Hidden Challenges in the Implementation of 61850 in Larger Substation Automation Projects

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Introduction

The IEC 61850 protocol is being used increasingly within the distribution, transmission and generation projects. Applications range from new facilities to upgrades, as well as the implementation of control philosophies that use communications as the means of performing the control and protection operations. This is a step away from hard-wiring devices together, which was has been the accepted approach for decades.

In 2007, we have seen a major change in regards to IEC 61850 in North-America, following the IEC 61850 trend in Europe and Asia. Companies are now requesting IEC 61850 capabilities available immediately or planned in the near future. As usual this starts with well defined pilot projects to examine the potential and the challenges of this new approach with the electric utilities.

In this paper we are presenting the experience gained in two projects, focusing on a major application that included approximately 300 IEDs using IEC 61850.

We also examine broad projects using the IEC 61850 approach, the challenges they presented and some of the lessons learned in their implementation. The examples are projects with which the authors have actually been involved. They featured the implementation of advanced control capabilities in the integration of IEC 61850 devices from different suppliers within the substation, as well as integrating IEC 61850 with other types of protocol(s), while still requiring information to be available in a timely manner for decisions to be taken.

We present the challenges coming from this technical evolution. One issue to be discussed is the implementation of IEC 61850 within a redundancy context, both at the equipment and communications levels, and its effect on the overall response time of a system, including the potential impact and issues pertaining to control and protection in such a redundant environment.

The new Paradigm

Although configuration files are one of the important features of IEC 61850 for the ease of information transfer and reduction of engineering time, it has been found that extensive inter-operability tests are required to ensure that the information files from different vendors can be properly understood and used by the other equipment vendors. The IEC committee is also aware of this and additional efforts are being made to increase the IEC 61850-10 conformance test visibility and execution.

We also have noticed that even when the configuration file can be easily read and interpreted; its integration within other vendor tools might be less easy and straightforward. This is especially true when the configuration, engineering and device interconnection paradigms are different between the vendors, for example fixed data sets and reports within the server versus dynamic data sets and reports creation by the clients.

Another shift with the IEC 61850 implementation is the replacement of hard wires with high priority network messages (GOOSE). This means that the communication links between devices must be highly reliable. For this reason, redundant communication is strongly recommended. As we will see, this requires special attention at the beginning of a project when creating the communication architecture, thus starting with the selection of the network components and continuing in the selection of the Ethernet interfaces within the IEDs themselves.

Early adopters of this approach are meeting new challenges on larger and more complex applications. In new implementations or upgrade projects using new IEC 61850 equipment and facilities, it can be challenging to properly integrate these large applications from different vendors, each with a different method of implementing IEC 61850 in their devices. One must ensure that the approach will allow for proper response times and scalability for future expansion(s), without ruling out the ability to handle even more advanced control possibilities that could be required in future "SmartGrid" applications.

Overview of a Large IEC 61850 Application

One typical project for discussion is the application of the IEC 61850 approach in a 220KV switchyard combined with a 33KV switchyard involving approximately 300 devices using IEC 61850. The site included fiber optic communication rings, full redundancy, hot standby data concentrators, protection relays interaction, and other metering devices.

Figures 1 and 2 present the high-level system architecture implemented for a major petroleum refinery project. In this case, it featured a 220KV substation with protection and control with tie-in/integration to the 33KV GIS.

The equipment for the 220KV area was subdivided into three redundant ring buses. The relays where selected with redundant fiber optic interfaces as to ensure easy configuration and implementation of the redundant fiber optic buses. Using a fiber optic interface eliminated the potential problems inherent to using copper Ethernet, especially with equipment spread-out over 10 local control bays that were up to 1 kilometer from the control center.

Within the 33KV switchyard there was no need for each relay to be on a fiber optic bus, since the distances were relatively short and hence the potential noise level was much lower. Instead, the communication architecture selected was a redundant fiber optic ring between the network switches, with a copper connection between the switches and the relays. Copper is used to optimize the quality / price ratio when dealing with a large number of IEDs that must be connected to the switches.

Because of the requirements in the use of the GOOSE messages, special attention must be given to the network switches that will be used, especially with regards to the use of redundant links and the desired link recovery times. Recovery times may have an impact on overall system performance especially during major events with a simultaneous failover between the redundant buses.

In this project, Rapid Spanning Tree Protocol (RSTP) had been planned. This created some of the limitations on the overall project, mostly related to the number of devices that could be tied to one network switch, in this case 27 IEDs per switch.

Redundancy Issues with IEC 61850

IEC 61850 is based on the inter-relay communication capabilities. Hence, within IEC 61850, redundancy of key communication components becomes of primary importance for the overall reliability of the system. This is especially true when dealing with protection issues.

In this project, redundant bidirectional fiber optic rings are used for each main ring, thus ensuring the needed reliability even in case of a cable breach.

Higher up in the architecture, Cooper Power Systems/Cybectec SMP Gateways with hot-standby capability are used to provide a continuous information flow to the redundant HMI/SCADA systems. The intelligent gateway's hot standby capability ensures no communication loss during failover.

Because of the amount of information available, the hot-standby intelligent gateways were divided into 6 sub-systems (refer to figures 1 and 2). Three are within the main 220KV substation and the three others are in the 33 KV substation.

Each pair of redundant gateways is connected to the relay network through their first network adapter and to the SCADA server network by a second network adapter. This ensures a clean separation between the 2 networks and reduces the load on both networks.

In previous projects, we gained experience with the redundant gateways However, being the first project using the IEC 61850 protocol with the redundant gateways, some minor integration issues where encountered; especially with redundancy communication between the gateways and the protection relays. These problems were detected at an early project stage and were corrected in a short time span.

The IEC 61850 DFR file retrieval feature is used by the gateways to push these files to the redundant SCADA system as soon as they are detected on the relays. This gives the operator instant access to the fault data without the need to go down to the relay or to create a separate remote connection. Again, for an optimal redundant support, all the devices need to work together to make sure that the total availability is maximal. In the case of DFR file retrieval, the data concentrators will try to push the file to the first available server. The servers will then synchronize their folders to duplicate the DFR files.

Network Switch Requirements

To ensure delivery of time critical messages, special care was taken in selecting the network switches. First of all, the network switches needed to meet the substation grade requirements. Second, they needed to support priority GOOSE messages used for interlocking. Finally, the switches needed to support the required redundant ring architecture.

RuggedCom switches, which passed the IEC 61850 conformance tests executed by KEMA Netherlands, where selected. During FAT tests, event burst testing was conducted, where 1000 binary points were toggled. With a network load of 95%, the switches did not encounter any problem with the exchange of GOOSE messages.

With the redundant ring configurations, there is an additional limitation of 27 relays per ring. This limitation is due to the fact that, for a stable ring configuration, Rapid Spanning Tree Protocol (RSTP) messages must not age too much. Excessively high delays within the ring will lead to unstable operation of the ring. The final limitation of 27 relays had no major influence on the main architecture; however these kinds of details needed to be considered when implementing the network architecture.

Protection Issues and GOOSE Messages

As this was one of our first major projects using IEC 61850; concerns about the overall communication performance led to the use of hardwired connections for the critical protection signals. GOOSE messaging is used for interlocking and distributed fault recording. The distributed fault recording means that once a protection relay detects a fault it will send GOOSE messages to the other relays and all the relays will start recording the fault. As the different relays are capturing/recording different voltages and currents, this distributed recording will provide the complete fault scenario allowing us a much better understanding/analysis of the overall interactions when faults occur.

The FAT tests proved the initial concern about the GOOSE messages response times were not justified. Based on the results of this application, we will likely remove the hardwiring in future projects.

Multi Vendor Integration and Future Expansion

This project used equipment from multiple vendors. All the selected equipment supports the IEC 61850 standard in different ways. The project was executed in two different geographical areas so early integration testing was not easy. Siemens Singapore was able to ship several relays to Cooper Power Systems' facilities in Canada. This greatly simplified early integration testing. This also allowed quick resolving of some minor issues that where encountered at an early project stage.

More extensive and FAT testing was done at Siemens' Singapore facilities. As the integration issues where already identified and resolved, no new problems where encountered.

As for future expansions, the network and engineering architectures are designed to easily absorb additions, as the IEC 61850 standard promotes. It is hard to define the ultimate limits of the network for the number of interconnected relays. As for the engineering effort, future expansions will just be a repeating exercise.

Future Developments for IEC 61850

There is still work to do to make IEC 61850 in future projects more accessible and attractive. The standard is evolving towards an official second version (2008) which will resolve some of the integration issues encountered by the early adopters of the standard.

Currently the main focus is to increase the acceptance of the standard, which will happen with better integration tools. In general, the tools need to be improved to capture all the benefits of the easy relay integration. This change is required not only for the data exchanges, but also for DFR files and other files now available in the relays.

Another issue for new adopters is the naming convention. Even though the naming standardization is one of the key advantages of the IEC 61850 standard it, is not easily read by everybody. The new generation of the integration tools should better hide this complexity. This will lower the hurdle utilities are encountering when using the IEC 61850 standard.

At the moment the IEC committee is working on extending the standard to improve the definition of inter-substation communication, as well as substation-remote control communication.

Conclusions

Although there are varying opinions on the use of IEC 61850, it is now here to stay and the benefits outweigh some of the drawbacks of this type of technology.

All of us must work together to increase the effective interoperability characteristics of this standard. Without this concerned effort, the overall use of different vendors within a

project may become a burden for the users who require such interoperability from the IEDs on their project, undermining the IEC committee's efforts for easy relay integration. Integration software must be made increasingly device independent and should be as user friendly as possible. At the same time, vendor configuration software must be able to easily use the created SCL configuration files.

References

Klaus-Peter Brand, Peter Rietmann, Tetsuji Maeda, Wolfgang Wimmer, "Requirements of interoperable distributed functions and architectures in IEC 61850-based SA Systems" CIGRE 2006

Rudolf Baumann, Klaus-Peter Brand, "The standard IEC 61850 – A simple but comprehensive solution for today's power system requirements" ABB Switzerland Ltd.

Siprotec4 Ethernet Module EN100 for IEC 61850 with electrical / optical 100 MBit Interface regarding RSTP

Gerrit Dogger, "IEC 61850 Overview and Application for SCADA Systems," South Eastern Apparatus School 2007

220KV System

GPS

HMI 1-220

HMI 2-220

Overhead projector

DMP

COLOR

Control Room

To Field Devices

SMP 1A-220
SMP 2A-220
SMP 1C-220
SMP 2C-220
SMP 1B-220
SMP 2B-220

MES 1-220
MES 2-220
MES 1-1-220
MES 1-2-220
MES 2-1-220
MES 2-2-220
MES 3-1-220
MES 3-2-220

14 x Modbus Meters (RS485)

To 33KV MRS1

Relay 1
Relay 2
Relay 3
Relay 4
Relay 48

SIPROTEC 4

NOTE:
PROTOCOL

1. INTER-CONN
2. IEC61850 RJ45
3. IEC61850 F.O (Multi-Mode)
4. PEER-TO-PEER RJ45
5. PEER-TO-PEER F.O (Multi-Mode)

SIEMENS

Major Petroleum Project in Asia

EMS

	DRN	Jerry	PROJECT:		TITLE: 220KV SYSTEM ARCHITECTURE
	CHK	KEE C Y			
	APP	TONG C B			TYPE NO: -	DWG NO: -
14-2-07	DATE	14FEB2007	JOB NO: -	PO NO: -	TAG NO: -	SCALE: NTS	SHT NO: 1+
REV	DATE	DESCRIPTION				
0					SIZE : A3

NOTE:

PROTOCOL

1. INTER-CONN RJ45
2. INTER-CONN F O (Multi-mode)
3. IEC61850 RJ45
4. IEC61850 F.O (Multi-mode)
5. PEER-TO-PEER LINK RJ45
6. PEER-TO-PEER LINK F.O (Multi-mode)

Overhead projector

COLOR

DMP

HMI 2 Workstation (new)

HMI 1 Workstation (new)

SCADA SERVER 2 (Formerly HMI 2-220)

SCADA SERVER 1 (Formerly HMI 1-220)

TERMINAL LAN

INDUSTRIAL ETHERNET/ IEC LAN

Workstation (Additional)

MES 1-220

MES 2-220

MES 1-1-33

MES 1-1-33

MES 2-33

SMP 1A-33

SMP 2A-33

SMP 1C-33

SMP 2C-33

MES 1-2-33

MES 3-1-33

MES 3-2-33

SMP 1B-33

SMP 2B-33

MES 2-1-33

MES 2-2-33

R.C s/w < 10

R.C s/w < 10

R.C s/w < 5

R.C s/w < 5

RC

SIPROTEC

By others

40 IEDs

20 IEDs

220KV

33KV MRS 1

33KV MRS 2

220 KV System Architecture (Refer to sheet 1 for details)

220KV

SIEMENS

Major Petroleum Project in Asia

EMS

		PROJECT:		TITLE:	220KV / 33KV GIS INTEGRATION SYSTEM ARCHITECTURE
	DRN	Jerry			
	CHK	KEE C Y		TYPE NO: -	DWG NO: -
13-2-07	APP	TONG C B	JOB NO: -	TAG NO: -	
DATE	DATE	13-02-07	PO NO: -	SCALE: NTS	SHT NO: 2+
0					
REV		DESCRIPTION			SIZE : A3