USING IEC 61850 FOR TELEPROTECTION

Miquel SERRA
DIMAT, S.A. – Spain
msa@dimat.es

Fernando CASTRO
DIMAT, S.A. - Spain
f.castro@dimat.com

ABSTRACT

The new standard IEC 61850 was originally intended for substation automation, and the communications procedures are based upon a fiber optics LAN. However the IEC has recently approved a New Work Item Proposal to generalise the use of IEC 61850 for communications outside the substation. This paper introduces the differences between LAN communications and WAN communications, the degradations usually associated with WAN channels and how they affect the performance of a teleprotection system. Finally, an IEC 61850-compliant teleprotection system is proposed.

INTRODUCTION

The IEC 61850 Standard defines a new structure for substation automation and communications inside the substation. This new standard results in some advantages as compared to the traditional, hard-wired substation, such as simplified wiring, where copper is replaced with a fiber optics LAN, or a greater degree or interoperability among devices from different manufacturers. However, when communications outside the substation are considered some specific problems have to be taken into account. More specifically, all types of WAN, including fiber optics networks, will suffer from degradations for which IEC 61850 is not designed. So, if IEC 61850 is directly used for transmitting teleprotection information to the remote substation, the performance, measured in terms of dependability and security, will be degraded. This paper exposes such a situation in detail and proposes an IEC 61850-compliant teleprotection system that simultaneously meets IEC 61850 and IEC 60834-1 (performance of teleprotection systems).

1. THE IEC 61850 ARCHITECTURE

IEC 61850 was originally intended to overcome practical problems in substation automation, such as complex wiring or reduced interoperability. To achieve this goal two basic aspects are introduced;

- A communications system among the different devices, based upon a fiber optics LAN, usually 100Fx. Optical switches are used to implement this LAN (fig.1)
- A normalised model for the data contained within each device, defining what functions each device should implement and what information the different devices should exchange among them

It is common practice to divide the substation LAN into two different levels;

- The so-called "Process Bus", that covers the communication within a given bay
- The so-called "Substation Bus", that covers the communications among bays

1.1 IEC 61850 messages

The IEC 61850 Standard defines three different types of Ethernet messages;

- *Sampled Values*: usually present in the process bus, this type of message is intended to deliver samples of the 50 Hz signal from the measuring transformer to the protection relay
- *Logging/Reporting*: usually present both in the process and substation busses, this message is intended to configure and supervise the different devices in the substation
- *GOOSE (General Object Oriented Substation Event)*: usually present in the substation bus, this is an urgent message that delivers protection information between the protection relay and the breakers, teleprotection devices, and so on.

1.2 Use of GOOSE messages for protection functions

The overall operation of the protection system in an IEC 61850 substation is the following (fig. 2);

- The measuring transformers take samples of the 50 Hz signal and deliver them using "Sampled Values" messages to the protection relay
- The protection relay analyses this information and makes decisions on whether to trip the line or not
- The protection relay encapsulates the decision in a GOOSE message and transmits this message to the breaker. The encapsulated information can be "*the line is OK, do not trip*" or "*there is a fault, trip the line*"
- This GOOSE message is repeated at given time intervals for redundancy purposes
- If an important event takes place, for instance a fault in the line, the sequence of GOOSE messages with the information "*the line is OK, do not trip*" is interrupted and replaced with a new sequence of GOOSE messages which convey the message "*there is a fault, trip the line*"
- This new GOOSE message is also repeated at given time intervals for redundancy purposes
- When the fault has been cleared the current sequence of GOOSE messages is interrupted and replaced with a third sequence of GOOSE conveying the information

"*the fault is cleared*"

1.3 The Logical Node concept

A Logical Node (LN) is, in fact, a function required by the user. It can be a protection function, control function, or others. It is usually implemented as a software routine within a CPU in the device. It has a normalised structure, with mandatory and optional software variables.

When the complexity of the function requires so, it is possible that the function be implemented using more than one LN. The different LNs might even be distributed among different physical devices.

Logical Nodes have a normalised name, consisting of 4 letters (PSCH, XCBR,...). The first letter is related to a generic group to which the LN belongs (P for Protection; T for transformer; W for Wind farms; X for breaker,...)

2. USE OF 61850 FOR COMMUNICATIONS BETWEEN SUBSTATIONS

The straightforward use of IEC 61850 for communications between substations has some practical difficulties;

- The exchange of information among the physical devices takes place not only at substation level but at network level as well. The definition of the architecture is thus generalised to cover all substations in a single SCD file (see [1]), which is an exponential increase in complexity
- The GOOSE messages that transport the protection information will no longer travel across an optical LAN; they will travel across a Wide Area Network (WAN), which implies certain types of degradations that do not exist in a fiber optics LAN and for which the GOOSE message is not prepared

The question to think about is, so, the following;

If a GOOSE message transports teleprotection information, can this GOOSE message travel directly outside the substation?

This question can be reformulated as follows;

Will a GOOSE message travelling between substations meet the requirements of IEC 60834-1 for teleprotection systems?

3. REQUIREMENTS OF IEC 60834-1 FOR TELEPROTECTION SYSTEMS

3.1 Typical degradations of WAN channels

All WAN channels are subject to degradations. Analogue channels (PLC, analogue radio,...) suffer from the following typical impairments;

- Background and impulsive noise
- Attenuation of the transmitted signal
- Interferences
- Frequency deviation between transmitter and receiver

Digital channels, on the other hand, suffer from...

- Random bit error rate
- Impulsive bit error rate
- Jitter (frequency modulation of the received clock)
- Propagation delay, which can be high if many multiplexers are used or if satellite links are present within the network

Even PDH and SDH systems are subject to channel degradations, such as losses of synchronism, false synchronism, synchronism slips,... that may take some time to detect and correct (up to 50 msec in SDH systems).

Tu sum up, there is no such thing as a perfect communications channel. All channels, it does not matter the type, are subject to degradations that may put the teleprotection information at risk. To prevent the risk of improper teleprotection operation the IEC 60834-1 defines some basic requirements that all teleprotection systems must meet.

3.2 Performance parameters of a teleprotection system

IEC 60834-1 (see [2]) defines the following basic performance parameters;

- Dependability: the ability to deliver a teleprotection information at the receive end in spite of the presence of channel degradations
- Security: the ability of the receiver to reject a false teleprotection information that has been simulated by the channel degradations

An additional parameter is the maximum transmission time: the teleprotection information has to be delivered at the remote end before a maximum transmission time. Dependability is usually measured in terms of *Probability of Missing Command (Pmc)* and Security is measured in terms of *Probability of Unwanted Command (Puc).*

3.3 Performance of a teleprotection system against channel degradations

IEC 60834-1 specifies how a teleprotection system should behave when posed with channel degradations. In a digital channel, for instance;

- Dependability should be Pmc = 1e-3 when BER = 1e-6 with a maximum transmission time of 10 msec, for all types of teleprotection applications
- Security should range from Puc = 1e-4 for blocking applications to 1e-8 for direct tripping applications, for the worst BER
- During losses of synchronism of the network multiplexers a loss of dependability is accepted but no unwanted commands should take place
- When the received signal is affected by jitter there is a jitter amplitude mask (as a function of frequency) below which no false commands should take place

IEC 60834-1 specifies the level of performance that should be achieved, but not what to do to achieve it! This is usually done by means of well-proven, proprietary frame structures.

4. THE PERFORMANCE OF THE GOOSE MESSAGE

Once analysed the typical degradations of a communications channel and how teleprotection systems cope with these degradations it is the right time to again think about the following question;

If a GOOSE message transports teleprotection information, can this GOOSE message travel directly outside the substation?

Will a GOOSE message travelling between substations meet the requirements of IEC 60834-1 for teleprotection systems?

This question can be reformulated in more specific terms;

- Since the GOOSE message is in fact an Ethernet message, protected by a CRC, will it meet the requirements of dependability and security as a function of the bit error rate?
- Will the repetition intervals of IEC 61850 meet the requirements of IEC 60834-1 about maximum operation time?
- The Ethernet message is generated by a DTE or a switch, both of them elements that do not introduce jitter or losses of synchronism. Will it be able to face the jitter introduced by the network elements?

To sum up, the GOOSE message was designed to travel within the substation, which is a mild communications environment. Extrapolating the GOOSE message to travel outside the substation is not straightforward, at least as far as teleprotection information is concerned. This is the reason why an IEC 61850-compliant teleprotection system should be used.

5. WHAT IS AN IEC 61850-COMPLIANT TELEPROTECTION SYSTEM ?

An IEC 61850-compliant teleprotection system is, in fact, a communications gateway specifically designed to transmit GOOSE messages to the remote end. Its principle of operation is as follows (fig. 3);

- The teleprotection is just another physical device (IED) connected to the fiber optics LAN
- When the relay, thanks to the Sampled Values messages, decides to trip the line, it sends a GOOSE message to the teleprotection
- The teleprotection receives this message and translates it into a proprietary frame structure or analogue signal that will meet the IEC 60834-1 requirements
- This proprietary frame structure or analogue signal will travel through the WAN and reach the teleprotection receiver, meeting the requirements of dependability and security in spite of the channel degradations
- When the teleprotection at the remote substation detects the incoming frame structure or analogue signal generates a GOOSE message that is equivalent to the GOOSE message at the local substation
- This GOOSE message will be delivered to the relay at the remote substation, which will operate accordingly

The most appropriate logical nodes for the design of an IEC 61850-compliant teleprotection system are PSCH (Protection Scheme), GGIO (Generic Input/Output), the mandatory LLN0 (Device Status) and LPHD (Physical Device Information), plus additional LNs to model the communications channel itself (still to be approved by the IEC).

6. CONCLUSION

The IEC 61850 Standard, originally intended for substation automation and communications within the substation, cannot be extrapolated for communications outside the substation as it is. To do so the corresponding gateways have to be defined. In the case of teleprotection functions this leads to the necessity of IEC 61850-compliant teleprotection devices which are able to exchange GOOSE messages with the protection relays and simultaneously exchange proprietary frame structures between both ends of the line.

REFERENCES

[1] IEC 61850-6 Standard: "Configuration Description Language for communication in electrical substations related to IEDs"

[2] IEC 60834-1 Standard: "Teleprotection Equipment of Power Systems; Performance and Testing"

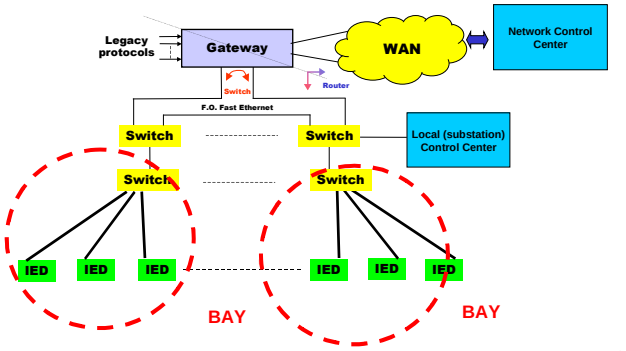

Figure 1: IEC 61850 substation architecture

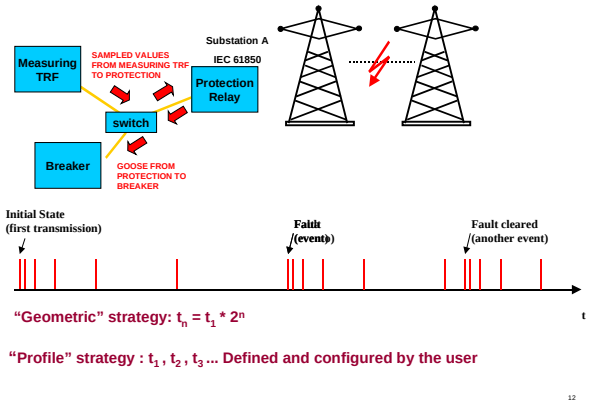

Figure 2: Use of GOOSE messages for protection

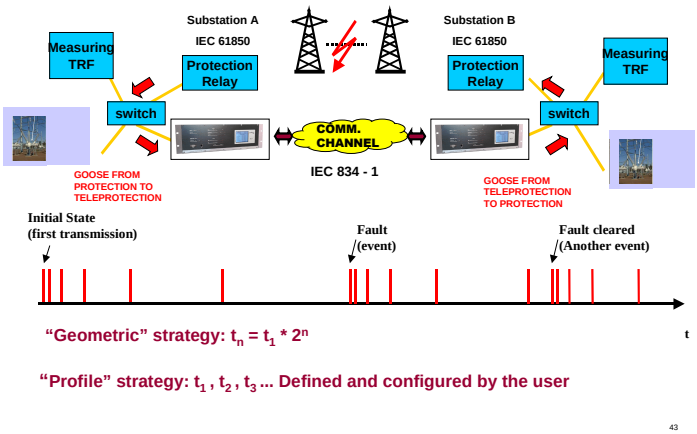

Figure 3: Concept of IEC 61850-Compliant Teleprotection