SCADA Data Gateway Server to Provide Transmission Data to Distribution Control Centers

Sajith Paulas, Danushka Gunarathne, Chirantha Jayasinghe and Amila De Silva

July 10, 2022

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S. J. PAULAS, Chief Engineer, Ceylon Electricity Board, Sri Lanka
sajith.paulas@gmail.com
W. D. M. D. R. K. GUNARATHNE, Electrical Engineer, Ceylon Electricity Board, Sri Lanka
ruwan.danushka@gmail.com
C. M. JAYASINGHE, Electrical Engineer, Ceylon Electricity Board, Sri Lanka
chiranthaj@gmail.com
A. D. De SILVA, Electrical Engineer, Ceylon Electricity Board, Sri Lanka
amiladananjaya@gmail.com

ABSTRACT

Information on transmission grid substations such as the status of switchgear, measurement data, and protection alarms are essential for proper day-to-day functions of automated distribution control centers. In Ceylon Electricity Board, Sri Lanka some distribution control centers are operated absence of required transmission information and therefore high demand for providing transmission data to them. Rather than provide required data directly from grid substations to distribution control centers, it was found that it is economical to route necessary data from a central location to the required location. The paper provides a solution by developing a central server which is called the SCADA data gateway server and its communication infrastructure established according to international standards.

KEYWORDS

SCADA - Supervisory control and data acquisition, IEC - International Electrotechnical Commission, ICCP - Inter-Control Centre Communications Protocol, DCC - Distribution control centers, CEB - Ceylon Electricity Board, NSCC - National System Control Center

INTRODUCTION

Distribution Control Centers (DCCs) of Ceylon Electricity Board (CEB) function independently in various branches which are called distribution provinces acquiring their downstream 33 kV switchgear states. Some DCCs were established by turnkey projects whereas the rest were implemented by the innovative CEB staff using trial Supervisory Control and Data Acquisition (SCADA) [1] software. Colombo City has a DCC, which is a fully-fledged DCC installed through a turnkey project. The other DCCs can monitor and control 33 kV feeder downstream switchgear within their territory such as auto reclosers and load break switches only. The main drawback when automating DCCs and deploying them during day-to-day activities such as outage management and distribution planning is the absence of particular 33 kV feeder information from transmission grid substations (GSs). To achieve an effective DCC, SCADA information of respective 33 kV feeders from grid substations is paramount.

SCADA information of grid substations including limited information of 33 kV feeders is communicated with the National System Control Center (NSCC) of CEB using Gateway or Remote Terminal Unit (RTU) at each grid substation using serial IEC 60870-5-101 [2] or ethernet IEC 60870-5-104 [2] communication protocol. SCADA signals available at NSCC can be transferred to DCCs using well developed international utility standard called Inter-Control Center Communications Protocol (ICCP) which is specified under IEC 60870-6 [3] protocol. Since the exchange data among other control centers are not considered in the formulation of NSCC of CEB, routing such SCADA data to DCC through ICCP is treated as not advisable with the following facts, by NSCC.

- The capacity of existing servers at NSCC are limited and therefore unable to include ICCP facility in their servers.

- Even ICCP facility is provided with an additional server there is a tendency of slowing down or even malfunction NSCC operation when generating quite a several events and alarms.
- It is necessary to deploy the original equipment manufacturer of NSCC each time when establishing a connection with each DCC through ICCP.

The alternative and possible method of providing required SCADA data to a DCC are to establish a communication connection between the gateway or RTU at the grid substation with the DCC. Configuring IEC 60870-5-101 or IEC 60870-5-104 master at DCC will enable acquiring SCADA data from gateway or RTU at grid substation by configuring additional port as 60870-5-101 or IEC 60870-5-104 as a slave. But same grid substation may require to connect to different DCCs since some of the 33 kV feeders of a particular grid substation are powering different distribution provinces. To connect many numbers of DCCs for a single grid substation required several ports in a gateway or in RTU which are equal to the number of DCCs which are going to be connected.

Considering the above facts, installing a central server to acquire all SCADA information from every grid substation and provide necessary information to every DCC respectively without a control facility is considered, studied, and implemented.

METHODOLOGY

Since SCADA information is available in IEC 60870-5-101 or IEC 60870-5-104 format in Gateway or RTU in every GSs, it is preferable to acquire all available SCADA signals except control signals but measurement signals, Alarms, and status information using the same communication protocol. Since data is available at Gateways and RTUs as IEC 60870-5-101 or IEC 60870-5-104 slave, a central server is configured as IEC 60870-5-101 or IEC 60870-5-104 master to acquire data. IEC 60870-5-101 is a serial protocol and it requires separate serial channels for each communication link from gateways to a central server. Therefore, it is necessary to acquire IEC 60870-5-101 serial data through ethernet media by deploying serial to ethernet converters. Transferring of IEC 60870-5-101 data to central server placed at CEB, Kent Road, Colombo 09 is illustrated in Figure 1.

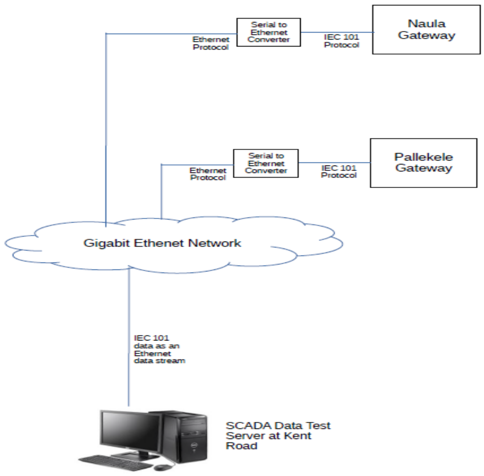

Figure 1: Transferring of IEC 60870-5-101 data to Server at Kent Road, Colombo 09

Communication between the central server and DCCs is established using IEC 60870-5-104 ethernet protocol to configure the central server as a slave and the DCC server as a master.

The SCADA information flow to DCC is illustrated in Figure 2.

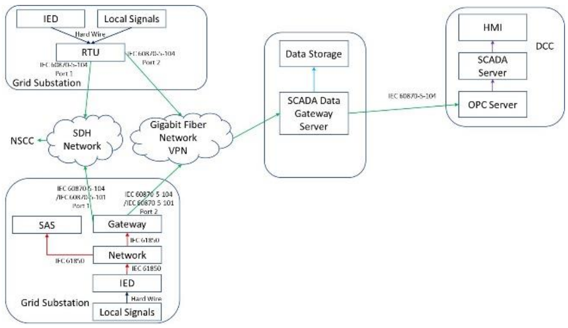

Figure 2: SCADA information flow to DCC

At present, limited SCADA information including switchgear status, measurements, and alarm signals is configured for 33 kV level at Gateways and RTUs. There are limited alarm signals such as Over-current & Earth fault Protection Operated, Under Frequency Load Shedding Operated, and Auto Re-closer Operated available but most of the protection alarms are grouped into one signal. It is necessary to configure separate alarm signals for the above including additional alarm signals such as fault current, fault impedance, and distance to the fault. SCADA data requirement for DCC from each GS is illustrated in Table 1.

SCADA data requirement from GS to distribution Control Centres		
Analog Signals	Current (R)	Feeder Specific
	Current (Y)	Feeder Specific
	Current (B)	Feeder Specific
	Voltage (R)	Feeder Specific
	Voltage (Y)	Feeder Specific
	Voltage (B)	Feeder Specific
	kW (R)	Feeder Specific
	kW (Y)	Feeder Specific
	kW (B)	Feeder Specific
	Fault Current (A)	Feeder Specific
	Transformer 1 Loading (A)	Grid Specific
	Transformer 2 Loading (A)	Grid Specific
	Transformer 3 Loading (A)	Grid Specific
	Transformer 4 Loading (A)	Grid Specific
	132/220kV Source 1 Current (R)	Grid Specific
	132/220kV Source 1 Current (Y)	Grid Specific
	132/220kV Source 1 Current (B)	Grid Specific
	132/220kV Source 2 Current (R)	Grid Specific
	132/220kV Source 2 Current (Y)	Grid Specific
	132/220kV Source 2 Current (B)	Grid Specific
Digital Signals	Earth Fault Trip Alarm	Feeder Specific
	Over Current Trip Alarm	Feeder Specific
	Under Frequency Trip Alarm	Feeder Specific
	Circuit Breaker Open / Close status	Feeder Specific
	Isolator Open / Close status	Feeder Specific
	Earth Switch Open / Close status	Grid Specific
	33kV bus coupler 1 Open / Close status	Grid Specific
	33kV bus coupler 2 Open / Close status	Grid Specific
	Local / Remote operation mode	Grid Specific

Table 1 SCADA data requirement from GS to distribution Control Centres

Therefore, it is necessary to implement the said requirement for new grid substations by transmission projects of CEB. Further, control & protection IEDs of existing 33 kV feeders necessary to be modified to include additional SCADA signals deploying Control & Protection – Transmission Branch of CEB. Necessary modifications of Gateways and RTUs need to be carried out by the Communication Branch of CEB.

Since DCC in the Central province had physical OPGW connectivity to Kiribathkumbura GS and is ready to integrate SCADA information from the central server, the DCC in the Central province was selected to conduct this research and development project.

SCADA DATA GATEWAY SERVER (IN-HOUSE DEVELOPMENT)

Working Principle

The basic architecture of the SCADA Data Gateway Server is depicted in Figure3.

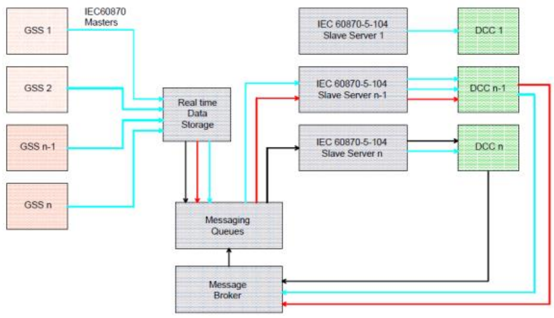

Figure 3: The basic architecture of the SCADA Data Gateway Server

There is one thread that is responsible to maintain the data from the GSs (source) and another thread that is responsible to send updates to DCCs who are interested in particular data points locate to them. These two disconnected processors are connected using messaging queues so that one process does need not to wait for the other process to finish.

The data from the source side is stored in a volatile real-time data storage, to have near-instantaneous data storing speed. This is data is stored in the random-access memory (RAM) of the hosting computer/s rather than stored in storage media-based databases like SQL.

Terminology

- GS Data Point
- DCC Data Point

A *GS datapoint* can be identified as a slot where a certain data signal value from a GS gets stored. This data point has the following attributes.

- Id
- Data Type- Type ID
- ASDU ID
- GS Comm ID
- IOA
- Name
- Description

GS datapoint can be subscribed by one or many *DCC datapoints.*
A *DCC datapoint* is a pointer to a *GS datapoint*, which is having same *Data Type- Type ID*. *DCC datapoint* has the following attributes.

- Id
- Data Type- Type ID (Equals to the subscribing GS datapoint)
- DCC Comm ID
- IOA
- ASDU ID
- Name
- Description
- GSS Data Point ID
- GI
- Cyclic
- GI Class

A *DCC datapoint* can receive data updates only when it subscribes to GS Data points. A DCC can subscribe to as many as data points it wishes from any GSs, subjected to authority.

Again, one *GS datapoint* can be subscribed by more than one *DCC datapoint*, by the same or distinct DCCs.

Software Development

This software has been developed as an open-source development.

Open-Source Libraries Used

- https://libiec61850.com/ [4]- IEC 60870-5-101/104 Client Server Libraries.
- https://docs.microsoft.com/en-us/ef/ [5]- Microsoft Entity Framework for configuration data storage with SQLite database.
- https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/concepts/linq/ [6]- LINQ for handling data structures.

Technologies used

- Visual Studio Community Base IED Environment with Dot Net Core 5.0 architecture.
- SQLite Database – for configuration settings storage.
- Mosquito MQTT – Messaging Broker and Messaging Queue

Operating System Compatibility

- Windows, Linux, MAC OS

SECOND PORT IN GATEWAYS AND RTUS

It was necessary to configure an additional communication port in Gateways and RTUs as IEC 60870-5-104 slave to acquire data to the SCADA data gateway server. The RTU databases were configured in offline software and configuration files were downloaded to the RTUs at the site. Gateways were configured in online mode. The configured ports are connected to the separate virtual local area network (VLAN) in the CEB communication network to access the SCADA data gateway server.

IEC 60870-5-101 ethernet converters were installed to acquire information from gateways with IEC 60870-5-101 ports and connected to the said VLAN in the CEB communication network to access the SCADA data gateway server.

COMMUNICATION NETWORK

It is necessary to connect the following connections to separate VLAN or wide area network (WAN) in Gigabit Ethernet network in CEB OPGW communication network.

- Additional second ports of the Gateways which are configured as IEC 60870-5-104 slave
- Additional second ports of the RTUs which are configured as IEC 60870-5-104 slave

- Additional second ports of the Gateways which are configured as IEC 60870-5-101 slave through ethernet converters
- Ethernet port of the SCADA Data Gateway Server which is configured as IEC 60870-5-104 master.

Further, at the grid substations, it was arranged to connect second ports of gateways or RTUs with or without converters to the communication multiplexer to establish said connectivity. Similarly, the IEC 60870-5-104 master port of the SCADA Data Gateway Server is required to be connected to the communication multiplexer at Kent Road, Colombo 09.

It is planned to connect each DCC to SCADA Data Gateway Server using a dedicated communication link through the Gigabit Ethernet network in CEB OPGW communication network. It is necessary to connect DCC to the communication multiplexer at the nearest grid substation through a fiber-optic connection. DCC of Central Province 02 is already connected to the Kiribathkumbura GS through a fiber-optic connection over the OPGW of the 33 kV feeder tower line. To connect DCC at the SCADA Data Gateway Server end it is required to install an ethernet switch which is connecting the communication multiplexer at Kent Road, Colombo 09. The communication network is illustrated in the Figure 4 Communication Overview diagram.

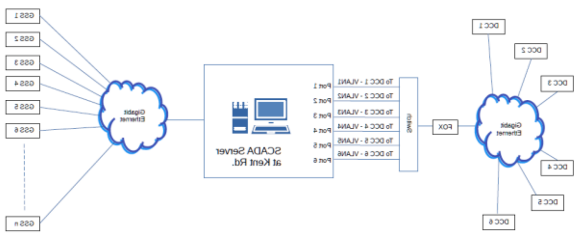

Figure 4: Communication Overview – SACDA Information Server

CYBER SECURITY

Apart from typical items such as gateways and RTUs in the CEB communication network, DCCs are connected externally to the network. Since the SCADA Data Gateway Server is located at Old System Control Building at Kent Road, Colombo 09 it is an internal device to the CEB communication network. To provide the guard against external threats, it was decided to install a Firewall at each DCC end.

DISTRIBUTION CONTROL CENTRE OF CENTRAL PROVINCE 02

Since the DCC direction of the SCADA Data Gateway Server is configured as IEC 60870-5-104 slave, it is required to configure the DCC server as an IEC 60870-5-104 Master station. But in SCADA software available at DCC at CP 02, IEC 60870-5-104 Master station is absent. Therefore, incorporating **O**bject Linking and Embedding (OLE) for **P**rocess **C**ontrol (**OPC**) [7] server is utilized to configure as IEC 60870-5-104 Master station. Today the acronym OPC stands for Open Platform Communications. [8] OPC server is acquiring SCADA information from SCADA Data Gateway Server through IEC 60870-5-104 protocol and then passes the same data to the SCADA software to display in the HMI.

CONCLUSION

Developing an in-house SCADA data gateway server provides a versatile and economical solution for the problems faced by the DCCs of CEB. Once all SCADA information is available at a central location it will be enabled to provide data to other third-party applications such as CEB Assist, web monitoring, and other DCCs too.

ACKNOWLEDGEMENT

The authors express their deep sense of gratitude to Ceylon Electricity Board to provide a working environment and infrastructure for this work.

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