MULTI-VENDOR DISTRIBUTED RECORDERS USING STANDARDIZED IEC 61850 GOOSE COMMUNICATION

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ABSTRACT
Users see value in using distributed systems compared to centralized systems for recorder applications. In these applications, the signals of interest are connected to devices without concern as to their use in recorder data records. Triggering of the recordings can be initiated from any of the devices to cause all other appropriate recorders in the system to locally initiate recording.

Prior to the development of advanced protocols such as IEC 61850 GOOSE, multi-vendor distributed fault recorders required many point-to-point copper connections causing the cost of these system to be prohibitively large. Using this new technology, each distributed recorder requires only a single connection to the Ethernet LAN. Because the IEC GOOSE protocol is transported on Layer 2, it can be used regardless of the other protocols used in the system.

As an example, consider a distributed recorder in distribution substation which consists of a single transformer differential protection relay and multiple feeder measurement units. The system uses the DNP3-TCP (IEEE 1815) protocol for communications. Each device measures only signals of local interest.

Because each device is already connected to the network, IEC 61850 GOOSE communications are possible with no changes to the communication system. Upon the detection of an interesting event from any of the feeder measurement or the transformer protection devices, a GOOSE message is sent to all devices commanding them to begin recording. Analysis of the resulting collection of records can then be used to determine quantities such as voltage sag/swells on unaffected feeders cause by a fault on another feeder.

Distributed recorders have many advantages over centralized recorders. One is the ease of system expansion. As new capabilities are added to the electrical system (for example a new feeder), there is no additional wiring needed to incorporate the new measurements within the distributed fault recorder; resulting in a substantial reduction in installation costs. A second advantage is the ability to manage the recording system from any point in the network; for example to manually trigger a recording from the comfort of your office.

KEYWORDS
Distributed recorder, IEC 61850, Interoperability, Process Bus, Merging Unit

INTRODUCTION

The basic role of a fault recorder is to collect information from multiple sources (primary equipment) and produce pre- and post-fault data for consumption by a centralized consumer. Many architectures of a fault recorder are possible. This paper presents the concept of a distributed fault recorder.

The Distributed Fault Recorder is characterized by having multiple independent recorders each generating a subset of the fault record using information already present at the IED. This reduces duplication of resources (and wiring) when multiple sources exist.

The advantages and disadvantages of the distributed approach will be detailed in this paper.

TRADITIONAL CENTRALIZED FAULT RECORDERS

A traditional fault recorder connects the secondary measurement sources of each measured value to a centralized "box" containing the entire fault recorder system. This unit contains all of the signal conditioning, digital conversion, and recording functions in addition to the triggering functions.

This system requires that the secondary signals be "brought" to the physical location of the "unit" using a double-wiring system as shown in Figure 1.

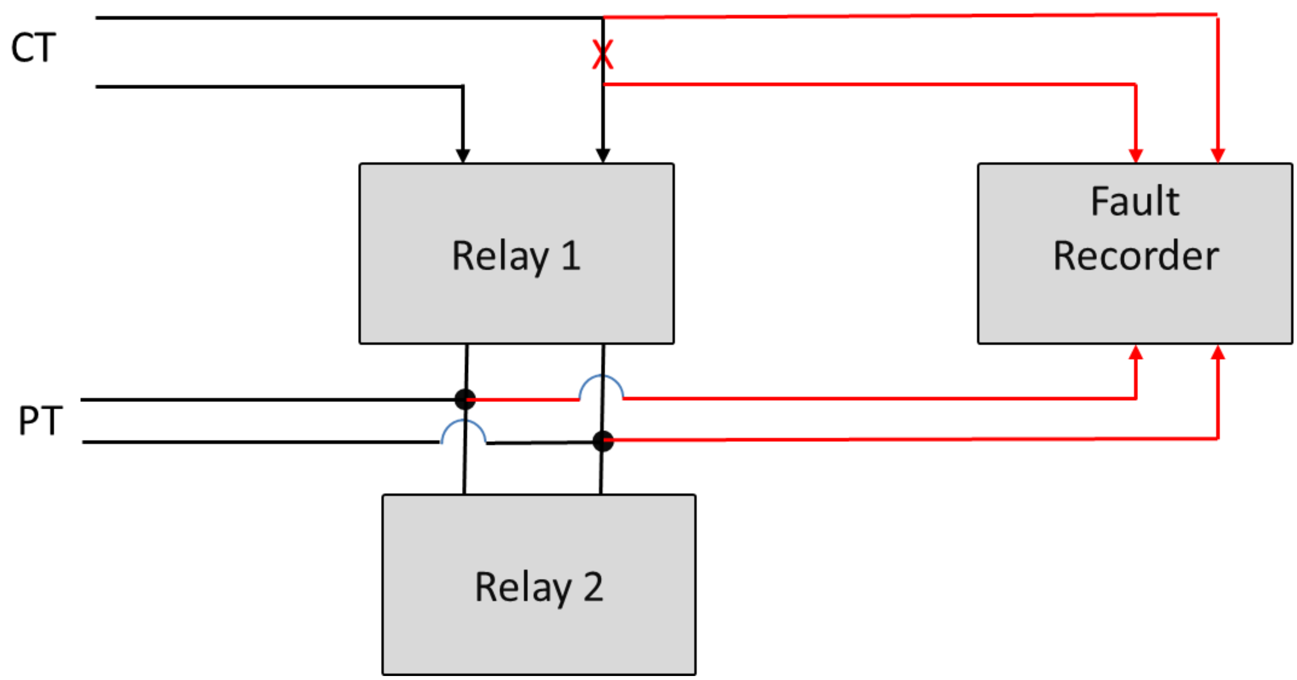

Figure 1 - Centralized Recorder "double-wiring"

DISTRIBUTED FAULT RECORDING CONCEPT

A distributed recorder is very different from a centralized fault recorder. The basic concept is to perform the recording where the signals are already present:

- Each individual recorder processes only part of the full data set
- Local logic in the recorder is used to initiate both local and remote triggering
- Existing IED protocols are overlaid with IEC 61850 GOOSE
- Upon recording completion, central resource is signaled to begin recording collection

There are a number of advantages when using distributed recorders:

- No "double-wiring" is needed. Signals already exist at the recorders
- Triggering setup is simplified because each source has fewer signals
- Simplified maintenance when signal levels change; only 1 device needs updates

IEC 61850 GOOSE INTRODUCTION

The IEC GOOSE concept is actually very simple to understand. But first, we must be clear on exactly HOW IEC 61850 performs communication.

IEC 61850 has two categories of service:

- request/respond (Client/Server) using MMS
- publish/subscribe (Peer-to-peer) using Ethernet Layer 2 services (no MMS)

The first category is the "normal" mode of communicating between clients and servers. In this mode, an "association" (connection) is first established between two endpoints and then communication takes place using the (rather complex) MMS protocol.

The second category is used for GOOSE and Sampled-Values. In this mode, the sender places simple messages directly upon the Ethernet layer without using MMS. These messages use the multicast mechanism of Layer 2 (LAN layer) to perform the communication. The "stack" required for GOOSE-only communication is far smaller than a client/server (MMS) stack and is simple (simpler) to implement than a full IEC 61850 implementation.

The steps required to configure a GOOSE publisher are fairly simple

- Create a list of measurement (and status point) which will be sent (a "Dataset")
- Configure the contents of the "GOOSE Control Block" (GCB) to use that Dataset
- Configure communication parameters (multicast MAC address, VLAN ID, etc)

The publishing device will now monitor the contents of the Dataset objects and transmit the entire contents of the dataset whenever any individual data point changes. That's all there is to GOOSE publishing.

On the subscribe side, you describe the data names from the dataset which are of interest and the destination for that data. During the subscriber configuration process, the subscriber "finds" the appropriate message and creates internal alerts when the published GOOSEs arrive.

All of this is normally set up using the standardized System Configuration Language (SCL) which is based upon XML. Standardized tooling exists which make this setup an easy process.

At this point, you may be wondering how GOOSE fits into the distributed recorder concept. The answer is that each recording device in the system both sends and receives multiple GOOSE messages. The local triggers, after optional conditioning with logic), are the source data for the dataset. Similarly, the received GOOSE messages are decomposed into individual points for use in cross-triggering (and trigger qualification) of the recording in the device. In this way, a single Ethernet cable carries all trigger-out and trigger-in and trigger qualification messages as well as “recording completed” messages. All of this is built into the basic IEC 61850 GOOSE.

IEC 61850 REPORTING INTRODUCTION

IEC 61850 uses “unbuffered reports” is the most widely used mechanism to deliver information to a device such as a central resource (“Client”) from a device such as a data recorder (Server). This is the normal background Client/Server communication in a IEC 61850 system.

Reports are very similar to GOOSE messages: messages are sent when needed and the data to be sent is named in the dataset which is named in the Control Block. However it is different in three respects:

- Messages are sent at a lower priority. One second delivery times are typical
- Messages are sent ONLY to the specific client setting up the communication
- Only changed data is sent; reducing the load on the system

There are many more details of the unbuffered reporting IEC 61850 service but it is sufficient to know that a server which has a completed recording can easily notify the central resource of that fact. DNP3 has similar mechanisms of events and unsolicited response which accomplish the same task.

CROSS-TRIGGERING

A major part of the distributed recorder is the cross-triggering. The concept is simple to grasp: each recorder “listens” for signals from all other recorders and uses those signals to initiate local recording. The signaling method must use a many-to-many connection scheme to achieve the cross-triggering. Hard-wiring could be used, which would result in N-squared wire counts. An alternative would be to use the IEC 61850 GOOSE scheme with its inherent one-to-many connectivity.

For maximum flexibility, each device could send signals corresponding to each possible trigger. However, this leads to complex configurations. A simpler scheme would be for the source to send a single signal “all recorders start”. Each recorder would listen for that single signal and initiate recording upon reception. The is shown in Figure 2

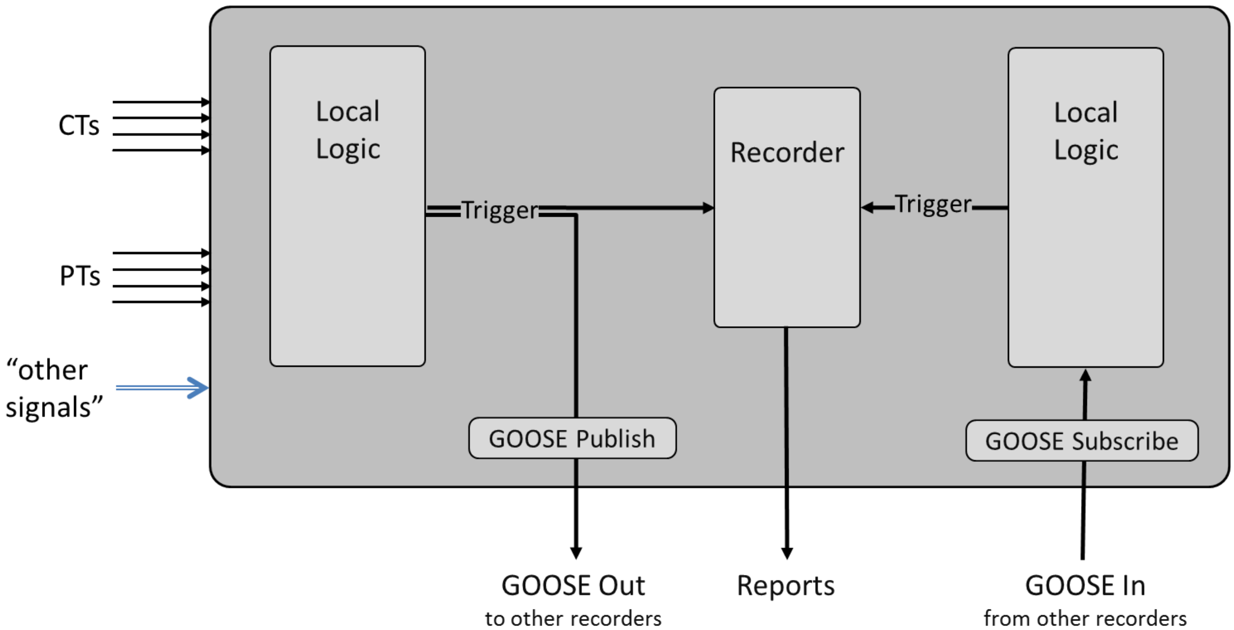

Figure 2- GOOSE single input/single output

Note that the local triggering need not be the same source as the global triggering; but it simplifies the configuration if both are identical.

The left box marked “Local Logic” makes the decision as to whether the present (local) conditions warrant recording initiation. The right box marked Local Logic decides whether the current GOOSE dataset contents indicates that a recording should begin. The degenerate case is where a single object within the GOOSE indicates “start all recorders”. However, much more complex triggering schemes could be used.

As an example of a more complex cross-triggering scheme, we could use the position of the busbar sectionalizer to publish two independent signals in the GOOSE: one for busbar open and one for closed. Recorders on the “far-size” of the sectionalizer would not trigger if the source recorder indicated that the busbar sectionalizer was open.

Because the GOOSE is communicated throughout the LAN, every recorder and subscribe to every GOOSE with near instantaneous (low milliseconds) reaction time.

DATA COLLECTION

Upon completion of the recording, each recorder signals to a central device that it is ready for data collection. This signaling can take place over any protocol such as DNP or IEC 61850. If IEC 61850 is used, the signal will be packaged within an IEC 61850 report. Details of the IEC 61850 reporting mechanism are outside the scope of this paper bus it is sufficient to know that the report includes of the contents of another dataset; which would have a dataset member indicating recording complete.

Upon receipt of the signal from the recorders, the centralized device will collect the recording. The timing of the data collection is not important because each recorder has already stored the data. A simple way to coordinate the collection would be to wait until the event is complete, which could take many minutes.

When the centralized device has retrieved all of the relevant data, it would combine the individual recordings into a single recording for further analysis.

EXPANSION CAPABILITIES

Two types of expansions are envisioned for a distributed recorder: more complex triggers and more data sources.

After an automation system has been operational for a period of time, it sometimes becomes apparent that more complex triggers or even more data from existing sources is desirable. Distributed recorders make this easy because each individual recorder can be reconfigured without coordination with other signal sources from other recorders. The GOOSE mechanism can be used to transmit analog data such as transformer temperatures which may affect how other recorders treat the signals within the outgoing binary message contents of the remainder of the GOOSE message.

The external trigger logic (connected to the “GOOSE In” can also be altered independently of the source messaging. For example, the recording trigger could be delayed based upon the contents of special signals from specific devices.

Another source of expansion is the addition of new primary equipment. In this case, secondary equipment will usually be installed to monitor and control the new primary equipment. This new secondary equipment will most likely also contain recording capability. These new devices are simply configured to send/receive GOOSE messages in the same manner as all of the existing devices. However, there is the added complexity that existing devices must subscribe to the GOOSE from the added device. Depending upon the complexity of the logic, this could be as simple as adding another signal “Or’ed” together to form the composite internal Trigger Recording signal. In any case, the existing recorders need no additional wiring because all signals are transported on the same Ethernet connection.

ALTERNATIVE SIGNAL SOURCES

Figure 2 shows “other signals”. These signals could take the form of GOOSE inputs carrying both analog and digital signals. GOOSE provides an important source of signals without requiring additional wiring.

Another signal source could be from Merging Units. A Merging Unit outputs high-speed time-synchronized samples of 3-phases of voltages and currents. Figure 3 shows the concept.

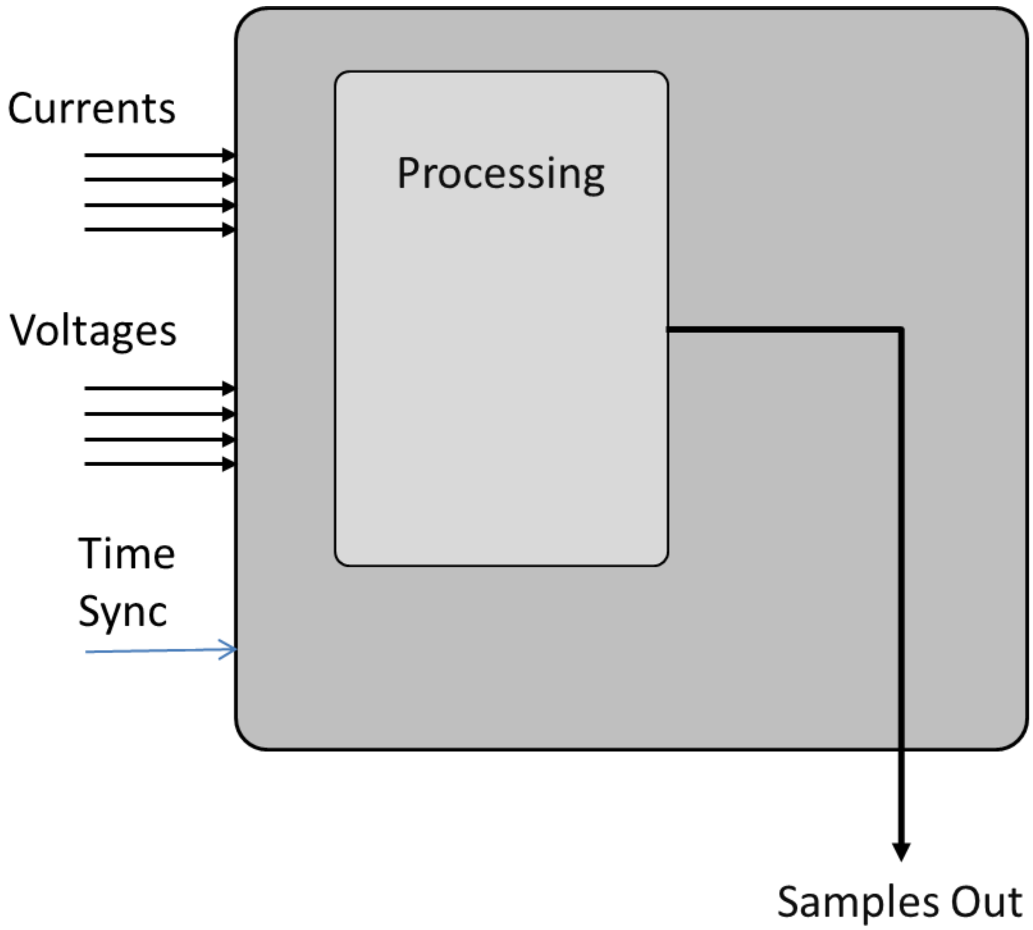

Figure 3 - Merging Unit Concept

The currents and voltages can be sourced from conventional magnetic transformers or from non-conventional transducers such as optical sensors, Rogowski coils, or Hall-effect sensors, etc. The important concept is that the output samples are independent of the source type.

The importance of Merging Units can be seen where a distributed recorder accepts voltages and currents from a Merging Unit and can use this for recording and/or triggering. This is an excellent way for a user to experiment with digitized samples while keeping the distributed recording functions separate from the type of primary equipment.

Figure 4 illustrates how a Merging Unit interfaces to conventional magnetic transformers.

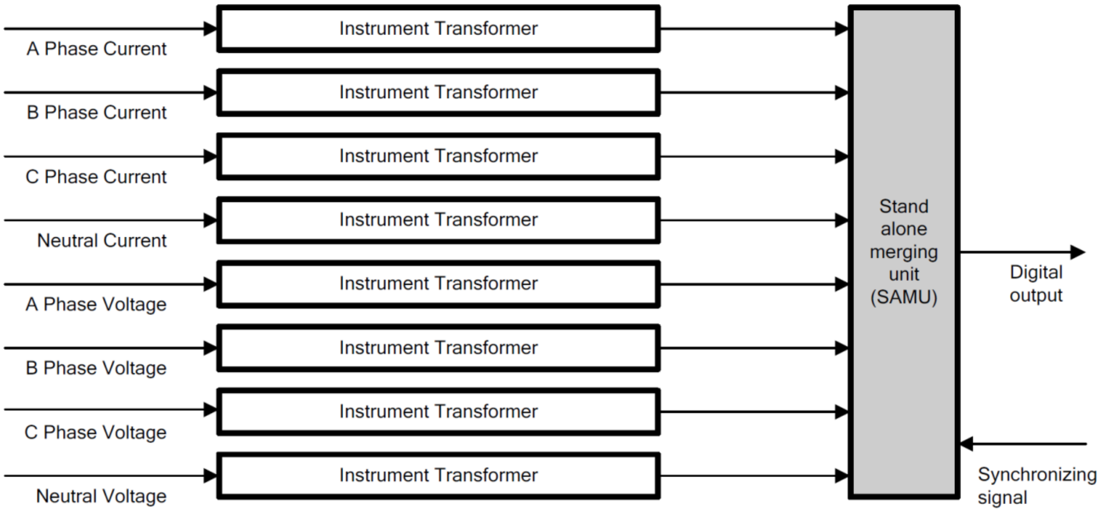

Figure 4- "Standalone" Merging Unit

Figure 5 illustrate how a Merging Unit interface to non-conventional sources.

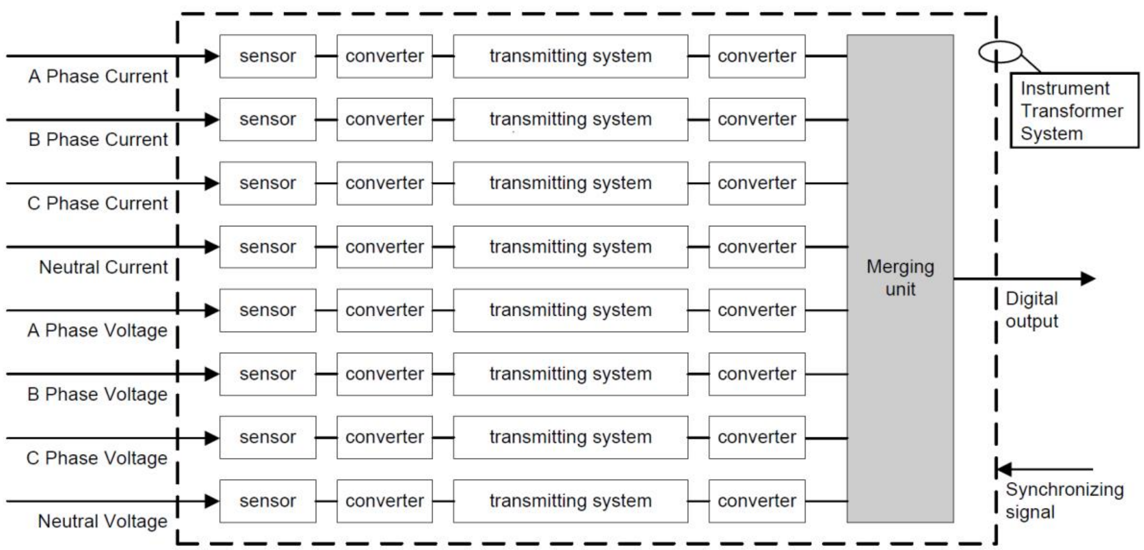

Figure 5 - Generalized Merging Unit

SUMMARY

This paper has examined the distributed fault recorder from a high-level point of view. The IEC 61850 GOOSE mechanism is used for the cross triggering but the "recording has been completed" signals can use any existing data protocol infrastructure already in use. Many details have been intentionally omitted in order to explain the basic concepts.

The advantages of distributed recording include:

- Removal of need to "double-wire" inputs

- Simplification of triggering schemes
- Expansion capability without additional wiring
- Ability to pilot the use of non-conventional transducers in a recording system

However, there are challenges to the distributed recorder:

- An Ethernet network must be established throughout to recording system
- Users must learn as least some of the basics of IEC 61850:
    - GOOSE publish
    - GOOSE subscribe
    - (maybe) IEC 61850 reporting mechanism

In the author's opinion, the advantages of using distributed recorders in place of centralized recorders far outweigh any disadvantage. The challenges listed above are actually concepts which will probably be incorporated somewhere in the users system in the very near future. In fact, building a distributed recorder may be a gentle introduction to IEC 61850 without the need to alter any other part of the system.

Bruce Muschlitz is a Research Engineer at NovaTech. He has more than 20 years experience in project leadership and utility communications protocols. Bruce is heavily involved with industry/national/international standards groups and chairs the UCAIug testing committee which is responsible for maintenance of the IEC 61850 device conformity testing program.

Bruce earned a BS in Computer Engineering and a MS in Electrical Engineering, from Lehigh University. He is a senior member of IEEE, as well as, a member of the DNP3 Technical Committee, UCA International Users Group Technical and Testing Committees. Bruce serves as a U.S. delegate of IEC TC 57 working groups 10 and 17. He is also a member of CIGRE,the IEEE Standards Association, and the Smart Grid Interoperability Panel.He also chairs the UCA International User Group Testing Subcommmittee.