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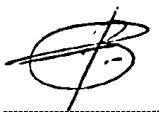
|  |  |  |
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# 1. Introduction

This document presents a high-level overview of the solution provided in response to Eskom's requirements detailed in their commercial enquiry for the development and supply of protection schemes, substation gateways, human machine interfaces and associated components for Eskom Transmission. The solution is presented in the form of a network architecture diagram and outlines the primary components which comprise the system together with a functional description of each component indicating its function and influence on the overall system.

# 2. Normative References

[1] ZA02251-22-D01 System Solution Communications Architecture Diagram.

# 3. Abbreviations

| Abbreviation | Description |
|---|---|
| BSW | Bay Switch |
| CT | Current Transformer |
| DB9 | D-sub 9 |
| DCC | Distribution Control Centre |
| DDR3 | Double Data Rate Type Three |
| DIN | Deutsches Institut für Normung |
| DNP | Distribution Network Protocol |
| DPAC | Discrete Programmable Automation Controller |
| ECC | Error-Correcting Code Memory |
| EIA | Electronic Industries Alliance |
| GOOSE | Generic Object Oriented Substation Event |
| GPS | Global Positioning System |
| GWSW | Gateway Switch |
| HMI | Human Machine Interface |
| I/O | Input/Outputs |
| IDF | Intermediate Distribution Frame |
| IEC | International Electrotechnical Commission |
| IED | Intelligent Electronic Device |
| IRIG-B | Inter-range instrumentation group |
| KVM | Keyboard Video Mouse |
| LC | Lucent Connector |
| MMS | Manufacturing Message Specification |
| MSTP | Multiple Spanning Tree Protocol |
| NCC | National Control Centre |
| NTP | Network Time Protocol |
| PCI | Peripheral Component Interconnect |
| PIU | Process Interface Unit |
| PT | Potential Transformer |
| RTAC | Real-Time Automation Controller |

| | |
|---|---|
| RTU | Remote Terminal Unit |
| SCADA | Supervisory Control and Data Acquisition |
| SEL | Schweitzer Engineering Laboratories |
| SLC | Single Level Cell |
| SNTP | Simple Network Time Protocol |
| SSD | Solid-State Drive |
| SSW | Station Switch |
| VLAN | Virtual Local Area Network |
| VRRP | Virtual Router Redundancy Protocol |
| VT | Voltage Transformer |

# 4. System Architecture

The system solution communications architecture diagram is presented in Appendix A and represents the full suite of schemes developed for the development/prototyping contract with Eskom.

The system solution incorporates a two-tier network architecture design consisting of low-tier, low capacity network switches which provide the physical connectivity to end devices such as the Process Interface Units, Intelligent Electronic Devices (IEDs), Gateways, Human Machine Interfaces (HMIs), routers and GPS units. The top-tier, high capacity, high-speed backbone switches provides physical connectivity to the lower-tier switches.

Data prioritization is achieved at a networking level by the class of service regime defined for different VLANs. At IED level, prioritization will be given to GOOSE by using the priority level assigned to its VLAN tag. SCADA data and remote engineering access data leaving the ethernet port of the IED is untagged with no priority level and hence the possibility to prioritize this data is not available.

The system design incorporates the dual main protection philosophy, whereby applications with dual main protection are physically split into two fully redundant, independent protection panels.

The solution features test mode, which facilitates the commissioning and testing of indications and controls between the HMI/Gateway and protection schemes of a single main, whilst the primary equipment remains operational, controlled and protected via the second main. Test mode is initiated by a software switch residing in the HMI under test and shall be released from test mode by the same HMI through the same software control switch. In the event, the HMI under test experiences a failure whilst the system is in test mode, an override software switch shall be available through the gateways HMI interface.

The main constituents of the system include the following:

1. Process Interface Units (PIUs)
2. Protection and Multifunction Intelligent Electronic Devices (IEDs)
3. Networking Equipment
4. GPS Time Synchronisation Units
5. Substation Gateways
6. HMIs
7. Measurements Panel
8. Substation Logic Processor
9. Station IED
10. Patch Panels and Patch Boxes
11. Fibre Cable and Patch Leads

## 4.1 Fibre Optic Cable and Patch Leads

Multimode fibre optic cable will be used to construct the ethernet network. Fibre optic patch leads will be used to connect devices that exist within the same panel. Fibre optic cable will be used when there is a need for fibre to leave a panel and connect to a device that may exist in a different panel. Provision in each panel will be made for splicing the 12-core multimode fibre optic cables.

## 4.2 Patch Panels and Patch Boxes

The system design will make use of patch boxes and 19-inch rackmount patch panels to facilitate both the splicing and patching of fibre optic cables and fibre optic patch leads respectively.

The fibre optic patch box is DIN rail mounted and is equipped with six LC duplex mid-couplers and pigtails and allows for the splicing of a single 12-core fibre optic cable.

The 19-inch rackmount fibre optic patch panel is equipped with two groups of six LC duplex mid-couplers with pigtails and allows for the splicing of two 12-core fibre optic cables.

## 4.3 Process Interface Units

At process level, Process Interface Units (PIUs) are used to digitise the binary signals hardwired from the substation primary plant equipment into event data published as IEC 61850 GOOSE to corresponding upstream protection IEDs. Both protection IEDs and PIUs support the ability to publish and subscribe to GOOSE messages.

CT and VT secondary circuits are hardwired to test blocks residing in the relevant protection/measurements scheme. CT secondary circuits traverse through the PIU junction box before connecting to the relevant protection scheme. VT secondary circuits are hardwired directly to the scheme.

In the control direction, tripping and closing commands to the breaker are communicated using GOOSE via the PIU. Trip signals originating from the Buszone protection and the emergency trip pushbutton are hardwired to trip the relevant breaker directly. In both instances, the hardwired trip signal extends from the protection scheme and the buszone scheme respectively to the junction box where it will be paralleled with the outputs of the PIU to trip the breaker.

Physical connectivity between the IED protection panel and PIU is achieved using multicore 1300 nm multimode fibre cable which terminates onto a wall mount patch box located at the PIU on one end. The other end terminates onto a 19-inch rack-mount patch panel residing in the protection panel. At both ends, 1300 nm multimode patch leads are used to patch through the fibre connection using LC duplex connectors. The PIU connects using this fibre patch-through connection to a bay switch located in the protection panel to which the protection IED also connects using 1300 nm multimode patch leads.

The process network which exists between the IEDs and PIUs are logically separated from the station network by enabling VLANs on each of the bay switches. GOOSE event data originating from PIUs are thereby prevented from being forwarded onto the backbone network.

There are two product offerings for the PIU i.e. the SEL-2440 Discrete Programmable Automation Controller (DPAC) for the tap change PIU and the SEL-2240 Axion for the breaker and transformer PIU. These are described in Tables 1 to 3 respectively below. The SEL-2440 is selected as the tap change PIU due to it having a smaller I/O requirement as well as providing cost saving benefits.

Each PIU is housed within a junction box. The breaker junction box includes both main 1 and main 2 breaker PIU's. The transformer junction box includes both main 1 and main 2 transformer PIU's as well as one tap change PIU.

The junction boxes are denoted in the system solution communications architecture diagram by the following designations:

- 6JB-7100 Breaker Junction Box.
- 6JB-7200 Transformer Junction Box.

**Table 1: Breaker Process Interface Unit**

| **Category** | |
|---|---|
| Model | SEL-2240 Axion |
| Firmware ID | SEL-2241-R138-V0-Z001001-D20170220 |
| Revision | R138-V0 |
| Ethernet Connection | 1 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 4 EIA-232, DB9 |
| Client Protocols | SEL, DNP3, Modbus, IEC 60870-5-101/104, C37.118 Synchrophasors, L&G 8979, CP2179, IEC 61850 MMS and MMS Client File Services |
| Server Protocols | SEL, DNP3, Modbus, L&G 8979, SES-92, IEC 60870-5-101/104, C37.118 Synchrophasors |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |
| Power Supply Rating | 125/250 Vdc; 120/240 Vac |
| Digital Inputs | 120 Inputs (220 Vdc/Vac) |

| | |
|---|---|
| Digital Outputs | 16 Standard Form A and 10 Form A Fast High-Current Digital Outputs |

**Table 2: Transformer Process Interface Unit**

| **Category** | |
|---|---|
| Model | SEL-2240 Axion |
| Firmware ID | SEL-2241-R138-V0-Z001001-D20170220 |
| Revision | R138-V0 |
| Ethernet Connection | 1 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 4 EIA-232, DB9 |
| Client Protocols | SEL, DNP3, Modbus, IEC 60870-5-101/104, C37.118 Synchrophasors, L&G 8979, CP2179, IEC 61850 MMS and MMS Client File Services |
| Server Protocols | SEL, DNP3, Modbus, L&G 8979, SES-92, IEC 60870-5-101/104, C37.118 Synchrophasors |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |
| Power Supply Rating | 125/250 Vdc; 120/240 Vac |
| Digital Inputs | 72 Inputs (220 Vdc/Vac) |
| Digital Outputs | 16 Standard Form A and 10 Form A Fast High-Current Digital Outputs |
| Analogue Inputs | 16 AI (±20mA, ±2mA, ±10V) |

**Table 3: Tap Change Process Interface Unit**

| **Category** | |
|---|---|
| Model | SEL-2440 |
| Firmware ID | SEL-2440-R214-V2-Z007004-D20160210 |
| Revision | R214-V2 |
| Ethernet Connection | 1 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 2 EIA-232, DB9 |
| Server Protocols | SEL, DNP3, Modbus, and IEC61850 MMS |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |
| Power Supply Rating | 125/250 Vdc; 120/240 Vac |
| Digital Inputs | 32 Inputs (220 Vdc/Vac) |
| Digital Outputs | 12 Form A and 4 Form C Digital Outputs |

## 4.4 Protection and Multifunction Intelligent Electronic Devices

For the development contract, the following protection schemes will be developed and prototyped:

- 6DIP-7100 Diameter interface for breaker-and-a-half applications
- 6FZD-7100 Line distance/differential protection with transfer
- 6BC-7100 Bus coupler protection with transfer
- 6FZDB-7100 Feeder for breaker-and-a-half applications
- 6TAB-7100 Transformer for breaker-and-a-half applications
- 6TA-7300 Transformer for double busbar applications
- 6TC-7100 Tap change panel

Furthermore, the automation commodities will also be grouped and developed into schemes which will consist of the following. These are discussed in section 4.12.

- 6AFS-7100 Fibre switching panel
- 6ACE-7100 Common equipment panel
- 6AGW-7100 Gateway (& HMI, Router) panel

Each of the protection schemes will be equipped with protection IEDs, the details of which are described in Tables 4-10 below. Each IED can support multiple GOOSE and MMS datasets. Each IED will be configured with multiple MMS buffered report control blocks for alarms, protection trips and indications, and multiple unbuffered report control blocks for analogue reporting. This will be used by both Main 1 and Main 2 substation gateways as part of the gateway redundancy regime. Furthermore, multiple GOOSE control blocks will be configured. This shall be used for publishing control information to the PIU and, secondly, for the transfer of inter-trip signals within the substation, indications and interlocking signals that may be required between IEDs.

Each IED will interface directly with a network switch at bay level using 1300 nm multimode patch leads with LC duplex connectors on either end.

For the 6FZD-7100 and 6FZDB-7100 feeder protection schemes, provision is made within the panel to facilitate a third-party differential protection IED. In certain applications, this third-party IED may be necessary to communicate over fibre with a corresponding existing IED located at the remote end of the feeder for differential protection. This third-party IED transfers its tripping to the schemes main protection IED using hardwired signals which is sent via GOOSE to the corresponding breaker PIU to trip the breaker. All third-party IED's are provisioned on the engineering VLAN for engineering access.

The 6FZD-7100 and 6BC-7100 schemes include an additional optional SEL-2440 I/O extension box which allows for the integration of additional hardwired signals which may be required for brownfield applications. The optional SEL-2440 I/O extension box will be included as part of the prototype scheme.

**Table 4: 6DIP-7100**

| **Category** | |
|---|---|
| Model | SEL-2240 Axion |
| Firmware ID | SEL-2241-R138-V0-Z001001-D20170220 |
| Revision | R138-V0 |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 4 EIA-232, DB9 |
| Client Protocols | SEL, DNP3, Modbus, IEC 60870-5-101/104, C37.118 Synchrophasors, L&G 8979, CP2179, IEC 61850 MMS and MMS Client File Services |
| Server Protocols | SEL, DNP3, Modbus, L&G 8979, SES-92, IEC 60870-5-101/104, C37.118 Synchrophasors, IEC 61850 MMS and MMS Server File Services |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |

**Table 5: 6FZD-7100**

| Category | |
|---|---|
| Model | SEL-411L |
| Firmware ID | SEL-411L-R120-V0-Z012002-D20161215 |
| Revision | R120-V0 |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) and 2 10/100BASE-T |
| Serial Connection | 4 EIA-232, DB9 |
| Server Protocols | SEL, DNP3, C37.118 Synchrophasors, IEC 61850 MMS |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |
| | |
| Model | SEL-2440 |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 2 EIA-232, DB9 |
| Server Protocols | SEL, DNP3, Modbus, and IEC61850 MMS |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |

**Table 6: 6BC-7100**

| Category | |
|---|---|
| Model | SEL-451 |
| Firmware ID | SEL-451-5-R318-V0-Z023012-D20170326 |
| Revision | R318-V0 |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 4 EIA-232, DB9 |
| Server Protocols | SEL, DNP3, C37.118 Synchrophasors, IEC 61850 MMS |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |
| | |
| Model | SEL-2440 |
| Firmware ID | SEL-2440-R214-V1-Z007004-D20160210 |
| Revision | R214-V1 |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 2 EIA-232, DB9 |
| Server Protocols | SEL, DNP3, Modbus, and IEC61850 MMS |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |

**Table 7: 6FZDB-7100**

| Category | |
|---|---|
| Model | SEL-411L |
| Firmware ID | SEL-411L-R120-V0-Z012002-D20161215 |
| Revision | R120-V0 |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 4 EIA-232, DB9 |
| Server Protocols | SEL, DNP3, C37.118 Synchrophasors, IEC 61850 MMS |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |

**Table 8: 6TA-7100**

| Category | |
|---|---|
| Model | SEL-487E |
| Firmware ID | SEL-487E-3-R314-V1-Z108101-D20170327 |
| Revision | R314-V1 |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 4 EIA-232, DB9 |
| Server Protocols | SEL, DNP3, C37.118 Synchrophasors, IEC 61850 MMS |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |

**Table 9: 6TA-7300**

| Category | |
|---|---|
| Model | SEL-487E |
| Firmware ID | SEL-487E-3-R314-V1-Z108101-D20170327 |
| Revision | R314-V1 |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) and 1 10/100BASE-T |
| Serial Connection | 4 EIA-232, DB9 |
| Server Protocols | SEL, DNP3, C37.118 Synchrophasors, IEC 61850 MMS |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |

**Table 10: 6TC-7100**

| Category | |
|---|---|
| Model | REG-DA |
| Quantity | 2 |
| Firmware | 2.23 |
| Ethernet Connection | 1 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 1 EIA-232, DB9 |
| Server Protocols | IEC 61850 MMS |
| Peer-to-Peer Protocols | IEC 61850 GOOSE |

## 4.5 Networking Equipment

In the two-tier network architecture design, the RSG2100 industrial managed ethernet switch will serve the lower tier levels and provide the required connectivity to all the end devices. All end devices will connect to these switches in a star network topology using 1300nm multimode multicore fibre optic cables.

In the network architecture design shown in Figure 1, the RSG2100 is referred to by more than one designation, depending on the location of the network switch. In the protection panel, the RSG2100 is referred to as the Bay Switch (BSW). In the gateway panel, the RSG2100 is referred to as the Gateway Switch (GWSW) and in the common equipment panel, the RSG2100 is referred to as the Station Switch (SSW).

There are two variants of the RSG2100 that has been offered with the main difference between these variants being the port count. The details of the two RSG2100 variants are detailed in Tables 11-12.

**Table 11: Large RSG2100 Variant**

| Category | |
|---|---|
| Model | RSG2100 |
| Firmware ID | 4.3.3 |
| Ethernet Connection | 10 multimode 100BASE-FX (LC Connector), 2 multimode 1000BASE-SX (LC Connector), and 2 10/100BASE-TX (RJ45) |
| Power Supply Rating | 88-300 Vdc; 85-564 Vac (dual supplies) |

**Table 12: Small RSG2100 Variant**

| Category | |
|---|---|
| Model | RSG2100 |
| Firmware ID | 4.3.3 |
| Ethernet Connection | 4 multimode 100BASE-FX (LC Connector), 2 multimode 1000BASE-SX (LC Connector), and 2 10/100BASE-TX (RJ45) |
| Power Supply Rating | 88-300 Vdc; 85-564 Vac (dual supplies) |

The RSG2488 industrial managed switch detailed in Table 13 below will be used to create the high-capacity, high-speed backbone network. The backbone switches will be in the fibre switching panel and will be connected in a ring network topology, utilising MSTP for managing link redundancy and load balancing.

Each of the lower-tier network switches will connect to a backbone switch in a star network topology using 850 nm multimode multicore fibre cables which will be spliced and patched through on either end using 19-inch rackmount patch panels.

**Table 13: RSG2488 Backbone Switch**

| Category | |
|---|---|
| Model | RSG2488 |
| Firmware ID | 4.3.3 |
| Ethernet Connection | 16 multimode 1000BASE-SX (LC Connector), and 2 10/100BASE-TX (RJ45) |
| Power Supply Rating | 88-300 Vdc; 85-564 Vac (dual supplies) |

The RX1500 router detailed in Table 14 below performs the task of routing traffic between VLANs and subnets that exist on the network. The router will reside in each of the gateway panels and will directly interface with the gateway switch using LC duplex connectors. Virtual Router Redundancy Protocol (VRRP) will be used to manage router redundancy.

**Table 14: RX1500 Router**

| Category | |
|---|---|
| Model | RX1500 |
| Firmware ID | ROX II |
| Ethernet Connection | 4 multimode 100BASE-FX (LC Connector), 6 10/100BASE-TX (RJ45) |
| Power Supply Rating | 88-300 Vdc; 85-564 Vac (dual supplies) |

Each of the networking devices described above will be configured for SNMP. RuggedNMS is a network management system which can be used to gather SNMP information from the networking devices. This information is used to build up the map of the network, allowing network administrators the ability to easily monitor and maintain the network.

In cases where RuggedNMS is not employed in the solution, the Gateway shall be configured as the SNMP Client/Manager to communicate with the following devices for critical alarms which will be communicated upstream to the respective SCADA master stations:

1. RuggedCom RSG2100
2. RuggedCom RSG2488
3. RuggedCom RX1500
4. RuggedCom RS416
5. Serial Device Servers
6. Routers
7. Backbone Switches
8. GPS
9. HMI Windows MIBS

RuggedNMS is not included for the development solution.

## 4.6 GPS Time Synchronisation Unit

The GPS Time Synchronisation Unit detailed in Table 15 below provides time synchronization to all SNTP capable devices that are part of the system. SNTP will be used to synchronize these devices over the network. The GPS Time Synchronisation Unit resides in the gateway panel and interfaces directly with the gateway switch using 1300 nm multimode patch leads with LC duplex connectors on either end. Furthermore, the GPS clock is equipped with an external surge suppressor and GPS antenna which are connected to the GPS clock using LMR400 low loss coaxial cable.

The gateway will use IRIG-B protocol from the GPS clock for time synchronization. Physical IRIG-B connectivity between the GPS clock and gateway will be achieved by connecting a serial cable from the serial port (DB9) of the GPS clock to Port 1 of the SEL3390S8 serial adaptor card (RJ45) mounted within the gateway. Foiled, screened, stranded cable will be used to facilitate this connection.

Where applicable, end devices subscribing to SNTP messages will be configured with the GPS clock as the main SNTP server and the gateway as the backup SNTP server.

**Table 15: GPS Time Synchronisation Unit**

| Category | |
|---|---|
| Model | SEL-2488 |
| Firmware ID | SEL-2488-R103-V0-Z004001-D20161207 |
| Revision | R103-V0 |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector), and 2 10/100BASE-TX (RJ45) |
| Time Distribution Protocols | IRIG-B, NTP |
| Power Supply Rating | 125/250 Vdc; 125/250 Vac |
| Antenna | SEL-9524B |
| Surge Suppressor | J01028A0044 |

## 4.7 Substation Gateway

The substation gateway detailed in Table 16 below resides in the gateway panel and interfaces directly with the gateway switch using 1300 nm multimode patch leads with LC duplex connectors. The gateway will be responsible for acquiring SCADA data from all devices that are part of the system using IEC61850 MMS. It will further facilitate the transmission of this data to NCC, STABNAC and DCC using IEC60870-5-101, and to the HMI using IEC61850 MMS.

Communication to the three control centres will be achieved using Ports 2-4 on the SEL3390S8 serial adaptor card mounted within the gateway. These ports natively support 4-wire RS422. Considering that there will be a single IEC60870-5-101 link for each of the control centres, both Main 1 and Main 2 gateways (for each link) will be daisy chained over RS422 using foiled twisted pair multicore cable and extended to an RS422 port residing at the BME in the Eskom Telecommunications Panel. The point of connectivity at which both gateways will be daisy-chained will reside at terminals installed in Main 1 gateway panel.

Apart from SCADA acquisition, both Main 1 and Main 2 gateways will utilise an external database synchronization mechanism using mirrored bits to manage gateway redundancy. Mirrored bits is a serial protocol which will require conversion from serial to fibre to extend physical connectivity between gateways. The SEL-2814 serial to fibre media converter will be used for this purpose.

The mirrored bits link has a second purpose and that is it administers which gateway reports to the control centre. Both gateways are identical in terms of its IEC60870-5-101 configuration. Real-time administration between the two gateways is thus important to prevent both gateways from reporting at the same time. Primary administration between gateways is achieved using the mirrored bits link. If the link encounters a failure, a backup dedicated GOOSE link is provided.

Communications between the gateway and HMI using IEC61850 MMS will be over the Ethernet network.

**Table 16: Substation Gateway**

| Category | |
|---|---|
| Model | SEL-3555 |
| Firmware ID | SEL-3555-R138-V0-Z001001-D20170220 |
| Revision | R138-V0 |
| Processor | Intel i7-3612QE Quad Core 2.1GHz |
| RAM | 2 x 4GB DDR3 1333MHz ECC MiniDIMM |
| SSD Storage | 120GB Industrial Grade SLC SSD |
| Expansion Slots | PCI Slot 2: SEL-3390S8 PCIe Serial Card, PCI Slot 4: SEL-3390E4 PCIe Ethernet Card |
| Ethernet Connection | 2 Multimode SFP 100BASE-FX and 2 10/100/1000BASE-TX |
| Serial Connection | 2 EIA-232 DB9 and 6 EIA-232/-422/-485 RJ45 |
| Power Supply Rating | 125/250 Vdc; 120/240 Vac |
| Client Protocols | SEL, DNP3, Modbus, IEC 60870-5-101/104, C37.118 Synchrophasors, L&G 8979, CP2179, IEC 61850 MMS and MMS Client File Services |
| Server Protocols | SEL, DNP3, Modbus, L&G 8979, SES-92, IEC 60870-5-101/104, C37.118 Synchrophasors, IEC 61850 MMS and MMS Server File Services |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |

## 4.8 HMI

The Human Machine Interface is divided into both hardware and software components which are detailed in Table 17. The HMI computing platform resides in the gateway panel and interfaces directly with the gateway switch using 1300 nm multimode patch leads with LC duplex connectors. The HMI retrieves data from the substation gateways using IEC61850 MMS and visualises this data using Vijeo Citect.

**Table 17: HMI Computing Platform and HMI Software**

| Category | |
|---|---|
| Model | SEL-3355 |
| Processor | Intel i7-3612QE Quad Core 2.1GHz |
| RAM | 2 x 8GB DDR3 1333MHz ECC MiniDIMM |
| SSD Storage | 2 x 60GB Industrial Grade SLC SSD |
| Expansion Slots | PCI Slot 2: SEL-3390S8 PCIe Serial Card, PCI Slot 4: SEL-3390E4 PCIe Ethernet Card |
| Ethernet Connection | 2 Multimode SFP 100BASE-FX and 4 10/100/1000BASE-TX |
| Serial Connection | 2 EIA-232 DB9 and 6 EIA-232/-422/-485 RJ45 |
| Power Supply Rating | 125/250 Vdc; 120/240 Vac (dual supplies) |
| | |
| HMI Software | Vijeo Citect 2016 |
| Client Protocols | IEC61850 MMS |
| Tag Licence | Full server, 5000 points |

Each HMI will be equipped with two 24-inch monitors which will physically be located at the operator workstation. As the monitors are physically detached, KVM extender modules will be used to extend the keyboard, mouse and video of the HMI computing platform to the operator workstation. Physical connectivity between the local and remote KVM modules will be achieved using 1300 nm multimode fibre cable. These are detailed in Table 18 below.

**Table 18: HMI Accessories**

| Category | |
|---|---|
| KVM Extender | MVX2-F Dual DVI KVM extender pair over multimode fibre |
| Monitor | LG 24MP58 24-inch Class Full HD LED Monitor |
| Keyboard | SKB-107-TP Industrial Keyboard with integrated touch pad. |
| Mouse | SM502 IP67 Silicone water and chemical-resistant mouse |

## 4.9 Measurements

A separate measurements panel incorporating the SEL-2240 Axion detailed in Table 19 below will be utilised for measurements. The SEL-Axion will be equipped with input modules allowing for direct CT and VT measurements. Furthermore, the SEL-2240 Axion includes an SEL-2243 power coupler which allows for the possibility of future expansion should more input measurement cards be required. The SEL-2240 Axion will include both IEC61850 MMS client and IEC61850 MMS server protocols. Where applicable, IEC61850 MMS Client will be used to acquire plant status data from the respective protection IEDs for busbar VT selection. IEC61850 MMS Server will be used to facilitate the transfer of measurement data to the both substation gateways.

**Table 19: Measurements Axion**

| Category | |
|---|---|
| Model | SEL-2240 Axion |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 4 EIA-232, DB9 |
| Client Protocols | SEL, DNP3, Modbus, IEC 60870-5-101/104, C37.118 Synchrophasors, L&G 8979, CP2179, IEC 61850 MMS and MMS Client File Services |
| Server Protocols | SEL, DNP3, Modbus, L&G 8979, SES-92, IEC 60870-5-101/104, C37.118 Synchrophasors, IEC 61850 MMS and MMS Server File Services |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |
| Power Supply Rating | 125/250 Vdc; 120/240 Vac |
| AC Analogue Inputs | 64CT and 64 PT inputs (0-22A, 5-400V) |

The SEL-2240 Axion will reside in the measurements panel and will connect to the station switch residing in the common equipment panel.

## 4.10 Substation Logic Processor

The substation-level logic processor detailed in Table 20 below will reside in the common equipment panel and is envisaged to perform overall system supervision. Data will be acquired from the IEDs and the Gateway depending on the data required for processing by the substation logic processor. The substation-level logic processor will include both IEC61850 MMS client and IEC61850 MMS server protocols. The substation-level logic processor interfaces directly with the station switch using 1300 nm multimode patch leads with LC duplex connectors.

**Table 20: Substation-Level Logic Processor**

| Category | |
|---|---|
| Model | SEL-3530 RTAC |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 17 EIA-232/-485, DB9 |
| Client Protocols | SEL, DNP3, Modbus, IEC 60870-5-101/104, C37.118 Synchrophasors, L&G 8979, CP2179, IEC 61850 MMS and MMS Client File Services |
| Server Protocols | SEL, DNP3, Modbus, L&G 8979, SES-92, IEC 60870-5-101/104, C37.118 Synchrophasors, IEC 61850 MMS and MMS Server File Services |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |
| Power Supply Rating | 125/250 Vdc; 120/240 Vac |

## 4.11 Station IED

The station IED detailed in Table 21 below will serve the purpose of a traditional RTU with hardwired I/O capabilities. The station IED resides in the common equipment panel and interfaces with the station switch using 1300 nm multimode patch leads with LC duplex connectors.

The station IED will terminate onto Krone LSA-Plus connector modules using the traditional IDF concept. Two power supplies will be incorporated into the design to supply independently the digital input and digital output circuits.

**Table 21: Station IED**

| Category | |
|---|---|
| Model | SEL-2240 Axion |
| Ethernet Connection | 2 multimode 100BASE-FX (LC Connector) |
| Serial Connection | 4 EIA-232, DB9 |
| Client Protocols | SEL, DNP3, Modbus, IEC 60870-5-101/104, C37.118 Synchrophasors, L&G 8979, CP2179, IEC 61850 MMS and MMS Client File Services |
| Server Protocols | SEL, DNP3, Modbus, L&G 8979, SES-92, IEC 60870-5-101/104, C37.118 Synchrophasors, IEC 61850 MMS and MMS Server File Services |
| Peer-to-Peer Protocols | MIRRORED BITS®, IEC 61850 GOOSE |
| Power Supply Rating | 125/250 Vdc; 120/240 Vac |
| Digital Inputs | 64 Inputs (48 Vdc/Vac) |
| Digital Outputs | 16 Form A Digital Outputs |
| Analogue Inputs | 16 AI (±20mA, ±2mA, ±10V) |

## 4.12 Automation Panels

The automation commodities as discussed above are grouped and developed into schemes. The 6AFS-7100 Fibre Switching Panel includes the large RSG2488 backbone switch and seven 19-inch rackmount patch panels to facilitate the backbone network. Both main 1 and main 2 6AFS-7100 fibre switching panels will be prototyped.

The 6AGW-7100 Gateway (& HMI, Router) panel includes the substation gateway, HMI, KVM, GPS time synchronization unit, router and a small RSG2100 variant (termed the gateway switch). Both main 1 and main 2 6AGW-7100 Gateway (& HMI, Router) panels will be prototyped.

The 6ACE-7100 Common Equipment Panel includes the substation logic processor, station IED and a large RSG2100 variant (termed the station switch). Provision is made in the common equipment panel for the interfacing of two third party

Buszone schemes. Two 19-inch rackmount fibre optic patch panels will be provided in the common equipment panel to facilitate the connection between the two external Buszone schemes and the station switch.

## 5. Acceptance

This document has been seen and accepted by:

| Name | Designation |
|---|---|
| Dinesh Bhana | Project Manager |

## 6. Revisions

| Date | Rev. | Compiler | Remarks |
|---|---|---|---|
| Dec 2016 | 0 | F. Ismail | Eskom Transmission Integrated Protection and Substation Automation Solution System Design Report for contract 4600060000 |
| Jan 2017 | 1 | F. Ismail | Updated with Eskom's comments |
| Feb 2017 | 2 | F. Ismail | Updated with Eskom's comments |
| Apr 2017 | 3 | F. Ismail | Updated with Eskom's comments |
| Apr 2017 | 4 | F. Ismail | Updated with Eskom's comments |

## 7. Development team

The following people were involved in the development of this document:

- Fareed Ismail
- Sagar Dayabhai

## 8. Acknowledgements

Not applicable.

## Appendix A: System Solution Communications Architecture Diagram