Solutions for Digital Substation

Fully complied with IEC 61850 SV & GOOSE

NR Electric CO., Ltd.

Introduction

The development from conventional protections to digital protections brings a qualitative leap in the development of substations. At the same time, the reliability of protection has also been enhanced greatly.

Digital substations based on IEC61850 map the conventional hard wiring of physical device to abstract model files. This has brought the possibility of configuring substations in which heavy physical labor is transferred to the computer system. Construction of digital substation based on model configuration makes the interoperations between devices easier with increased flexibility.

The digital substation comprise of intelligent primary devices and networking secondary device based on IEC61850 protocol to realize information sharing and interoperations. Compared with conventional substations, communication interfaces and communication protocols are changed at bay level and station level; however, the major difference is the process bus of digital substation. Intelligent primary devices, merging units and intelligent control unit are substituted for traditional CT/VT, primary devices, and conventional cable wiring.

Digital substations has introduced GOOSE scheme which enables the replacement of conventional binary inputs and binary outputs by digital models. All digital BI and BO are configurable and delivered to Ethernet switch via one optic fiber. This significantly reduces the amount of cable wiring in a modern substation.

The use of Sampled Value (SV) makes current/voltage sampling at primary side easier and more reliable. The voltage and current signals are captured at primary side, converted to digital signals and transferred to protection and control devices via optic fibers. This can lower the requirement of transformer insulation and reduce the interference experienced in the analog signals transmission.
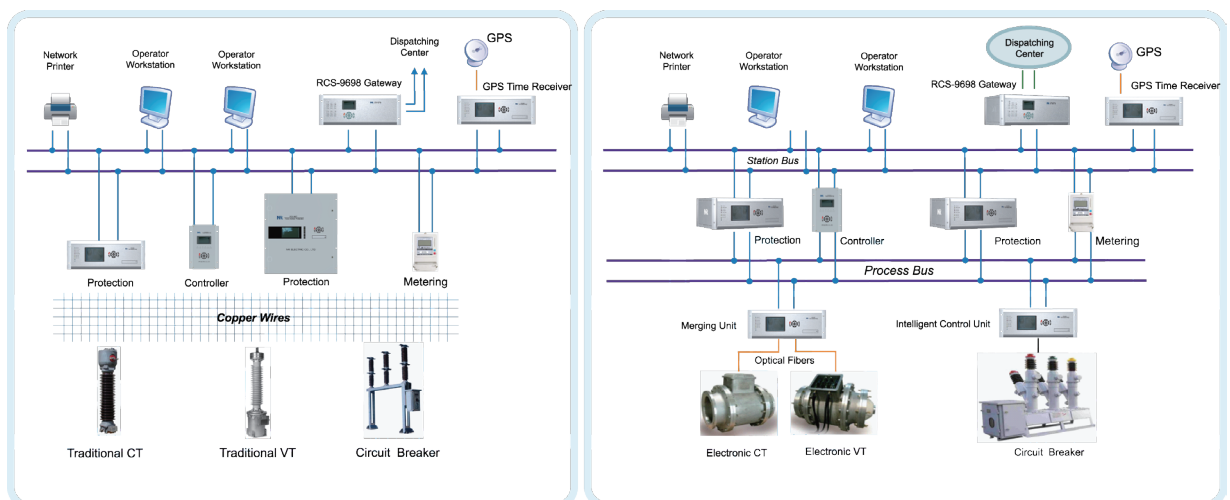
Conventional Substation

Digital Substation

Benefits of Digital Substation

- Digital substation replace numerous copper wires between switchyard and IEDs by a few optical fibers.

- Reduce installation time & workload to save construction cost.

- Reduce outage time during maintenance & extension.

- Achieve data sharing and interoperability via the unified data format of IEC 61850 standard.

- Adopt optical/electronic CT/VT to avoid CT secondary circuit open, CT saturation problems and get strong immunity, easy isolation, smaller size and lower maintenance cost.

Typical Schemes of Digital Substation

❯❯ Typical Schemes of Digital Substation Complied with IEC61850

The digital substation uses innovative Ethernet technology to realize information sharing at process bus and station level. Currently, digital substations can be classified into 3 modes.

	IEC61850 adopted at station level	IEC61850 adopted at process bus	Electronic CT/VT are used
Scheme 1	√		
Scheme 2	√	√	
Scheme 3	√	√	√

- **Scheme 1: Digital substations with IEC61850 in station level**

The configuration of substation automation system described in Scheme 1 is similar to the conventional substation automation system(SAS). The Intelligent Electronic Device (IED) can be installed in the bay level and communicate with station level using IEC61850.

This mode can solve intercommunication and information interoperation problems between IEDs in conventional substations. Since communications and functions of IEDs are regulated by IEC61850 standard, the information transmitted between each node is standardized. This improves the maintainability and extensibility of the entire system.

Interlocking GOOSE signals and cooperating signals between relays can be realized by the network in station level as well.

- **Scheme 2: Digital substations with conventional transformer and GOOSE information**

Compared with Scheme 1, Scheme 2 introduces the independent process bus based on IEC61850 for information exchange in station level. Intelligent control units are used in the process bus for each bay and are connected to the corresponding IEDs via optic Ethernet network.

IEDs are allowed to be installed anywhere in substation according to the requirements. Large amount of copper wiring between IEDs and primary devices in conventional substations are replaced by optical fibers.

- **Scheme 3: Digital substations based on full information   exchange in station level and process bus**

In Scheme 3, electronic CTs/VTs are used instead of conventional CT/VT. Electronic CTs/VTs include active CT/VT, passive CT/VT and built-in GIS. Voltage and current signals are captured at primary side, converted to optic signals and transferred to protection and control devices via optic fibers. This can lower the requirement of transformer insulation and reduce the interference suffered in analog signal transmission.

So far, electronic CTs/VTs are widely used in many 220kV and 110kV digital substations in China.
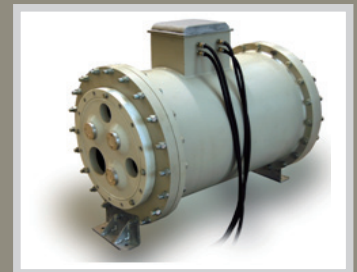
❯ Recommended Networking Scheme

The operation of a digital substation rely on a reasonable communication frame. Communications in and between process bus, bay level and station level is accomplished by high speed Ethernet network. The entire communication network includes:

- Station level communication network between bay level and station level.
- Process bus communication network between bay level and process bus.

The communication protocols of station level network, the process bus GOOSE network and analog sampling SV network are independent and assigned with different tasks.

Features of MMS network data in station level

- Strong abruptness;
- Massive volumes of data;
- Low requirements on real-time transmission.

MMS network is the communication bridge between SCADA, dispatching centers and IEDs in bay level. Interlocking GOOSE is also implemented in this layer. The full use of Ethernet switch to process the message priority can bring the realization of GOOSE scheme between relays.

◆ Features of GOOSE network data in process bus

- Small volumes;
- High requirements on transmission reliability and real-time performance.

GOOSE network in process bus can be configured with SV network or independently.

◆ Features of SV network

- High reliable massive volumes of data;
- Real-time, stable and reliable data transmission

NR Electric's PCS series protection and control devices are fully compliant with IEC61850 protocol and can be directly connected to SCADA, Gateway and Protection Management Units. The perfect IEC61850 engineering configuration tools can generate SCL files which can be used for data and information exchange with other engineering tools from third party manufacturers.

According to the features of network structures, NR Electric frames a digital substation networking scheme. In this scheme, MMS network is configured independently, GOOSE and SV are combined to form the network.
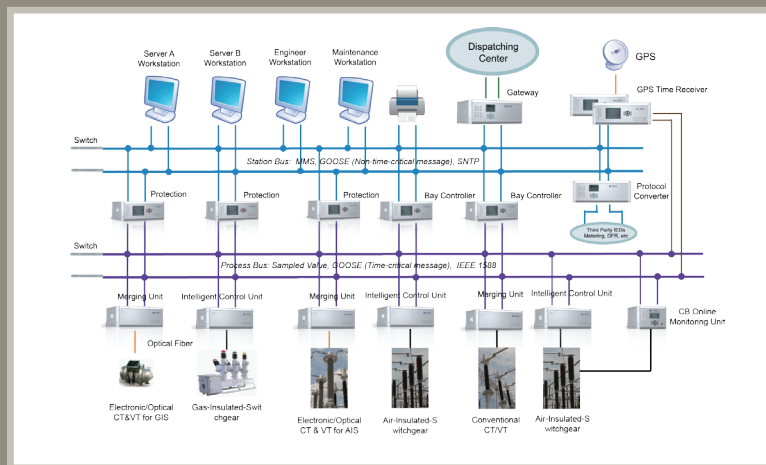

Figure 1. Scheme of independent MMS network and GOOSE+SV combined network

The advantages of this scheme are excellent communication quality and simple network structure. The reason to configure SV and GOOSE network together in the process bus is due to the different features of their data flows: SV has large but stable data flow, while GOOSE has small but burst data flow.

GOOSE network and SV network can form different networks according to the voltage levels. For example, for PCS-978 transformer protection may work at different voltage levels, the device can provide optional modules to support ndependent process bus networks with different voltage levels. This configuration scheme can simplify network designs, ease commissionings and optimize network reports.

Each MMS, GOOSE and SV boards of PCS series devices are equipped with two mega bytes fiber optical Ethernet ports to support double network structure.

Protection & Control Devices for Digital Substation

NR Electric's PCS series protection & control devices are developed based on the full patented UAPC hardware platform and can be widely used in digital substations.

Figure 2. PCS-9250 series ECT/EVT for GIS application

❯ Devices in Process Bus

◆ PCS-9250 Series Electronic CT/VT

The PCS-9250 series ECT/EVT can be applied to GIS/AIS circuit breakers at all voltage levels. The rated secondary output of ECT is 2D41H (for measurement)/01CFH(for protection), the measurement accuracy is 0.2s/5TPE. The rated secondary output of EVT is 2D41H, the measurement accuracy is 0.2/3P.

The PCS-9250 series ECT/EVT mainly include the following products.

Name	Model
ECT for GIS application	PCS-9250-EGC
EVT for GIS application	PCS-9250-EGV
Combined ECT & EVT for GIS application	PCS-9250-EGI
ECT for AIS application	PCS-9250-EAC
EVT for AIS application	PCS-9250-EAV
Combined ECT & EVT for AIS application	PCS-9250-EAI
Optical CT	PCS-9250-OAC
Combined optical CT&VT	PCS-9250-OAI
DC electronic CT	PCS-9250-EACD
Medium-low voltage electronic CT	PCS-9250-LAC
Medium-low voltage electronic VT	PCS-9250-LAV

Figure 3. PCS-9250 series ECT/EVT for AIS application

◆ PCS-221 Merging Unit (MU)

The data captured by ECTs/EVTs or conventional CTs/VTs are converted to standard digital signals by PCS-221 merging units. The digital signals are compliant with IEC60044-8, IEC61850-9-1, IEC61850-9-2 protocols and will be directly sent to protection devices or SV network in the process bus.

The merging units can be installed in protection room. If permitted, merging units used for regular data sampling and GIS applications can be locally installed on site.

◆ PCS-222 Intelligent Control Unit (ICU)

The intelligent control unit is used in the switch station as an intermediate link for circuit breakers.

The intelligent control unit convert analog signals (e.g.: Status of primary devices such as circuit breakers and switches) into digital signals and sends it to the

Figure 4. Outdoor MU & ICU

protection & control devices via GOOSE network. At the same time, the tripping and reclosing commands issued by protection & control devices will be converted into analog signals to control the primary equipments.

Figure 4 shows a intelligent control unit installed in a switch station. It measures and sends the analog signals such as temperature and humidity to bay control units via GOOSE network, and finally these signals will be transmitted to the station level for supervision.

◆ PCS-222E Merging Unit & Intelligent Control Unit

PCS-222E MU&ICU can operate as Merging Unit and Intelligent Control Unit. The data captured by ECT/EVT/OCT or conventional CT/VT is converted to the standard digital signals by the MU functions. This digital signal is compliant with IEC60044-8, IEC61850-9-1,IEC61850-9-2 protocols and will be directly sent to the protection devices or bay control units or the SV network in the process bus.

The PCS-222E can also operate as an Intelligent Control Unit. It can be used in a switch station as an intermediate link for circuit breakers. It converts analog signals(e.g.: Status of primary devices such as circuit breakers and switches) to digital signals and sends it to protection & control devices via GOOSE network. At the same time, the tripping and reclosing commands issued by protection & control devices will be converted into analog signals to control the primary equipment.

❯ Devices in Bay Level

◆ PCS-900 Series Protective & Control Devices for Digital Substation Application

NR Electric's PCS-900 series protection, control and management devices are intelligent electronic equipement fully complied with DL/T667-1999(IEC60870-5-103) and IEC 61850 protocol. It supports connections to both electromagnetic CT/VT and electronic CT/VT and is widely applied to digital substations.

The PCS-900 series protection management relays are complied with GOOSE commnunication scheme, power industry communication standard and the new generation substation communication standard:

NO.	Model	Description
1	PCS-931	The PCS-931 is a line differential relay used as the main and backup protection for transmission lines of all voltage levels
2	PCS-902	The PCS-902 is a line distance relay intended for applications to transmission lines of all voltage levels.
3	PCS-915	The PCS-915 busbar protection provides comprehensive and scalable busbar and breaker failure protection for single busbar, double busbar and double busbar with transfer bus. Up to 24 branches including feeders, bus coupler and bus section are allowed to connect to the PCS-915
4	PCS-921	The PCS-921 breaker failure protection provides auto-reclosing, circuit breaker failure protection, pole discrepancy protection and energizing protection. It can be applied to one-and-a-half breaker system and angle connection system of all voltage level.
5	PCS-978	The PCS-978 numerical protection system can provide full-scheme protection and control in one rack for various transformer applications.

◆ PCS-9000 Series Management Relays for Digital Substation

NR Electric's PCS-9000 series intelligent management relays can be widely applied to digital substations up to 100kV. It supports connections to both conventional electromagnetic CT/VT and modern electronic CT/VT. It is fully compatible with DL/T667-1999(IEC60870-5-103) standard, IEC61850 communication protocol and GOOSE process bus.

NO.	Model	Description
1	PCS-9611	PCS-9611 directional overcurrent protection provides protection, control, monitoring and measurement of distribution, as well as backup protection for transformers and transmission lines.
2	PCS-9613	The PCS-9613 relay is a current differential protection and overcurrent protection, control and monitoring unit with auto-reclosing function for distribution feeder lines in solidly grounded, impedance grounded, Peterson coil grounded and ungrounded system.
3	PCS-9631	The PCS-9631 relay is a digital protection, control and monitoring unit for shunt capacitor banks in solidly grounded, impedance grounded, Peterson coil grounded and ungrounded system with single wye, double wye or delta connection.
4	PCS-9651	The PCS-9651 automatic transfer device integrates power transfer function, bus section protection, control and monitoring, and can be applied to different busbar configurations (including inner bridge connection, single busbar, sectional single busbar and other arrangements) .
5	PCS-9656	The PCS-9656 Arc Protection provides a fast busbar protection in substations, power plants and industrial enterprises. In case of short circuit faults in switchgear, the arc faults in the protected area which is covered by arc sensors can be quickly cleared via arc protection, avoiding harm to personnel and assets. The arc protection uses arc sensors to detect the arc light caused by short circuit faults.

♦ **PCS-9705 Bay Control Unit (BCU)**

PCS-9705 Bay Control Units (BCUs) are used for the control and monitoring of different types of bays inpower networks. PCS-9705 series BCUs are especially suitable for applications in control systems with distributed control IEDs in all bays with high demands on reliability. The IED can be used up to the highest voltage levels.

PCS-9705 BCUs are designed for the control, monitoring of circuit breakers, disconnectors, and earthing switches in any type of switchgear and different switchgear configurations. Additionally, PCS-9705 series BCUs enable the manual control of a tapchanger.

Model	PCS-9705A	PCS-9705B	PCS-9705C	PCS-9705D	PCS-9705E
AC inputs	5VT/4CT	13VT	8VT/7CT	24VT	12VT/12CT
Binary Inputs	Up to 120	Up to 120	Up to 120	Up to 140	Up to 140
Binary Outputs	Up to 32pairs	Up to 32pairs	Up to 32pairs	Up to 25 pairs	Up to 25 pairs
Configurable Outputs	Up to 30	Up to 30	Up to 30	Up to 20	Up to 20
DC Inputs (4-20mA,0-5V, 0-250V)	Up to 16	Up to 16	Up to 16	Up to 16	Up to 16
DC Outputs (4-20mA)	Up to 4	Up to 4	Up to 4	0	0
Synchro-check	1 breaker	0	2 breaker	0	4breaker
Interlocking Logic	Yes	Yes	Yes	Yes	Yes
Support to ECVT (optional)	Yes	Yes	Yes	NO	NO
IEC61850 Process Bus (optional)	Yes	Yes	Yes	NO	NO

♦ **PCS-9882 Ethernet Switches**

The PCS-9882 Ethernet Switches can be applied in substation automation system (SAS), power plant Network Control System (NCS) and industrial control system. They both adopt high-performance switch chip to ensure line-speed transmission. The excellent management of the CPU enables flexible configuration and powerful functions extension capability which can improve the application in digital substations. Severe environmental and interference factors are taken in to account during the design and the manufacturing of PCS-9882 to ensure reliable data transmission.

PCS-9882 Ethernet Switches can provide 1000Mbps Ethernet or optic interfaces, thereby establishing a fast network with higher data transmission rate to meet the increasing requirements for equipment communication.

❯ **Devices in Station Level**

♦ **PCS-9700 SAS System**

NR Electric's PCS-9700 Substation Automation System(SAS) is a high-tech automation system which integrates protection, monitoring and remote control functions. It focuses on innovative computer science and network communication technology to form a higher grade automation system that is compliant with the latest international standard.

The PCS-9700 substation automation system can be used on central control stations and substations of all voltage levels, or as the Network Control System (NCS) for power plant automation system and industrial control system.

◆ RCS-9698G/H Communication Gateway

The RCS-9698G/H Communication Gateway can be used as a remote communication controller on substation automation system, network control system and industrial control system to directly acquire and transmit remote information. It operates independently and has no interaction on HMI system. RCS-9698G/H is recommended for use in substations with voltage level higher than 110kV.

It collects data from bay control units, protective relays and intelligent electronic devices using IEC60870-5-103 or IEC60850 standard protocol. These data will be converted using IEC60870-5-101, IEC60870-5-104, CDT, MODBUS or DNP protocols(new protocol that are available) and sent to central control stations or dispatching center via analog channel, digital channel network. Meanwhile, the RCS-9698G/H can transmit tele-control and tele-regulation commands from dispatching center or central control stations to equipments in substation.

Users can select either single unit device (RCS-9698G) or dual-configuration device(RCS-9698H) according to the actual engineering conditions.

Implementation of Digital Substation Based on IEC61850

❭ Configuration Process of Digital Substation Model

Digital substations are mostly operated based on IEC61850 standard. It provides descriptive languages of digital substations and introduces 4 kinds of files: ICD file, SSD file, SCD file and CID file.

A complete configuration scheme of digital substation installed in PC is shown in Figure 5.
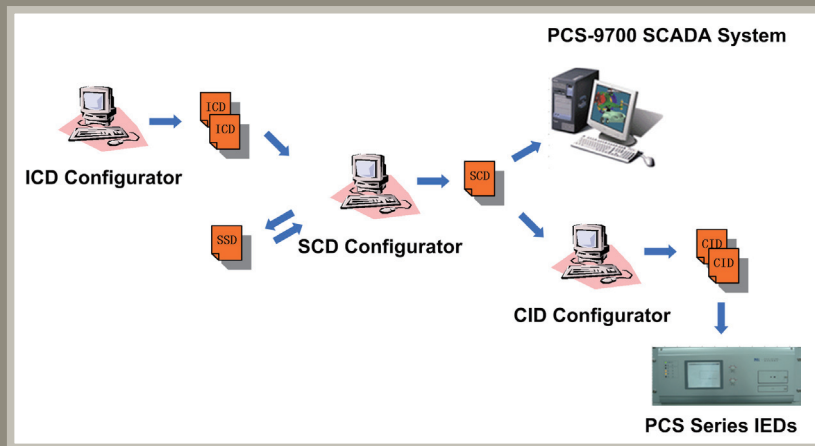

Figure 5. The configuration scheme of digital substation

❭ Introduction of SCD Configuration Tool

SCD can give general descriptions of digital substations, making it a direct important factor in the on-site commissioning and extension work of digital substations. To provide better service for the operation of digital substation, NR Electric further develops the complete SCD configuration tool.

To start SCD, click 'visualscd.exe' to open Visualscd tool. As shown in Figure 6, create a new subnet under 'communication 'of 'SCL'. The type and properties of subnet shall be in accordance with the actual on-site requirements.
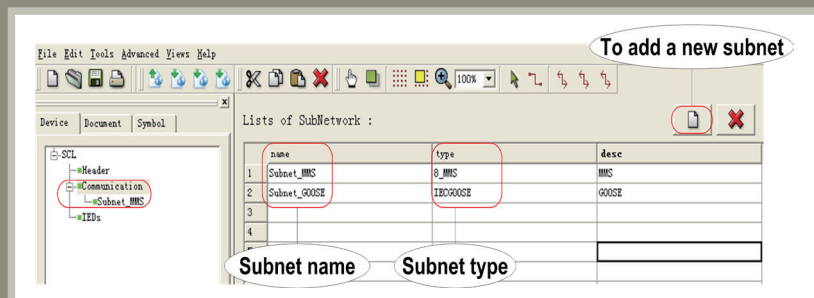
Figure 6. How to establish new subnets in SCD tool
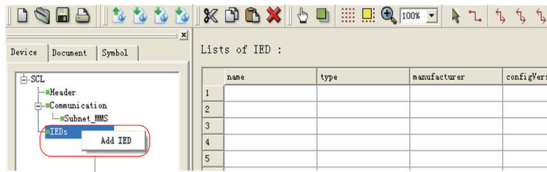
To import ICD files

Figure 7. Import ICD file into SCD tool

After adding the subnet, import the ICD file and change the ICD subnet to the actual on-site sub-network.
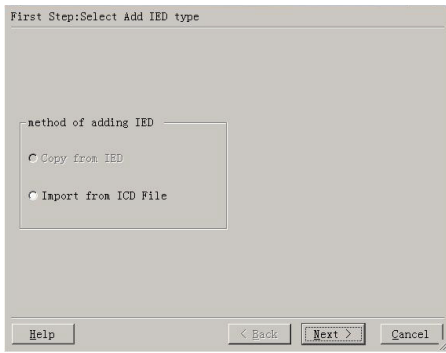

Figure 8. How to add IEDI

Right click 'IEDs' and choose 'Add IED' to open the window in Figure 8.
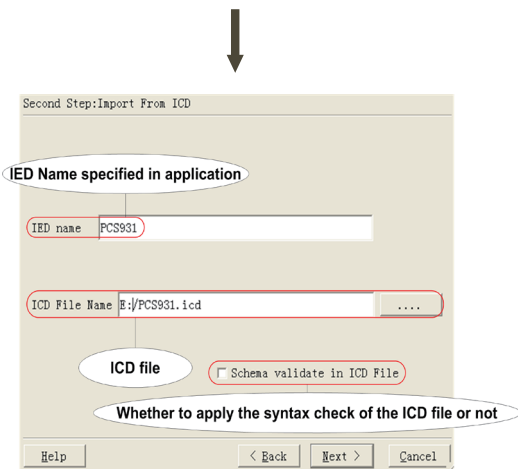

Figure 9. How to allocate IED name for the imported ICD file in SCD tool

Select 'Import from ICD File' and click 'Next' to open the window in Figure 9.
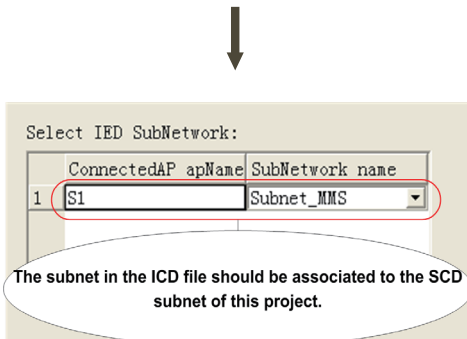
Insert IED name and ICD File Name, and click 'Next'.

Figure 10. How to associate the subnet in the ICD file to the SCD subnet of this project

Create the connection of GOOSE and SV network after importing the IDC file. Take GOOSE wiring for example, the relevant GOOSE information in ICD file are gathered in a GOOSE data set and saved in LD folder in GOLD. Create a GOOSE control block (GOCB) in the sub-window GSEControl, select the relevant data set, now the GOOSEID have been filled with the index directory of GOCB by default, and then the default index directory of GOCB is chosen as GOOSEID. Users can modify the Information according to actual on-site conditions.
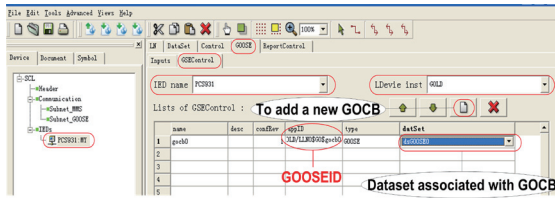
Figure 11. How to establish GOCB

After GOCB is created, users can start to setup the relevant communication parameters.
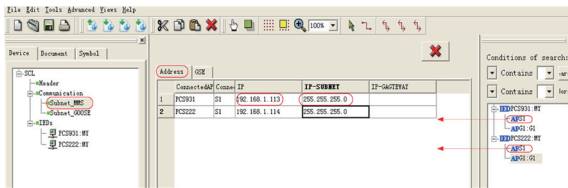

Figure 12. Configuration of MMS communication parameter

MMS parameters can be setup in Address window.
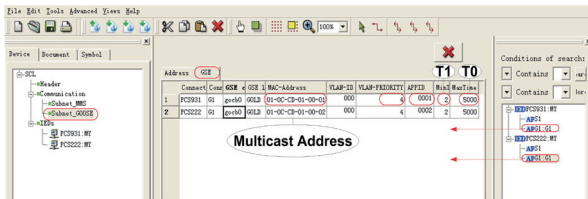

Figure 13. Configuration of GOOSE communication parameters

GOOSE communication parameters, which are applied to GOCB, can be setup in GSE window.
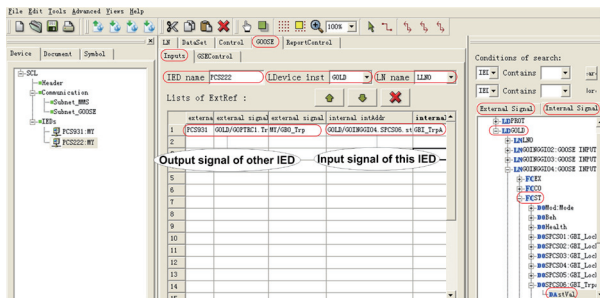

Figure 14. Configuration of GOOSE wiring

Once the data configuration is finished, users can start to arrange GOOSE wiring in the window shown in Figure 14. The wiring of GOOSE communication is configured at the receiving terminal. Users are allowed to create and configure the connections between virtual connectors of different devices.
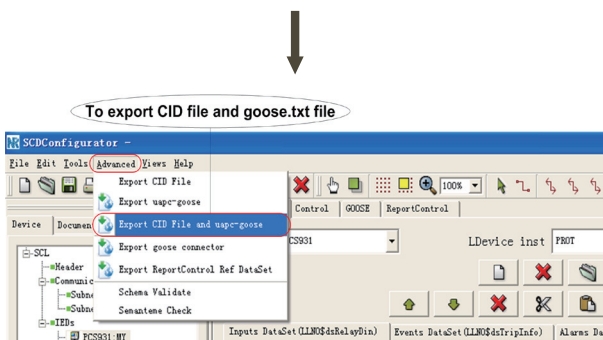

Figure 15.   Export CID file and GOOSE configuration file from SCD tool

Next, export the Config file goose.txt and the CID file from SCD tool, and download them to the corresponding IED.

Now the substation configuration is completed.

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