BENEFITS OF CONVERTING CONVENTIONAL INSTRUMENT TRANSFORMER DATA INTO SMART GRID CAPABLE PROCESS DATA UTILIZING IEC 61850 MERGING UNIT

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ABSTRACT

An important aspect of "Smart Grid" is the acquisition and distribution of process information. This paper describes the advantages of IEC 61850-9-2 Merging Units feeding a digital process bus with sampled values. The collected data is transmitted via optical fibers to an Ethernet based network, avoiding any electrical transients from primary substation equipment. These Stand Alone Merging Units (SAMUs) can be implemented in parallel without impacting existing protection, metering and supervision equipment, thus allowing a smooth transition from traditional operation to digital Smart Grid data processing capabilities. The structure of the SAMUs together with a discussion of the advantages and present limitations are presented.

INTRODUCTION

The standard IEC 61850 defined a digital communication protocol between secondary control and protection devices in substations. The latest addition to this standard, IEC61850-9-2, specifies the process bus, defining the communication protocol of sampled values from instrument transformers. This new development opens up new possibilities for information networking within substations or even through wide area measurements to Network Control Centers. This method of digital communication has the advantage of distributing enormous quantities of information, compared to the parallel wiring found in today's substations. All time crucial sensor data for multiple protection units can now be transmitted digitally.

MERGING UNIT STRUCTURE

The standard IEC61850-9-2 defines an open framework for the design of merging units. The usergroup organization UCA defined the subset standard IEC61850-9-2LE[1], which is the guideline for all present merging units. Figure 1 shows a Stand Alone Merging Unit (SAMU) designed to sample conventional instrument transformer signals and transmit them via a process bus. The following paragraphs describe the functional blocks of such a merging unit.

Figure 1: Stand Alone IEC61850-9-2 Merging Unit

Overview

Figure 2 describes the structure of a merging unit. It consists of 3 major functional blocks. The first block senses the analog input signals from the current and voltage instrument transformers. The signals are scaled, filtered and fed to analog-to-digital converters. Very essential to a useful operation of the merging units is the time synchronization of the data acquisition. The digital data are merged together in a digital processor and converted to an Ethernet protocol. This Ethernet protocol is transmitted via optical fibers to the substation bus.

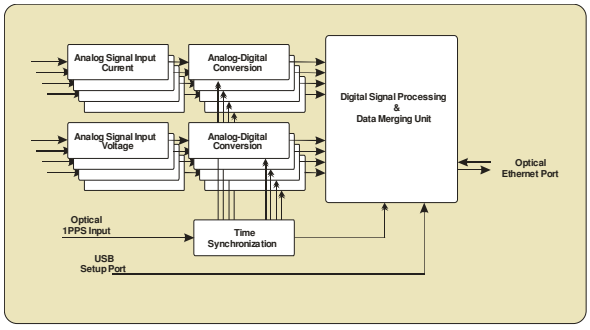

Figure 2: Stand Alone Merging Units Structure

Analog Signal Input

Similar to conventional solid-state protective relays and metering devices, the analog input signals have to be scaled and filtered. The conditioned signals are then fed to an analog-to-digital converter. The present IEC61850-9-2 standard does not define in any great detail the implementation of signal filtering and the analog-to-digital conversion procedure. Depending on if the main

task of the individual merging unit is to convert signals from protective or metering current transformers (CTs), the details of filtering and sampling may have to be implemented differently. IEC 61850-9-2LE defines two different sampling rates. The basic sampling configuration is 80 samples/cycle, which is sufficient for most modern solid state relays. IEC61850-9-2 defines a higher sampling rate, 256 samples/cycle, in addition to multi-sample Ethernet packages. However, this application is limited due to the higher load of the Ethernet bus. The sampling rate, together with the Ethernet switch transmission rate (100baseFX), determines the maximum number of merging units that can be used in a single bus configuration.

Time Synchronization

Precision time synchronization and time stamping of individual samples are required in order to utilize the Ethernet protocol and Ethernet switches as communications media. Utilizing global positioning systems and IREQ-B signals the data acquisition can be synchronized with multiple merging units, not only in a local substation but also globally over a wide area. These clocks generate a single pulse every second (1PPS) with high accuracy. The 1PPS pulse is used internally to calibrate the processor clock and to time stamp each sampled value. Merging units utilizing the IEEE 1588 standard are in the development stage. They use a synchronization signal distributed by an Ethernet switch.

Digital Signal Processing

All digitized signals are processed and merged in a central processor unit. This processor unit generates the final Ethernet protocol and transmits a package containing a single sample of all connected instrument transformer signals as defined in IEC61850-9-2LE.
This processor unit can be configured externally to customize the identification of the data. In order to provide an extraordinary high level of cyber safety, the merging unit can be set to only transmit data but does not allow the use of the Ethernet port to receive data for configuration purposes. A USB input port together with a PC/laptop can be used to customize the units.

INSTRUMENT TRANSFORMERS

Most of today's instrument transformers are using magnetic coupling principles and provide an analog current or voltage output. These signals are fed via copper wire to intelligent electronic devices (IEDs) such as protective relays, meters, recorders etc. Most of these IEDs are based on solid state technology, internally converting the analog signal to a digital signal for signal processing purposes. The process bus moves this analog to digital conversion from the IEDs to the instrument transformers.
Lately, non-conventional instrument transformers have found a greater acceptance due to enhanced performance characteristics and safety concerns. IEC61850-9-2 allows the seamless integration of both non-conventional and conventional instrument transformers.

Conventional Instrument Transformers

The accuracy of conventional instrument transformers is defined within a predefined load characteristic, which limits the number of IEDs connected to it. This is specifically the case for current transformers (CTs), where multiple cores have to be used to circumnavigate the problem. This severely limits the amount of applications that can be served by a single installed sensor. However, this problem is elegantly solved by using a Stand Alone Merging Unit (SAMU), allowing the conversion of analog data to digital data at the instrument transformer level with a burden less than 1VA to the sensor. This low burden doesn't impact the accuracy and allows the merging unit to be installed in parallel with existing control and protection equipment. Thus, a standalone merging unit is an ideal tool for retrofitting or migration to digital substation automation.
The implementation of merging units in existing substations can be done without impacting the operation or modification of the installed instrument transformers. SAMUs are designed to either be installed in the control room or in the substation close to the instrument transformers. Fiber-optic cables from the merging units to the control room provide safe and secure signal transmission.

Non - Conventional Instrument Transformers

Non-conventional instrument transformers have been limited by the lack of standard 1/5 A or 110V analog signals normally provided by conventional sensors. This problem is solved by the introduction of the IEC61850-9-2 process bus. Non-conventional instrument transformers such as shunts or Rogowski coils combined with optical data links, as well as pure optical sensors, can now be used in parallel with existing conventional instrument transformers. This gives the electric utilities access to a greater variety of sensors with different performance characteristics, without significant re-design of existing substations.

APPLICATIONS

The introduction of merging units and the digital process bus creates new ways to operate a power grid. The availability of time synchronized sensor data not only allows the operation of local intelligent electronic devices (IEDs) but also enables stability analysis over a wider area.

Protection and Metering

The most common applications utilizing instrument

transformer data are protective relays and revenue metering devices. As mentioned previously, the process bus moves the analog-to-digital conversion process from these devices and puts it closer to the instrument transformers. This makes digital data with identical dynamic characteristics available to a number of IEDs, allowing a cross performance check between IEDs. It also eliminates the wiring of primary signals to different IEDs, saving costs and eliminating the risk of erroneously wired signals. Most modern IEDs already use the IEC61850 standard to transmit events between themselves and the station bus, utilizing the so called GOOSE message (Generic Object Oriented Substation Event). The IEC61850 standard will open up a new, more flexible generation of protective relays and revenue meters heavily based on software.

Fault Recording and Monitoring Devices

The availability of sampled values in an Ethernet format allows the use of PCs for non time-critical recording and monitoring applications. Time synchronization allows the analysis of faults or blackouts over a wide area by collecting and comparing events on a sampled value level. This allows system planners to gain a deeper understanding of the dynamics of the power grid by analyzing and comparing data from faults or outages. The simple and straightforward installation of Stand Alone Merging Units (SAMU) and development of the digital process bus together with a PC based fault recording hardware provides the ideal test bed for utilities, allowing them to gain experience with this new technology. As mentioned before, adding IEDs is very easy and can be done in parallel with existing IEDs

Wide Area Measurement

BPA[2] have investigated the concept of wide area measurements to gain real time dynamic stability information of the power grid. This stability information will gain significant importance with the development of a Smart Grid and its flexible distributed loads and renewable power generation. The Stand Alone Merging Units (SAMU) provide time stamped sampled values which can be easily accessed through the process bus. Time sliced packages can be transmitted via Internet- or a local network to a central computer, where data can be analyzed together with packages from other areas. This analysis would give operators a tool to further enhance the power grid toward a smart grid philosophy.

IED testing and verification

A very important part of substation maintenance is the testing and verification of protective relays. Hitherto, currents and voltages had to be injected into relays to verify their functionality. This is a very tedious process, since the relay has to be disconnected from the instrument transformers and has to be injected with currents and voltages generated by an external source. Testing of relays and other IEDs connected to a process bus is greatly simplified, since the relay can be tested in place by setting it into test mode and injecting test signals into the process bus. The test signals are generated by a computer, transmitting them via the Ethernet, eliminating the need for any tampering with the wires carrying analog signals to the relay.

FUTURE DEVELOPMENTS

The IEC61850-9-2LE was introduced as a standard for sampled values feeding a process bus in 2004. The experiences during installations such as presented at CIGRE 2010[3] gave material for further improvements of the merging unit designs. Some of these ideas are discussed in the following paragraphs.

Time Synchronization

Present merging units utilize an external supplied optical 1PPS to synchronize the internal clock. As described previously, this requires an additional optical link going from a master clock to the individual Stand Alone Merging Units (SAMU). Another approach is to provide internal GPS clocks, if the merging units are placed in the field. The latest developments in Ethernet switches are leading towards the implementation of IEEE 1588. This standard provides the required timing information over the Ethernet, therefore eliminating a separate fiber and master clock connection.

Redundancy

Redundancy concepts are major subjects for operating substations. Multiple concepts are discussed based on the utility policy and requirements. One such concept is embedded in the Ethernet switches. This system calls for a ring configuration, where all Ethernet communication is transmitted into both directions of the ring. If one side of the ring fails, the information is still available through the other side. The switches are able to instantly switch over without losing a single Ethernet package. A downside of this concept is the reduction of usable bandwidth through the ring configuration.

Signal dynamics

As mentioned previously, the concept of Stand Alone Merging Units (SAMU) is to provide sampled values to a process bus. So far, this task was usually performed inside the IEDs. The manufacturer of the IEDs had the freedom to design the analog receiver and filter according to his own functional algorithm. The interoperability capabilities of SAMUs require that the dynamic characteristics of different merging units are comparable and do not influence the functionality of the IEDs. This is an area where several working groups are meeting to generate a common understanding of the requirements.

Ethernet media

Ethernet switches are key elements in the process bus. They have the task to govern a conflict free distribution of the sampled values. So far, 100baseFX switches have been utilized to connect merging units to the process bus. This creates a limitation to the number merging units that can be connected to a single bus without overloading or creating unreliable transmission of real time sampled values. Developments toward the gigabit Ethernet as well as timing capabilities defined by IEEE 1588 will significantly increase the performance of the process bus.

SUMMARY

The process bus defined in IEC61850-9-2 is becoming an increasingly important factor in digital substation designs. The availability of instrument transformer data as sampled values is a significant part of the Smart Grid philosophy. It allows the introduction of non-conventional instrument transformers into existing substations, while at the same time modernizing existing sensors with Stand Alone Merging Units (SAMU). The process bus opens up connectivity to new IEDs, which in the future very well may be PC based. At the same time, installation, testing and maintenance of IEDs is significantly simplified. The standardization of the process bus as an open protocol gives the utilities the freedom to choose equipment from different suppliers.
The implementation of process bus in substations can be compared with the technology change from mechanical relays to solid state relays. It is a major paradigm shift, allowing much greater flexibility and major cost savings.

REFERENCES

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