Substation to substation (ss2ss) GOOSE exchange for critical relay operations

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SUMMARY

With the extensive use of IEC61850 and the GOOSE technology in today's power systems, it is possible to make network SMART. For teleprotection or signal comparison, interoperability is possible for direct communication links. The paper will describe the use of GOOSE messages as signal comparison or teleprotection messages across substations for feeder protection.

Overcurrent or distance protection devices can only clear faults that occur on the protected line selectively after a delay time. In such cases to achieve non-delayed and selective tripping on 100% of the line length for all faults, the protection devices should exchange and process information with the opposite end by means of signal transmission systems. The signal transmission system consists of the signal transmission equipment and the communication media over which the information are sending between substations.

Today the transmission of teleprotection information is typically done with dedicated and / or proprietary extra equipment, e.g. via direct fiber links, via multiplexers with 2MBps or also 64kBps connections. These connections are reserved exclusively for the directional or teleprotection signal and no other information can be transmitted via this channels.

The use of GOOSE messages for transmitting high-speed binary information within a substation or protection scheme is now widely accepted. However, until now the exchange of GOOSE messages is typically done only with devices located within the same substation. Using IEC61850 and the GOOSE mechanism it is possible to transmit all sorts of information via the Ethernet network, such as indications, counters and measurement values.

The evolution of Ethernet and its substation-to-substation (ss2ss) connection has opened up new possibilities for replacing the conventional teleprotection equipment by effective use of the GOOSE messages for the information exchange between substations. Tagging of telegrams together with modern switching technology allow new communication topologies.

This paper will highlight the use of GOOSE messages for inter substation communication. Detailed description of the engineering process will show how to setup the application with modern system configuration tools. Nevertheless if the principle and the functionality of GOOSE is understood and one has a powerful system configuration tool , the means to apply a ss2ss communication interface with the same functionality and reliability as we would exchange a GOOSE message from one relay to another inside a substation.

This paper will describe different transmission schemes with the use of GOOSE messages instead of conventional teleprotection techniques. Comparison of the transfer time with GOOSE and a conventional teleprotection system will be done.

The use of GOOSE for the teleprotection and directional comparison not only minimizes the need for separate communication equipment but also reduces the need for extra inputs and outputs in the relay hardware and thereby reducing the initial overall investment and later the asset management costs of the widely used distance protection scheme. Especially if high bandwidth connections are available between substations GOOSE will become a full alternative to conventional teleprotection solutions.

KEYWORDS

IEC 61850, GOOSE – messages, teleprotection, directional comparison, communication equipment

1. INTRODUCTION

The use of GOOSE messages to transmit high-speed information via an IEC61850 station bus within a substation or protection scheme is now widely accepted and almost regarded as ‘old hat’. However, up until recently the exchange of GOOSE messages was typically only done for devices located within the same substation over an Ethernet network.

With the IEC61850 standard becoming so widely accepted around the world and its application in more than a thousand systems / substations around the world its application has begun to evolve into areas not previously thought of. The need for exchanging GOOSE messages from one substation to another or one V-LAN to another has become quite apparent and it is this that we try to describe in more detail here.

With relatively basic knowledge of the GOOSE messages and the systematic application thereof in the DIGSI system configuration, it is quite easy to create a setup for inter substation communication via GOOSE.

In this example we describe the exchange of a directional signal of two directional phase overcurrent relays. The directional signals are transmitted bi-directionally between the two substations, that being substation A and substation B using an IEC 61850 GOOSE message. The relays in both substations will use the directional indication from the local and remote end to make an instantaneous trip decision, this if the fault is in the overhead line or cable between the devices protecting it. Measured voltages and currents are used for the directional decision on both sides. This application is similar to teleprotection schemes used for distance protection. For teleprotection also directional indications are exchanged.

2. HOW IS THIS PROTECTION APPLICATION HANDLED TODAY – TRADITIONAL SETUP?

Today the transmission of teleprotection information is typically done with dedicated and/or proprietary equipment, e.g. via direct fiber links, via multiplexers with 2 Mbit/s or also 64 kbit/s connections. Also low bandwidth PLC – equipment is used widely. These connections exclusively used for teleprotection information, so other information cannot be transmitted via this connection in parallel.

A typical setup for teleprotection is shown in figure 1. It is assumed that the protection device has an integrated digital interface in this example. This digital interface allows mirroring binary signals over a serial communication link. Converters allow the adaptation to communication equipment or a direct fiber optical link is used. This configuration is very similar to the configuration used later for GOOSE, because the digital interface is directly integrated in the device. However propriety telegrams are used and devices from the same vendor must be placed on both sides. Traditional schemes using a contact as relay output and connect it with a binary input of the teleprotection equipment. Signal transfer is then done between teleprotection equipment from the same manufacturer. In the other substation, a contact of the teleprotection equipment is again used to indicate the directional information on a binary input of the relay.

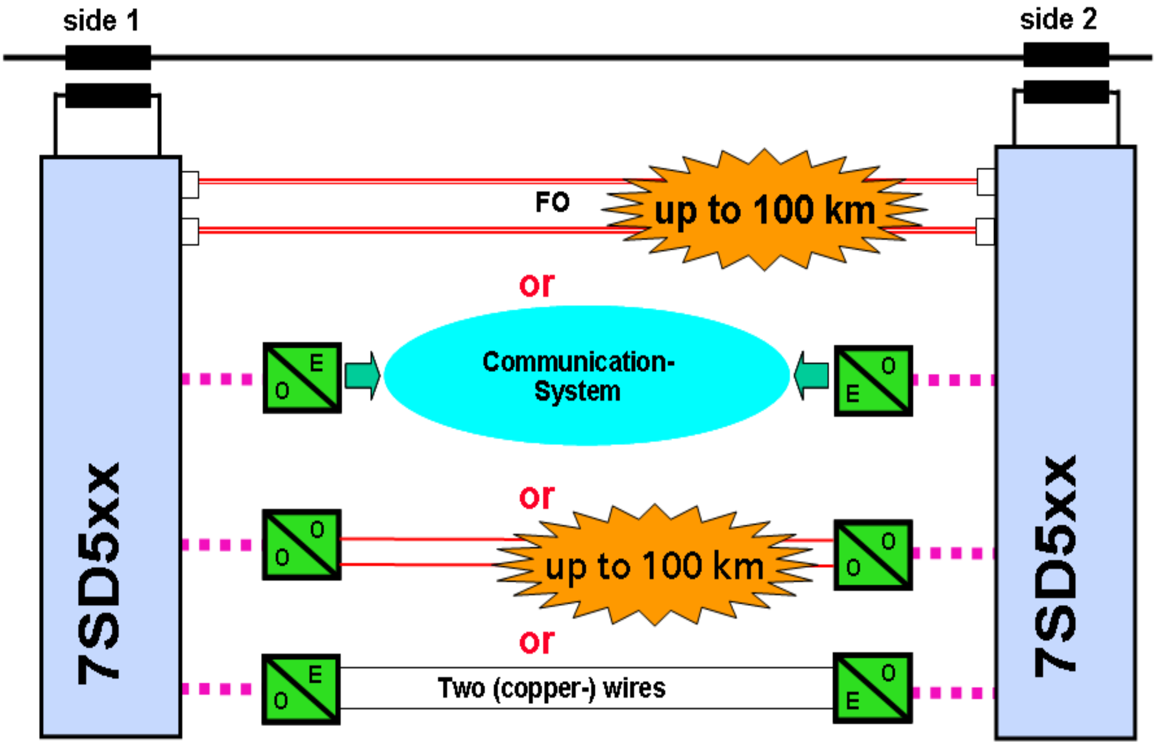
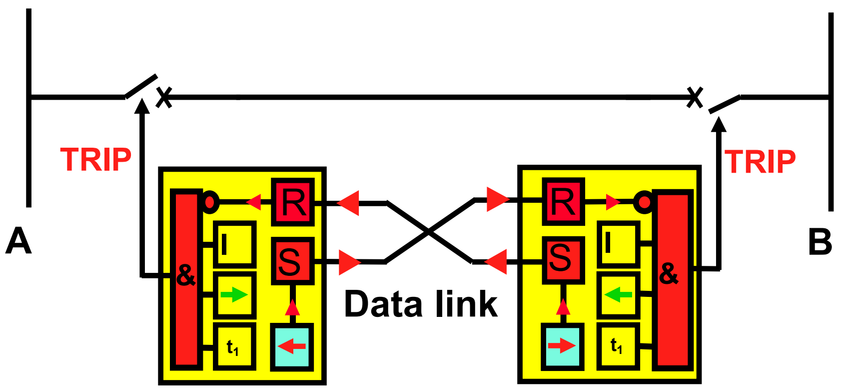


Figure 1: Existing setup for teleprotection communication with integrated digital serial interface.

3. FUNCTIONAL CHART OF DIRECTIONAL COMPARISON

The following chart shows the principle of the directional comparison of two O/C relays. Teleprotection schemes look very similar. This paper will not discuss directional comparisons or teleprotection methods and focus on the transfer of signals required for the specific applications.



I Start time-over-current stage

Sense "operative direction"

t1 Time delay

R Receive information "inoperative direction" -> blocking

Sense "inoperative direction"

S Send information "inoperative direction"

Figure 2: Functional chart for directional comparison

At the beginning and end of the line A to B respectively, the application of directional time-over current protection with directional comparison logic function is installed. In the instance of a fault on the line part A – B both devices sense "short circuit forward". In this instance no blocking signal is transferred to the remote end and both protection devices trip with a time delay t1. This time is set to 30-50 ms in order to safely receive the blocking signal.

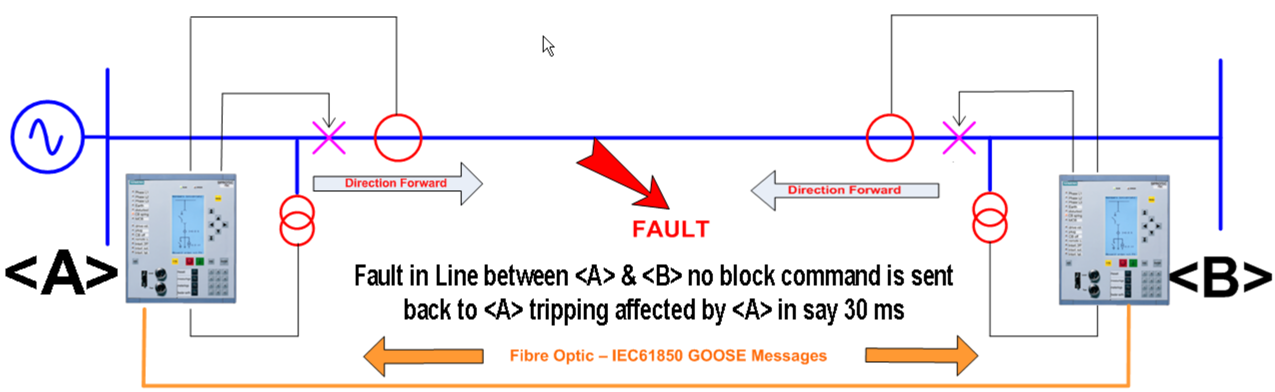


Figure 3: Reverse Block Principle across a line – Fault in line

Where the fault, (through fault), is located outside of the line part A – B, for instance beyond B, the protection device in B senses “reverse direction” and thus blocks the protection at A, so the protection system beyond B can handle the fault and operate selectively. If the protection beyond B does not clear the fault in a set time, an alternative protection stage in A could pick-up or become effective acting as a backup stage.

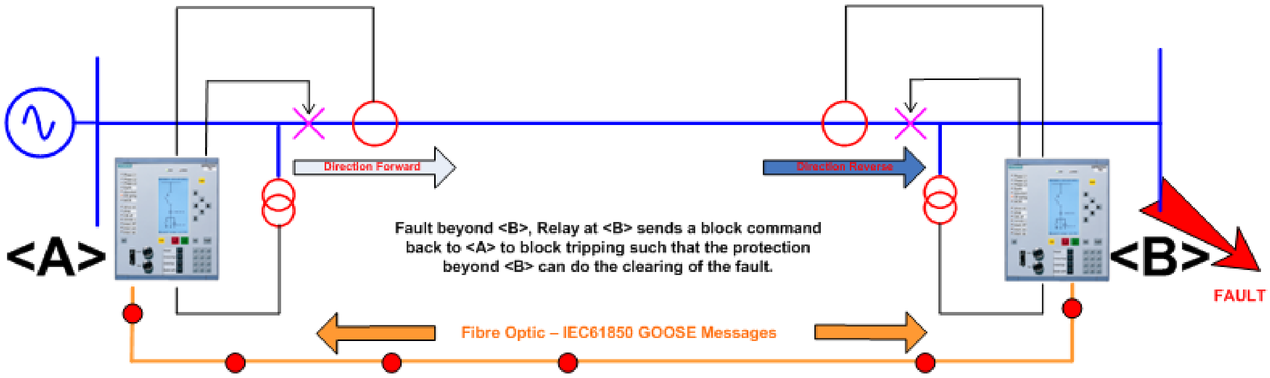


Figure 3: Reverse Block Principle across a line – Fault outside line

4. SETUP WITH IEC 61850 – GOOSE MESSAGES

Using IEC61850 and the GOOSE mechanism it is possible to transmit all sorts of information via the Ethernet network, such as SP (single point indications), DP (double point indications), counters and measurement values. At present the **ss2ss**-communication philosophy is not described in the IEC61850 standard Edition 1, but will be included in editions 2 of the IEC standard in more detail together with the file exchange and engineering process. Nevertheless if the principle and functionality of GOOSE is understood and one has a powerful system configuration tool such as DIGSI, you have the means to apply a **ss2ss**-communication interface with the same functionality and reliability as you would have exchanging a GOOSE message from one relay to another inside a substation.

The network sketch in **figure 4** shows a typical setup for communicating between different substations. The IEC 61850 network in each substation in built by one or more optical Ethernet ring configurations, which are connected with switches. GOOSE – messages are send between the devices inside the substation and client – server communication is running between devices and a substation controller. If the substations are linked by a layer 2 communication network, which may be also a fiber optical link, one must avoid that all GOOSE – messages from one substation are transferred to the other substation via this link. Only one or a few selected telegrams that contain the exchanged directional signals must pass through this link.

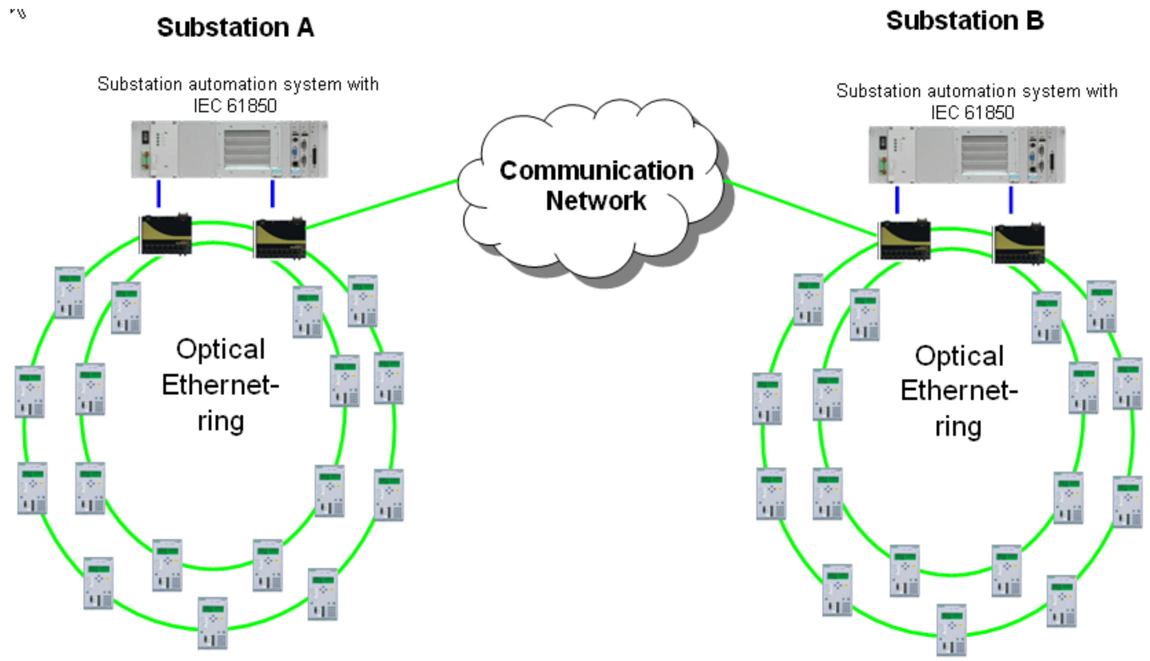


Figure 4: Setup for inter substation communication

The representation of the cloud in-between the substations can be affected in a number of different ways and is dependant on the existing infrastructure as to how to best establish this interconnection. This topic is touched on in more detail in the chapter 6. The task for this application to work is to transfer a layer 2 Ethernet datagram over an IP – network.

5. SETTINGS FOR BOTH SUBSTATIONS IN THE DIGSI PROJECT

This chapter shows in detail the engineering in the configuration tools. Traditional wiring is done now by drawing logical connections in system configuration software. Using devices of different vendors on both sides this logic must be tested intensive, because the IEC 61850 standard does not describe the application.

Prerequisite: In the DIGSI projects for each of the substations the internal communication - all the devices / IEDs must be configured for a client / server communication relationship using the IEC 61850 protocol for GOOSE functionality between the devices. In our example only the additional settings for ss2ss communication are mentioned, but not the settings for normal substation internal communication.

The following steps have to be configured in both substations.

First the blocking signals, which shall be transmitted, must be calculated in a CFC-Chart, (**C**ontinuous **F**unction **C**hart), by the phase segregated directional indications. This reverse or forward indication is calculated by the relay after a pickup condition from the measured currents and voltages. These indications are assigned as inputs of a CFC-Chart **(see Fig. 5)**. The output signal ´Reverse Direction´ of the CFC – chart must be created as a single point indication and is assigned as an output (source) of the CFC-chart. The application will be named substation-to-substation communication (SS2SS Com) (see Fig. 5).

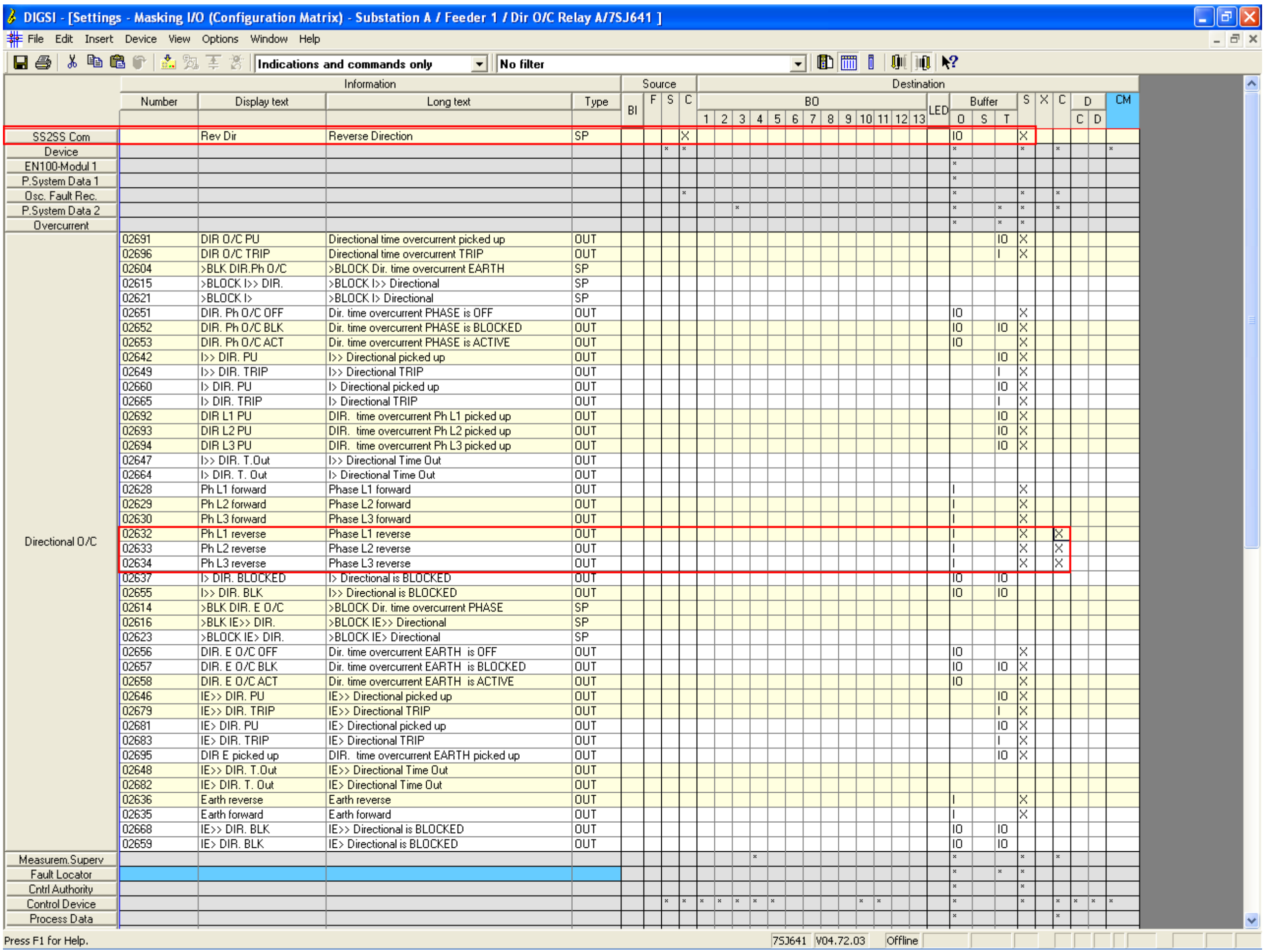


Fig. 5: Assignment of directional signals as input of a CFC – chart

The signal output of the logical block must now be transmitted to the other substation. Therefore, the signal is configured to the IEC 61850 substation control interface (S) as a destination (output) and can be used later in the System Configurator as an input for a GOOSE message. By assigning this signal to S the configuration software automatically, create an entry in the ICD-file, which is a XML – description of the signals of the device, which can be used in the System Configurator and must later be imported in the system configuration of the other substation.

In the CFC-chart the calculation must be done in a "fast-plc"-task **(see Fig. 6)** to generate the output with an approximate 5 – 10 millisecond delay. An OR-Gate is used to create the group indication for ´reverse´.

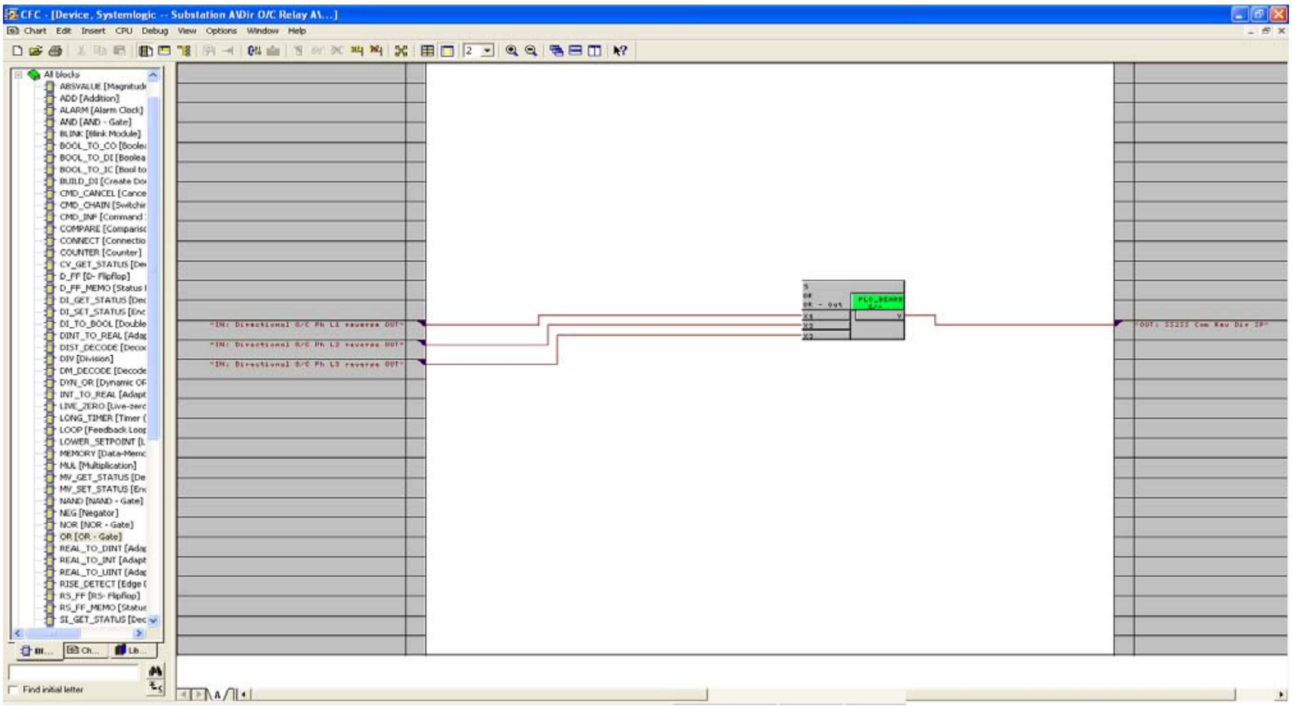


Fig. 6: CFC – Chart for group indication ´reverse´ from the phase segregated inputs

That indication ´reverse´ will also be created in substation B and must be transmitted via GOOSE to substation A. A single point indication must be created to subscribe that information of the other substation **(see Fig. 7)** in each relay.
The directional blocking information has to be configured to the CFC as a source **(see Fig. 8)**.
This information will be connected via the CFC-chart to block the directional overcurrent **(see Fig. 9).**

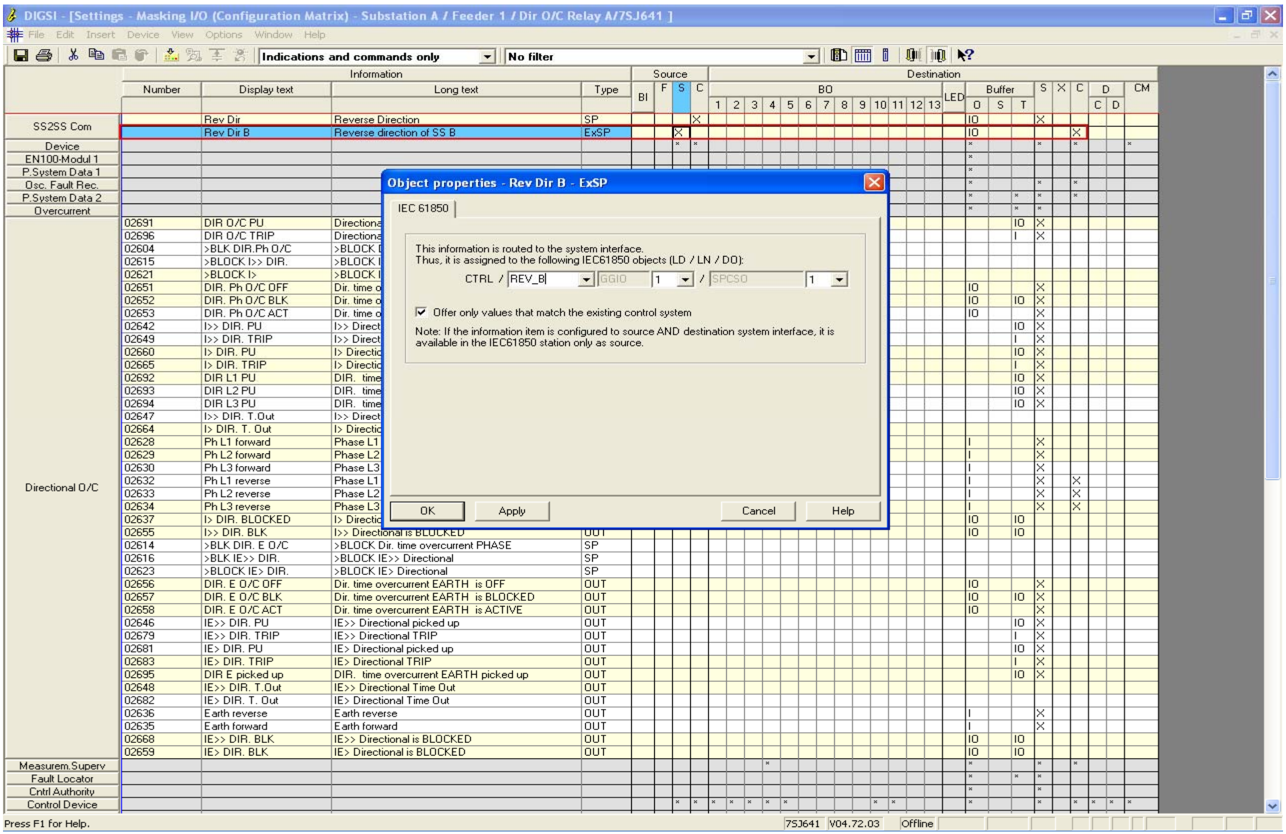


Fig. 7: Create an external single point indication for receiving the ‘reverse’ indication

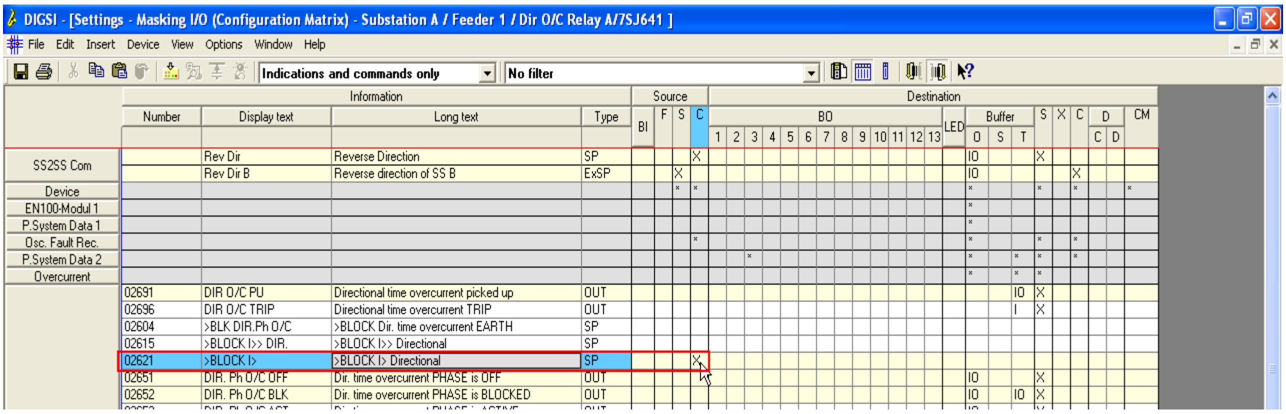


Fig. 8: Configure the Blocking information to the CFC as a source

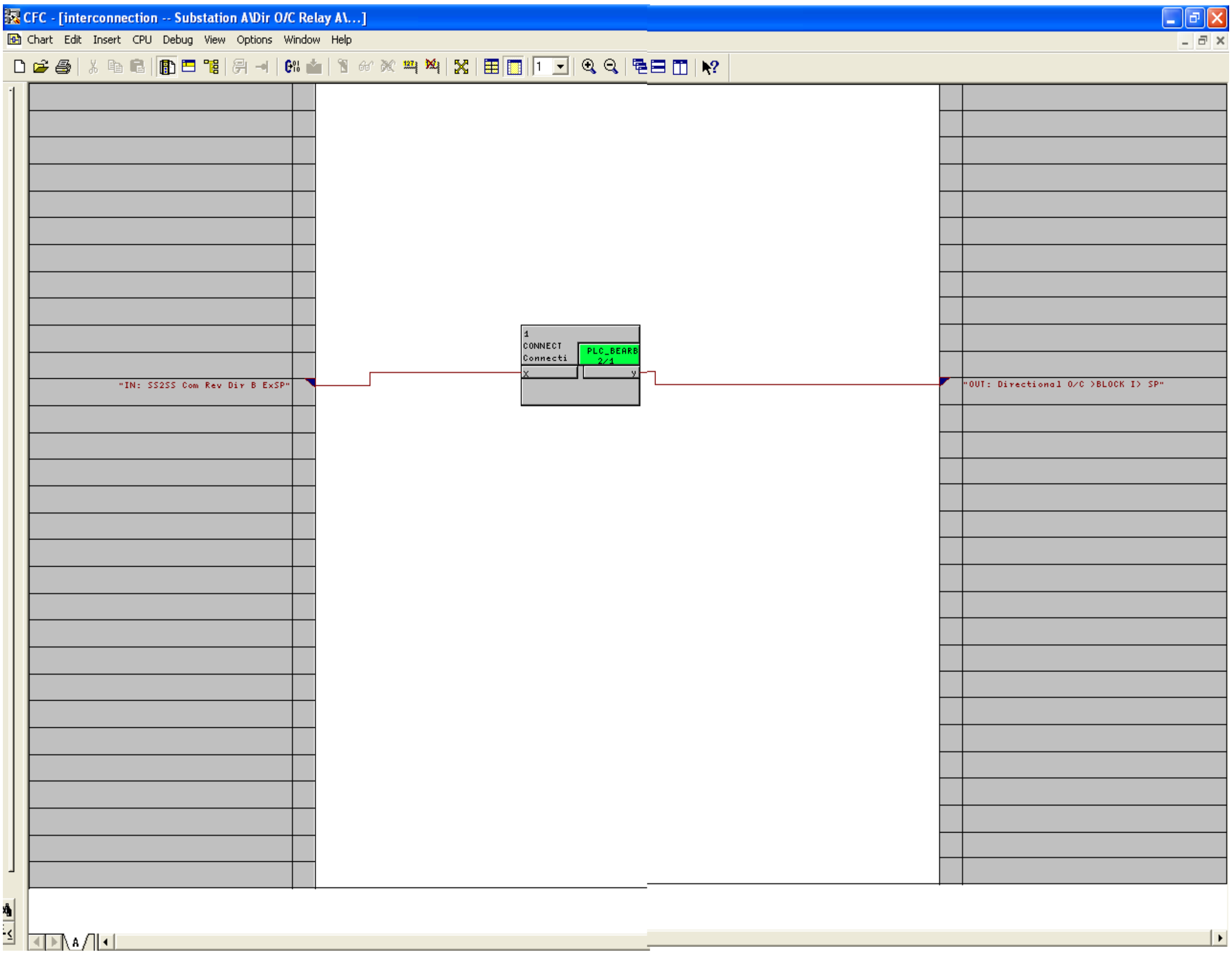


Fig. 9: CFC-chart for interconnecting the “reverse direction” information to BLOCK I> Directional

Export the ICD-files of both devices **(Fig. 10)** and import them in the respectively other DIGSI project **(Fig. 11)** and integrate them in the station configurator **(Fig. 12 and 13**).

The workflows in both DIGSI projects is exactly the same.

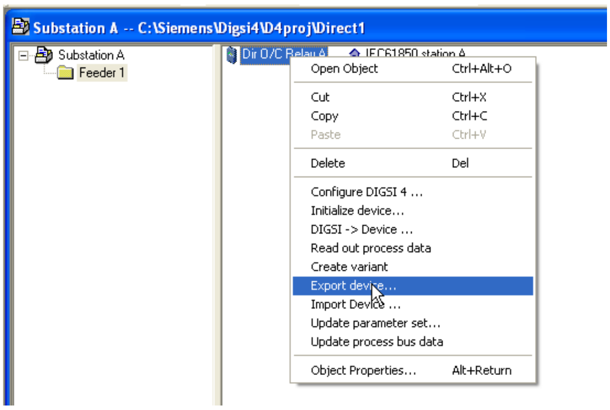


Fig. 10: Export of ICD-file of substation A

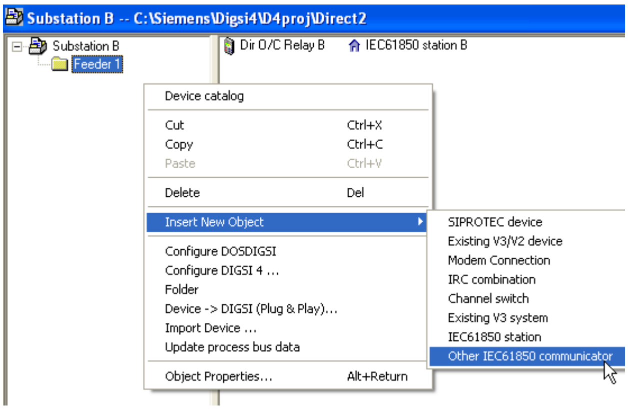
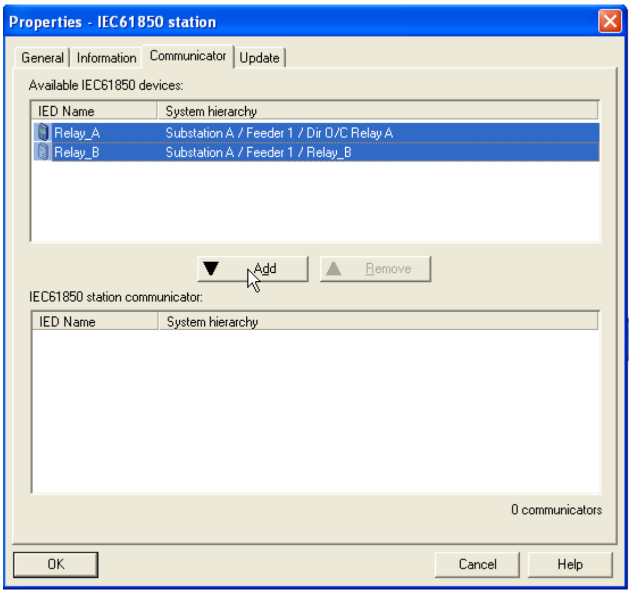


Fig. 11: Import of ICD-file in substation B



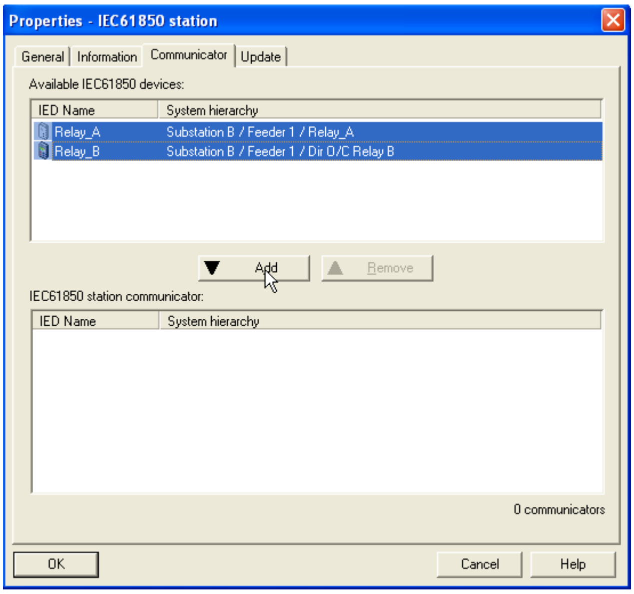


Fig. 12: Integration in station configurator of substation A

Fig. 13: Integration in station configurator substation B

Set the interconnections for the GOOSE messages in both DIGSI projects, as shown **in Fig. 14** for substation A. Pleases ensure and check that the properties of the GOOSE application **(Fig. 14)** and the datasets **(Fig. 15 and 16)** are identical in both projects.

These properties will be automatically created by DIGSI (APP-ID, VLAN-ID, VLAN priority, Dataset name, GOOSE Control Name, GOOSE-ID, Config revision and MAC-address). Under normal conditions the values proposed by the system can be taken without changes, but not the VLAN-ID. The VLAN-ID shall have a unique value, which is just used for the ss2ss communication. One telegram with the GOOSE properties is used for the exchange the information. The ss2ss – application should be the first GOOSE application in an IEC 61850 project for both substations, to ensure that they both have identical parameters automatically.
An expert mode in the system configurator allows adapting single values of this GOOSE – telegram.

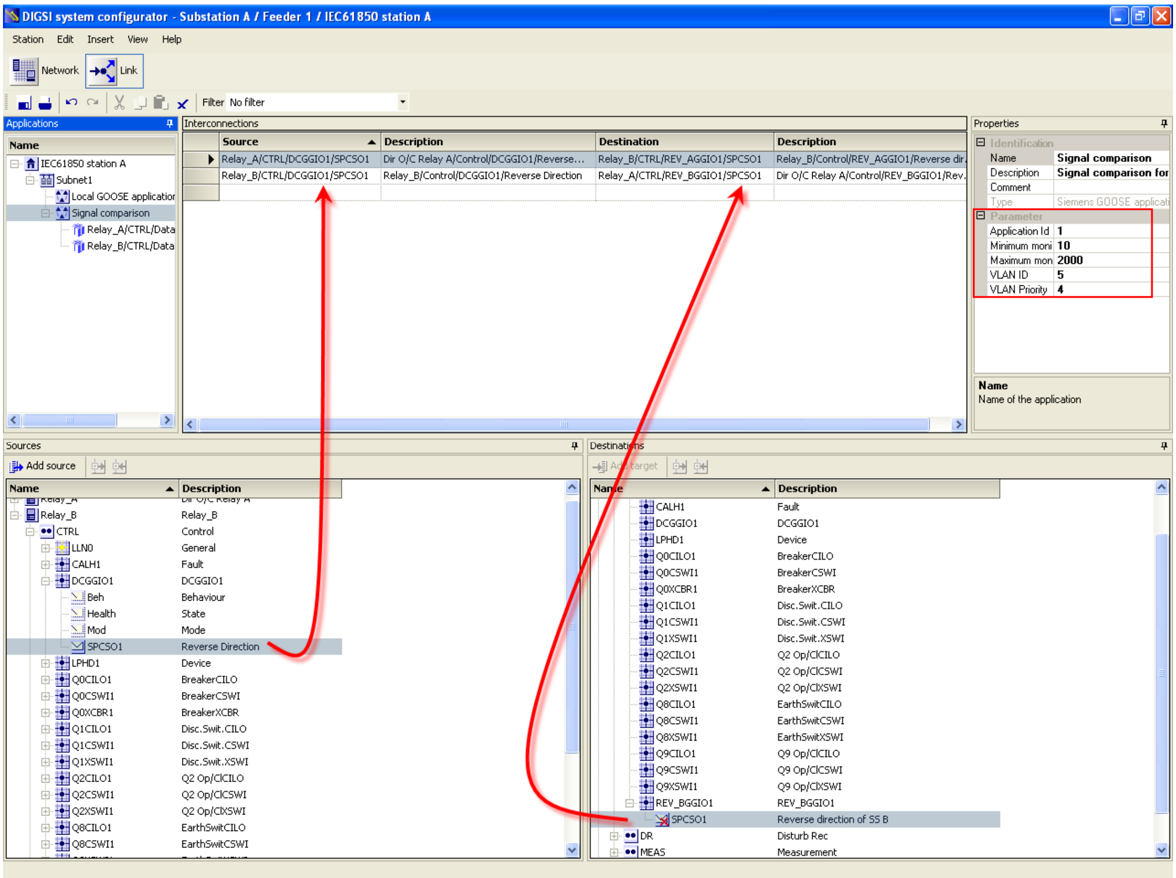


Fig. 14: Configuration of GOOSE – messages for SS2SS – communication in substation A. The same engineering step must be done for B.

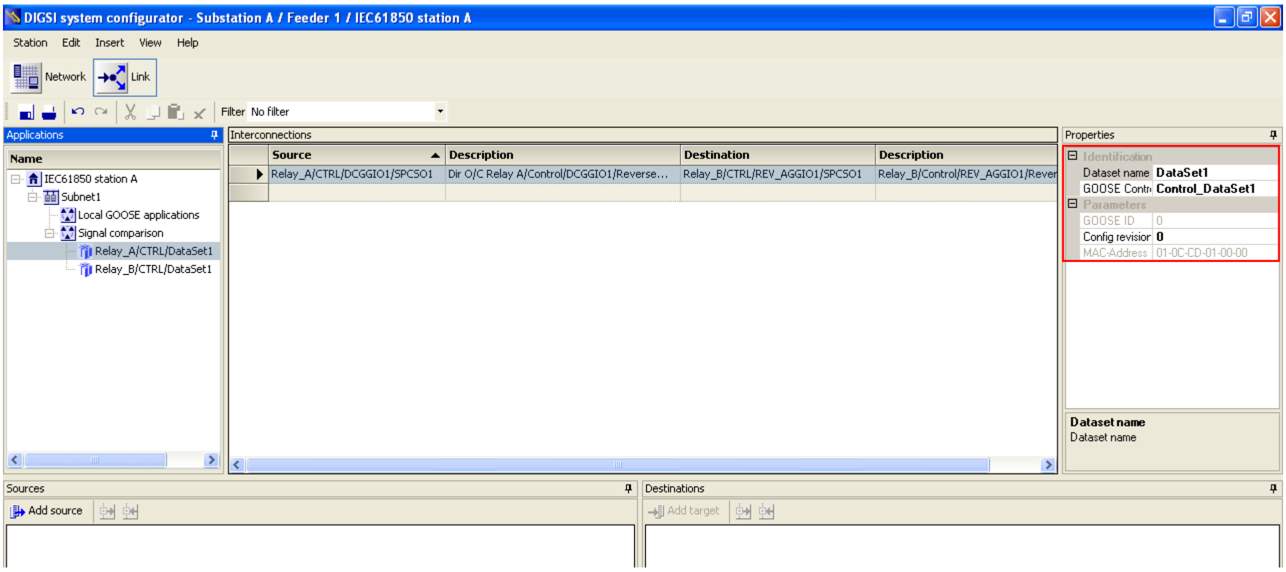


Fig. 15: Properties of the GOOSE message in substation A

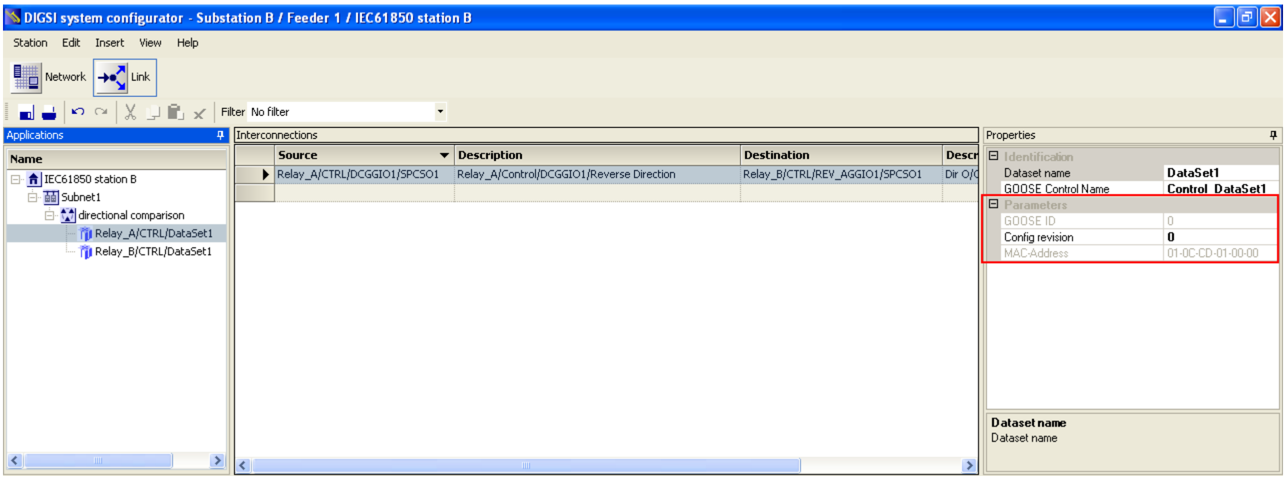


Fig. 16: Properties of the GOOSE message in substation B

Save and close the station configurator. The content of the substation configuration file (SCD – file) is automatically created and the devices are updated afterwards with this information by the configuration tool of the vendor. The GOOSE – telegram which is exchanged between the substations is now content of both SCD – files and will be sending out by both devices after the update. This can be checked online with test tools or by a Browser on each sending device.

6. DIFFERENT NETWORK CONNECTIONS FOR THE TRANSFER OF GOOSE-MESSAGES

Different connections for intersubstation communication are available. Low bandwidth connections can not be used for the direct transfer of GOOSE – messages like in traditional teleprotection schemes. A typical GOOSE – message for this application have 160 – 200 Bytes. Bandwidth calculation must consider how often this message is repeated if a change occurs. If it's repeated heavily every millisecond 1,6 Mbit/s are enough.

Direct fiber optical link

This type of connection is achieved through a dedicated fibre optical connection. Switches of different substations can be connected together directly or via a router **(see Fig. 18)**. These devices must be able to support layer 2 - GOOSE tunnelling, this more dependent on the size and design of the network. Bandwidths of up to 1 Gbit/s is possible, but is really not necessary for this application because only 160 – 200 Bytes must be transmitted over this 100 Mbit/s or 1 Gbit/s connection. Even if the GOOSE – telegram is repeated every 1 ms the channel will be loaded with max. 1,6% if a 100 Mbit/s connection is used. Typically a GOOSE – message will be repeated every second under steady state conditions and after a change in a signal rapidly after 1 ms – 5 ms only for a short time. This fast repetition time (maxGOOSE) is settable for each GOOSE – telegram in the sending device.

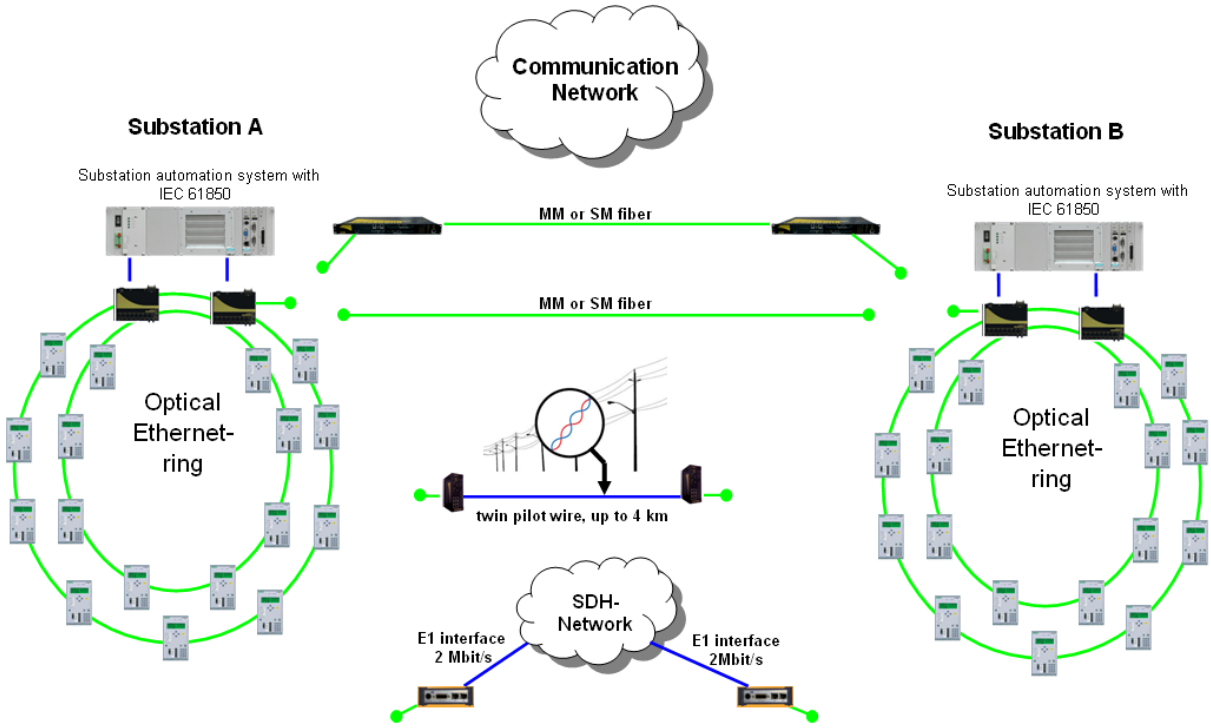


Fig. 17: Different communication opportunities for ss2ss – communication with GOOSE

VDSL-switches
This type of connection is achieved via available substation hardened VDSL-switches. Distances of up to 4 km between substations are possible. The switches are directly connected with simple pilot wires (1 pair). The bandwidth will be dependant on the distance and diameter of the pilot wires and will have a bandwidth of up to 40 Mbit/s or more.

Routing layer 2 GOOSE – messages to an E1 – interface (2 MBit/s G.703.6 interface)

A converter is connected with the Ethernet network and receives the dedicated GOOSE – messages for ss2ss communication from a port of a switch which is programmed to pass the layer 2 telegrams through, with their specific VLAN-ID or multicast address.

The other side of the converter is connected to a G703.6 – interface with a multiplexer. Through a switched SDH – network the telegrams will be transferred via a point to point connection to the other substation and converted again into Ethernet based GOOSE – telegrams.

7. REQUIRED LAYER 2 ETHERNET SETTINGS

One parameters of a GOOSE – telegram is the VLAN-ID. With this ID you split one physical layer 2 network into multiple logical networks. This sounds complex, but is in fact a simple way to separate GOOSE messages and is ideal for the described application. For ss2ss communication it is neither necessary nor useful to transmit all available GOOSE messages between the different substations. You just want to transmit the one GOOSE telegram you have created for ss2ss communication. So in the system configurator you provide a unique VLAN-ID for this ss2ss GOOSE.

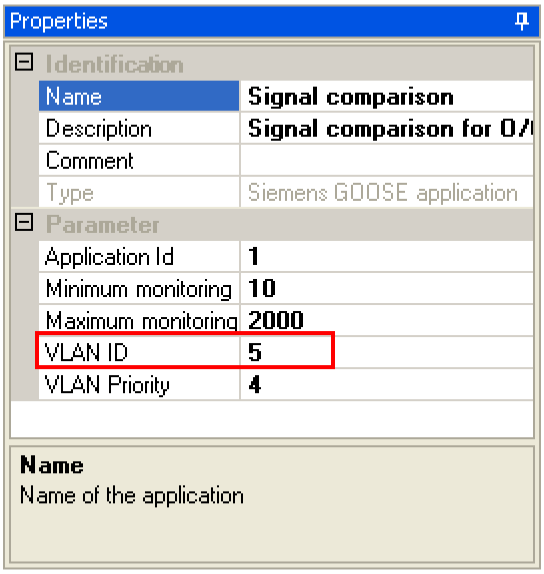


Fig. 18: VLAN-ID setting in DIGSI station configurator

The default value for the VLAN-ID is “0” in the IEC61850 standard. Typically it is not necessary to change this default value, but for ss2ss communication it is quite useful to avoid useless network traffic via the inter substation connection which will often be the bottleneck of any network, if there is any.

The port of the Ethernet switch, which is connected to the other substation, has to be configured as a member of the same VLAN. This has to be done in both substations. That’s all. Now all other GOOSE messages are separated and will not be transmitted to the other substation.

If existing or other settings for VLAN-IDs for other GOOSE-messages have to be considered in the Ethernet switch configurations, the same can be achieved by setting a multicast filter in the Ethernet switch. This means that one has to set a filter for every GOOSE which is available at the bus, but not the GOOSE you want to transmit. This requires a little more work and effort to configure on all the affected switches, because every GOOSE message has to be considered. It would be nice if switch vendors who provide substation hardened switches, would focus their energy now, into creating more convenient or efficient ways for GOOSE separation via multicast filter tables. This can help to reduce network traffic on the overall network if GOOSE is used intensively for all connections between relays. VLAN-ID or multicast – filtering are features of substation hardened switches which allow to separate the GOOSE – telegram for this application easily.

8. DELAY TIME AND SUPERVISION OF THE COMMS - CHANNEL

For the delay time we will not consider the pickup or tripping time of each relay. After the directional indication is generated logically in the device a group – indication is calculated in a CFC – chart. In the fast – PLC the maximum delay will be 5 - 10 ms. To avoid this delay the phase-segregated signals can be directly assigned into a GOOSE – message but then more logic in necessary on the receiver side. Max. 3 - 5 ms later the telegram will be on the network. The delay in the local network is typically < 1 ms. For the transfer the delay time depend on the used communication media. Best choice is a fiber optical link (< 1ms) but even if a SDH – network is used the delay time is < 5 ms. Receiving the blocking telegram need another max. 5 ms. Normally a GOOSE – message will be faster than a contact and binary input interface on the sender and receiver side which need 10- 20 ms

in total. The performance of integrated digital interfaces (see fig. 1) is equal to the GOOSE – application.
Special logic blocks allow monitoring the repetition of GOOSE – telegrams on the receiving relay. This integrated comms–supervision feature will generate an alarm if there is a failure on the communication link. In addition, monitoring functions for missing or faulty telegrams are available via an integrated Web-Server on the receiver side.

BIBLIOGRAPHY

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