from other protocols to IEC61850 data attributes. This mapping information can be stored as a separate file or can be a part of other protocol configuration files. (Points b and c are Converter Implementation specific and different vendors shall adopt different methods.)

Mapping details of IEC61850

The object-oriented data modeling of IEC61850 makes it difficult to map to/from other standard protocols. This becomes highly complicated when we consider the quality & timestamp attributes of IEC61850, which is common for a set of

data in many cases. But it should be taken care as far as possible that the specifications of both the protocols are not lost by this mapping. The following things have to be taken care for ensuring an optimized conversion environment.

- It is always advised to map the data from other protocols to the standard logical node models available in IEC61850 servers. The user is advised to restrict the use of generic I/O nodes (GGIO) only when they are very much essential.
- The mapping should be based on the data references (tags) of IEC61850 & the address references in other protocols. It should restrict the data conversions to the minimum.
- The mapping should be in such a way that it should consider the maximum features of both the protocols. There should be provisions/procedures to map quality, timestamp etc.
- There should be standard configuration & mapping files for major devices / ieds used for the application which will minimize the user configuration & errors.

Limitations of Protocol Gateways in Sub-Station Migration using IEC 61850

Protocol gateways come with a number of limitations in a sub-station migration project. This section details some of the important ones as well as touches upon the issues related to mapping IEC 61850 data types to other protocols. Considering these limitations, it is very imperative to really understand the implications of introducing an IEC 61850 Protocol Converter in a sub-station before starting such a project.

The key limitations include:

a. IEC61850 is aimed to have high data integrity by ensuring single protocol for the entire substation. Implementing protocol gateways will result in an overall data integrity level which is less than a Sub-Station, fully built based on IEC 61850 based equipments.
b. Limitation with respect to engineering capability support of IEC 61850
c. Investment in re-configuration and protocol mapping of the gateway if some changes need to be done in the downstream older systems
d. Cannot use the gateway at the process level, unless the gateway is tightly integrated into process bus systems and conforming to the IEC 61850 process bus requirements
e. Gateway introduces a finite latency in the communication network. The existing equipments with proprietary or standard protocols, all work on much lower communication throughput, and hence the net data exchange throughput available in a Sub-Station with old and new equipments interconnected using protocol converters will come down.

f. In the interim, the Utility or system integrator ends up needing to learn about his new IEC 61850 system and the Communication gateway in addition to knowing about and maintaining his older system.
g. IEC61850 uses a totally object oriented approach in data modelling and it's communication. We are introducing compromises on this model & it's functionalities by introducing the Protocol gateways.

Limitations in supporting complete IEC61850 functions

It is not possible to achieve the total functionalities of IEC61850 by using the protocol converter. So we have to put compromises on its functionalities.

- It is always advised to have support for the following ACSI Models to have better features of IEC61850
    1. Logical Device model
    2. Logical node model
    3. Data Model
    4. Data set model
    5. Reporting models
    6. Control Model

- The following ASCI models can be treated as optional for the protocol converter as it does not cause serious data losses.
    1. Substitution model
    2. Setting group control model
    3. Log control model
    4. GSSE
    5. GOOSE

Data Mapping: Issues in mapping from IEC 60870-5-101 to IEC61850

We can associate **functional constraint** of IEC61850 with **ASDU type** of IEC 60870-5-101. But this again causes an overlap in many cases. For example, IEC61850 can have a functional constraint "ST" which stands for the status indications. This status information can contain single point (SPS), double point (DPS), integer (INS) etc. & we have multiple ASDU types of IEC 60870-5-101 to which these can be mapped. In order to take care of the mismatching features of functional constraint with ASDU types, we may have to consider the final data attribute type or CDC types of IEC61850 for proper mapping arrangements.

Suitability of communication gateways in IEC 61850 migration

The communication gateways provide some unique advantages to sub-station migration to IEC 61850 technologies. These are more in the nature of achieving a smooth, staggered and low cost transition to the new technology. These include:

a. Implementing new technologies without changing or modifying existing systems and investments
b. Taking advantages of the IEC 61850 benefits in a staggered fashion at different levels within the sub-station.
c. Affordable cost of Gateways helps keep migration costs under control
d. Replacement of old systems with IEC 61850 based systems easier at later stages without effecting operations smoothly with almost negligible engineering effort
e. System integrators of limited expertise are able to configure and install gateways thereby reducing expensive consulting

Conclusion

This paper tries to address the issues related to IEC 61850 Gateways in a sub-station migration scenario. IEC 61850 is an advanced and unique protocol, which looks at Sub-station communication and engineering in totality and bringing never before advantages in Sub-station automation. However migrating to IEC 61850 throws up a number of issues, and some of them could be addressed by implementing protocol gateways in sub-stations. The suitability of the same however needs to be addressed based on the utilities migration strategy and long term requirements, rather than building specific glues for the short term.

References:

1. [CIGRE2002]The automation of new and existing substations: why and how. Sponsored by the CIGRE Study Committee 34