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DESIGN AND OPTIMAL SOLUTION ON UNIFIED SUBSTATION AUTOMATION SYSTEM IMPLEMENTATION

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ABSTRACT

The IEC61850 based substation automation system (SAS) solution are being implemented by many providers to power industry which is open challenge to re-fine communication network, IED interoperability and HMI functionality to derive the improvement in SA protection ,control and monitoring. The available multi-vendor SA system could not get uniform SAS functionality. Therefore, this paper will review the SAS engineering design, SA architecture, communication network & its interconnection with PRP and HSR protocol. The proposed SA architecture including HMI uniform functionality based on optimal solution have been presented in this paper in line with described design process methodology .the proposed scheme will helpful for diagnosis fault during maintenance, ease for operator to manipulate uniform SA system ,got better performance, reduce cost of system and become reliable.

KEYWORDS: IEC61850, Substation Automation System, SA Engineering Design, HSR/PRP, uniform HMI functionality

INTRODUCTION

The Substation is the key for power system transmission and distribution network.[1] for improving the reliability of power system ,it is in wide spread use for the purpose of protection, control and monitoring in Substation automation system(SAS), and also where the power system can be accessed by the supervisory network management system.[2],[3] Evolving from serial communication based centralized systems to IEC 61850 based distributed approaches as of today, with integrated or independent process bus and station bus. Intelligent Electronic Devices (IEDs) [4] [5] [6], taking into account the digital communication and the interaction among themselves such as merging units, Phasor measurement unit protective relays IEDs, bay Controllers BCUs, metering and monitoring devices, are integrated into the substation automation network, The IEDs reports/signals and settings are integrated in this system, The HMI control and monitor the switchgear/GIS equipments and Gateway for operational and non-operational data communication to and from control centers SCADA.[5][7] [8] IEC 61850 specifies a network redundancy scheme [9] that improves the system reliability for substation communication. It is based on two complementary protocols defined in the IEC 62439-3 Clause 4 standard parallel redundancy protocol (PRP) and high availability seamless redundancy (HSR) protocol in clause-5.[10], [11],[12].

The basic functionality of Substation Automation is given by its tasks and will not be changed by IEC 61850. Initially, the communication is the milestone of SA and, therefore, IEC 61850 the most important key for designing systems. The selection of mainstream communication technology is made as per client specification based on their standards. Therefore, these features support designing optimized systems. Optimization includes not only functional performance but also economic aspects like investment, availability, expandability and maintainability, i.e. all life cycle costs. For specification, design and engineering, the most important feature of IEC 61850 is its support to strong formal description of the substation and its automation system.

The rest of the paper is organized as follows. In Section 2, briefly present the SA engineering design. In Section 3, proposed SA architecture with HMI

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uniform functionality and its testing finally, in Section 4, proposed optimal solution for SAS scheme

Section 4, proposed optimal solution for SAS scheme and engineering design, in section 5 summarize our work.

SUBSTATION AUTOMATION ENGINEERING DESIGN

The following factors are to be considered while engineering design for substation automation system.

Project Technical Specification (PTS)

The customer specification and standards have to include three areas of requirements, i.e. the functionality needed, the performance requested, and all constraints applicable. The functionality refers mainly to the given single-line diagram of the substation and the protection and control functions of the substation automation system. The performance includes not only the reaction times on certain events but also figures for reliability and availability [3].

In Project technical specification (PTS) all information related to project is described regarding SLD of substation, communication requirements, protection requirements and customer standards and specification which are helpful to be considered for engineering design.

Single Line Diagram (SLD)

The SLD shown in figure-1 is the arrangement of disconnector, earth switch, circuit breakers, CT/VT arrangements and it provides the following below information as given below.

- No. of Voltage levels e.g 380KV/132KV/13.8KV.
- No. of bays.
- No. of Transformers.
- CT/VT detail.
- No. of Feeders (transmission line/UGF/Cable).
- Explain the scheme of arrangement like 1-1/2 CB scheme or double BB single CB scheme etc.
- Auxiliary supply system

On the basis of above information, the other design information can be estimated. For example if the number of bays are known then the no. of bay control Unit can be known, no. of IEDs can be known etc.The SLD is the part of specification The XML based Substation Configuration description Language (SCL) of IEC 61850 offers a formal way to describe the SLD. Passing the SLD in this form as file reduces misunderstandings and enables automatic processing of it without new data entry and finally SLD help in estimation of data flow in network

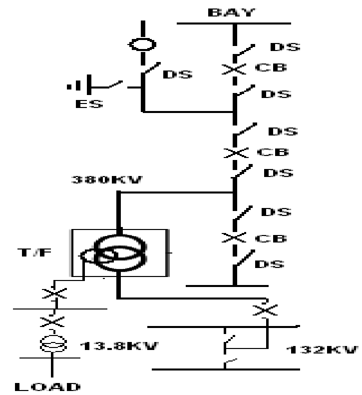

Figure-1 Single line Diagram of typical Bay

Specification Method Functionality

The functionality as given by the SLD is to be refined and the given SLD figure-2 shows the one and half circuit breaker scheme used for EHV substation.

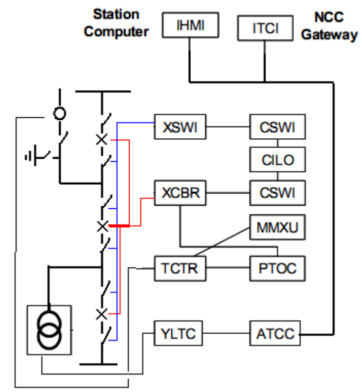

Figure-2 Functional Single line diagram

All requested functionality should be specified without reference to any implementation to allow optimizing the solution. IEC 61850 offers the concept of logical nodes (LN) for formally defining functions Specifying according to IEC 61850.To give signals, functions and connections the proper meaning, we have to know which power equipment and bay within the GIS refers to what function. This may be done with help of SCL. The resulting file is called System Specification Description (SSD) file. However, this SSD file doesnot define specific details of function implementation and and function. The LN class definitions according to IEC 61850 are given: XCBR Circuit breaker, XSWI Isolator or earthing switch, TCTR Instrument transformer/transducer for current, YLTC Power transformer, CSWI Switch control, CILO Interlocking, MMXU Measuring unit, PTOC Time over current protection, ATCC Automatic tap changer control, ITCI Tele- control interface or gateway, IHMI Human machine interface, operators place.

Performance
Performance divided into response time, safety and reliability. These requirements guide the allocation of LNs and their related functions to devices .response time requirements can be subdivided into average response time requirements, For safety it might be sufficient to specify the degree of safety to be met as a safety probability per function, typically a failure probability of 10-5 /h to 10–6 /h for protection related functions. [3]

Constraints
The constraints include some boundary conditions like the geographical extension and topology of the substation, the existence of building structures, GIS bay, shielded rooms for the station HMI. The performance requirements together with the given constraints define the final physical architecture.

Design process methodology
The general design process from customer specification to final system design described in figure-3. The design process can either start with the functional specification, SLD information and known SAS functionalities gathered all information prepare the SSD which is a tool at first stage of design. above figure shows two alternate process dependent on designer and limitation, the multifunctional IEDs plays an important role with its communication architecture in a cost optimal way. The overall system structure is known now, and detail design can be started. When starting with the constraints and performance requirements, this determines the minimum number of IEDs needed at the interface locations, and their main functionality.
This first design step must already cover the requirements for functional redundancy (e.g. main and back up protection). Based on this and the required functionality the interfacing IEDs are determined, and which functions are available on them. Finally the connecting communication architecture is designed in a cost optimal way. This kind of approach is mostly used if a large number of IED types (possibly from several manufacturers) are available, or IEDs can be flexibly configured. To get maximum benefit from tool support the specification has to be translated into the SCL based SSD (System Specification Description).The SSD is an unambiguous input, which enhances the quality of the specification and allows functional simulation to see the interaction of LNs and to get a base for estimation of communication load, performance, completeness. The grouping of LNs to LDs is done by selecting the groups of logical functions i.e LN in logical device LD and then combines all LD in IEDs in such a way that a minimum number of devices results but all constraints are fulfilled.

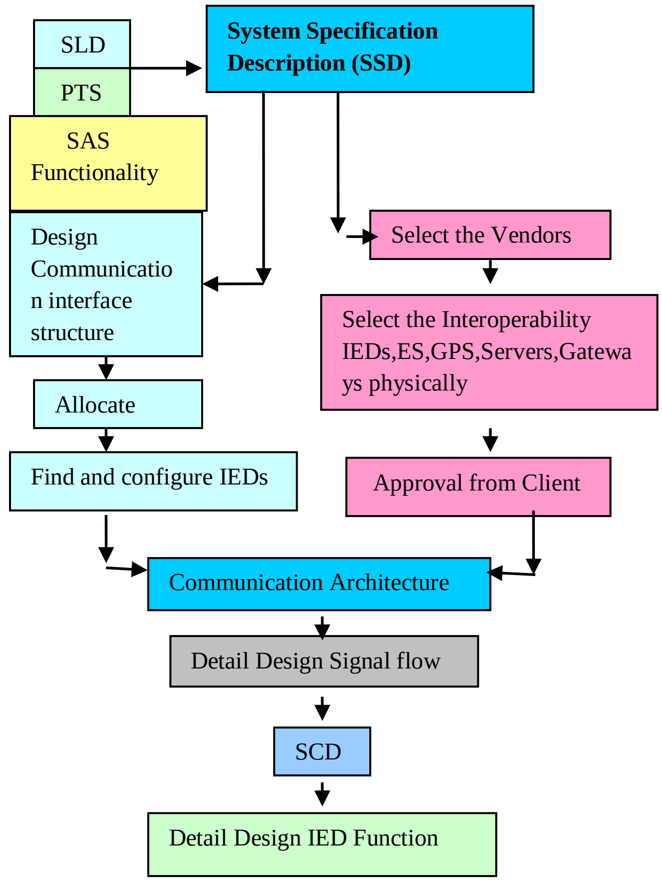

Figure-3 Steps of the design process

Finally, we have to find proper devices for implementing this optimized solution. The best way is to select the multi-function IEDs in order to minimize the cost.
The figure-4 shows the SLD of substation with its communication architecture, describes that analog values CT/VT data and DS/ES/CB status are given to BCU in hardware which processed and send to HMI/Gateway via communication protocol/architecture via Ethernet switches, it's suggested that BCU should be multifunction that can be used for controlling ,monitoring, measurements and synchrocheck function in order to compact the system but this BCU must have enough BI/BO cards so that can be used for measurement and synchronization. When protection IEDs are being selected so it should be reviewed to use that how many active function shall be used and then different vendors/manufacturer are reviewed for selection to get desired functions. e.g if the line protection IEDs

are to be selected then choose IEDs which has differential protection function, distance protection function, autoreclosing function, auto-synchronization function, direction earth fault function, overcurrent function, under voltage function and over voltage function.

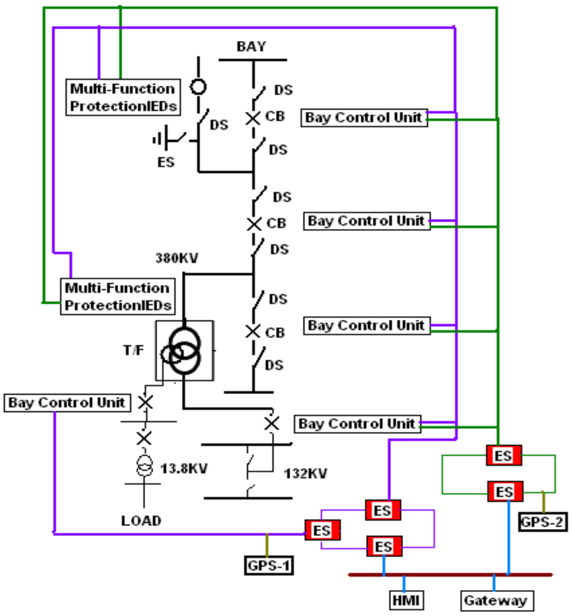

Figure-4 Example of Selection Of IED and Allocation of Function:

Substation automation architecture

The architecture of overall substation automation system is illustrated in Figure-5 and it is comprised on three levels

- Process level
- Bay level
- Station level

Process Level

At this lower level all CT/VT inputs are hardwired to digital I/O Box card of BCU, and Protection devices for upward Communication to the SAS System [5]. Various feeders status, CB/DS/ES indications, measurements and metering as well as fault records are collected within these bay devices and sent to upstream levels for diagnosis and analysis to servers/HMI and Remote control center via SCADA. Dual Fiber Optic Star topology is adapted to ensure a high level of Redundancy and Connectivity to the System.

Two sets of Ethernet switches form the actual interface for all bay level devices to the SAS. Inter-Bay communication and communication to SAS is achieved over IEC-61850 protocol for all BCUs/ I/O Boxes/ Protection relays allowing for easy Interoperability with third party devices. Signals from Auxiliary Systems such as HVAC, Fault recorder, firefighting equipment UPS, Battery & Chargers, ACDB and DCDB etc. will all be hard-wired to interface BCUs to integrate in SA system. The detailed overview of the communication structure the SAS Base Design drawing plays better understanding to review complete substation automation system.

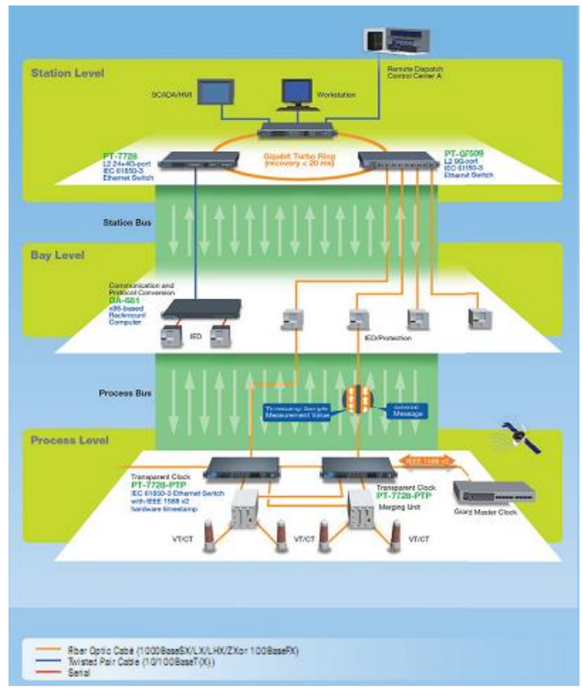

Figure 5 Substation Automation System level

Bay level

The process level equipments (CT,VT,DS/ES/CB etc) are connected to process bus to Bay Control IEDs is known as BCU at the bay level that measure the monitoring, protection, control and recording functions [5][16]

Station Level

It includes Human Machine Interface (HMI) and gateways, GPS, Servers and Ethernet-switch to communicate with remote control center RCC and integrate IEDs at the bay level to the substation level. It also performs different process related functions such as implementation of control commands for the process equipment by analyzing data from bay level IEDs it provides the time stamped sample values of current, voltage, angle, frequency, active/reactive and apparent power etc alarm/Event organization and advance function of SAS such as dynamic interlock table, dynamic monitoring function of bay level to

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Station level devices. At station level the Station Controller is also called Full Server when it is working independently. In large applications, where the number of bay level devices and interfaces is comparatively high e.g. large High voltage substations, it is possible to extend the Full Server Station Controller by adding additional machine(s) called Device Interface Processor' (DIP) or for even higher performance with additional Full Server Computer. As far as hardware is concerned, DIP is same like FS. The main automation unit is the Full Server whereas the DIP works in conjunction with a FS only to enhance the Automation capability required at station level. In case of usage of two Full Servers for one system the configuration is split between the units. one unit handles the Bay Controller Configuration and the other unit handles the Protection devices. The solution FS / FS, take more time for parameterization. To reduce the cost it is recommended that use the same PC for HMI and GW. This solution will be also better for the parameterization and supervision of the system. If you have a large substation with a lot of device is it better to use FS and DIP solution. The difference between these solutions is the FS/DIP can handle only 225 devices but the data transfer between the PC go automatically. The FS/FS solution can handle 380 devices.

Solution 1

PC CPU Core	Number of PCs	Devices	Master Values	Slave Values	PC RAM
4	1	180	10000	20000	4GB

FS	1	180	10000	20000	4GB
DIP1					

Solution 2

PC CPU Core	Number of PCs	Devices	Master Values	Slave Values	PC RAM
4	2	250	20000	40000	4GB

FS	1	125	10000	20000	4GB
DIP1	1	125	10000	20000	4GB

The primary tasks of the station controller/servers are

Data Concentration

they are responsible for communication with the substation numerical relays and IEDs and are performing intelligent pre-processing and filtering of IED data.

Safety and Security

Performing switching authority of control commands to ensure that controls are only executed under safe conditions. Bay level and station wide interlocking is implemented in BCUs and exchanged via GOOSE function.

Advanced Automation Applications

Utilizing mathematical capabilities, applications are developed here to monitor, alarm, and control for overall optimization of the electric system and the system components (transformers, breakers, switches, CTs, and VTs).

Requirement of redundant protection.

It is preferred in power system network to use the redundant protection IED with different vendor/manufacturer because all different vendor IEDs are sensitive on different types of faults but these redundant IEDs should have same multifunction to be used and same CT/VT requirements and protection class.

Communication topology

The communication according to IEC 61850 takes place between IEDs. Multiple communication ports may exist. IEC 61850 is based on Ethernet, and Ethernet allows different physical variants. Since the standard and Ethernet is supporting both client-server relations and peer-to-peer communication. Many protocols may be reviewed like PRP, HSR, SAN and RSTP etc depends on client requirements.

Process bus architecture varies in a great deal depending on the applications, typically bay oriented, with the process bus traffic contained at bay level, or bridged to where it is required via dedicated links or managed switches. The commonly considered process bus architectures include: [27]

- Point-to-point connections
- Dual stars
- Single ring with RSTP/HSR
- Dual ring with RSTP/HSR

Dual networks with PRP protocol While designing Ethernet LAN for substation automation systems, ease of maintenance and expansion should be taken into consideration. The architecture should meet the following requirements [27]

- Reliability requirement
- Bandwidth requirement
- Redundancy design
- Latency delay
- Network convergence
- Scalability and expandability
- Maintainability

Ethernet Redundancy Protocol

In general, seamless redundancy is known as the multiplication of communication paths between source and sink of a communication relation where the multiple paths have to be used simultaneously [13]In case of an N-fold redundancy, with all paths in operation simultaneously in parallel, **N-1** communication paths can fail and the message will still be delivered from source to sink without any interruption. [5]

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All applications in the substation associated with data Transmission over the substation LAN should be measured and the IEDs selected/involved should be taken into consideration [5] While the number of redundancy protocols in existence is quite high, not all fulfill the requirements in industrial automation or fields that pose even stronger constraints on reconfiguration time like e.g. applications in substation automation or even motion control. These facts have been widely discussed in the past [14]. In [15], different methods with different approaches for achieving redundancy are described. The International Standard IEC 62439-2 specifies the commonly used Redundancy Protocol MRP and in the IEC 62439-1, the application of RSTP to industrial networks is described [16] IEC 62439 standard looks at two unlike classes of network redundancy [3],[4] management in the end nodes as well as redundancy management within the network. These types of methods have been studied for industrial automation networks form several years [23][24][25] in IEC 62439-3, PRP and HSR are the most two promising parallel network approach gathered [22] The information presented in the following table is taken from the Table 2 page 1024 of IEC 62439, refer to [1].

The Redundant systems eliminate single points of failure and improve overall system availability, security and dependability. As Ethernet communication is becoming more and more common in protection schemes in substations, the redundancy requirements no longer cover only protection devices but also the communication systems within the substation. Indeed, to achieve a high system reliability and availability, the Communication network needs to avoid any traffic interruption when one of its elements is disturbed.Ethernet networks have redundancy protocols that are supported by identified Ethernet standards. These are supported in Layer 2 and Layer 3 of the OSI model.

Spanning Tree

There are several flavors of Spanning Tree.

- STP (Spanning Tree Protocol),
- RSTP (Rapid Spanning Tree Protocol).
- MSTP (Multiple Spanning Tree Protocol).
- LACP (Link Aggregation Control Protocol)

and these are High Availability Ethernet Protocol.

- MRP (Media Redundancy Protocol)
- PRP (Parallel Redundancy protocol).
- HSR (The High-availability Seamless Redundancy Protocol).
- CRP (The Cross-network Redundancy Protocol).
- BRP (The Beacon Redundancy Protocol).
- DRP (The Distributed Redundant Protocol).

The widely used redundancy protocol is PRP for HV and EHV which is described below.

Table-1 List of protocol function

Protocol	Frame loss	Network Toplogy	Recovery Time
MRP	Yes	Ring	From 500 ms to 10 ms worst case for 50 switches
DRP	Yes	Ring and double ring	100ms worst case for 50 switches
BRP	Yes	Meshed	4.8 ms worst case for 500 end nodes
CRP	Yes	Meshed	2s worst case for 512 end nodes
PRP	No	Meshed	0s
HSR	No	Ring	0s

Parallel Redundancy Protocol (PRP)
IEC 62439-3 Clause 4

PRP [18] introduces two parallel networks to which nodes/IEDs are connected. These nodes named Dual Attached Nodes (DAN) are linked to two different networks or LANs. Source information generates two reports i.e main and duplicated and sent through the two different networks; on the other side information is received duplicated (if no error happens). Destination takes the main reports and discards the one that arrives after, the duplicate, which arrives through the other LAN as sketched in Figure 6.[23]

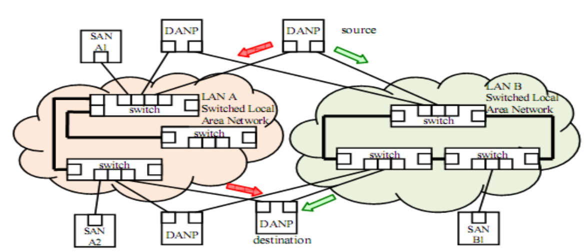


Figure-6 PRP Network

The networks are completely separated to ensure failure independence and can have different topologies. Both networks operate in parallel, thus providing zero-time recovery because both redundant channels are working Hot-Hot and the continuous checking of redundancy to avoid failures [19].The PRP protocol normally used for HV and EHV

substation communication networks where system reliability is more considered over LV switchgear networks where only single attached node can be used. The PRP has Zero time recovery in case of network failure, reduced network engineering costs and reduced cost by converging critical and non-critical networks onto a single network [20].
The PRP can easily be implemented in software by a dedicated driver that manages two standard Ethernet ports and provides **N-1** redundancy as shown in Figure 7 [19].

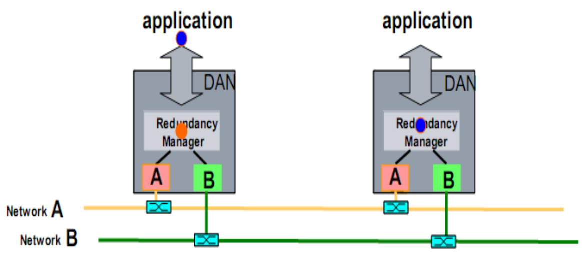


Figure-7 Normal operation of PRP

The Figure-8 & 9 describing the PRP parameters observed in DIGSI software.

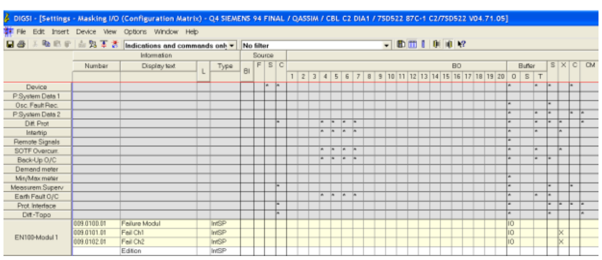
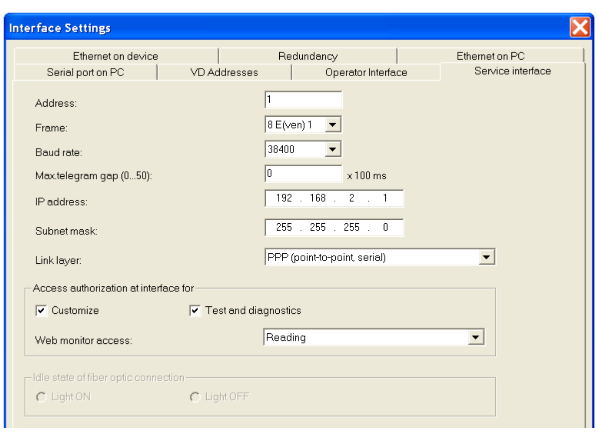


Figure-8 Showing DIGSI Software setting for PRP.



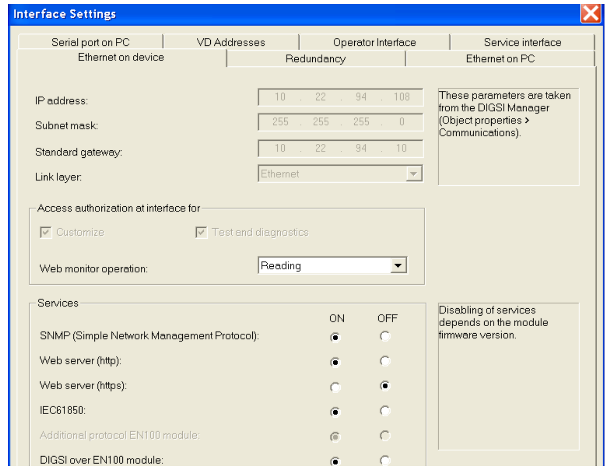


Figure-9 showing interface setting for PRP in DIGSI software.

Non-PRP Nodes, called singly attached nodes (SAN) are either attached to one network only, or are attached through what is known as a red box, a device that behaves like a DANP. The Redundancy box (Red Box) provides full connectivity for virtual dual attached nodes (VDAN) and acts as proxy node for VDAN. Red Box has 3 ports in which 2 Ports can be used for data receive/send and other port is Interlink as mentioned in below Figure-10 & 11.

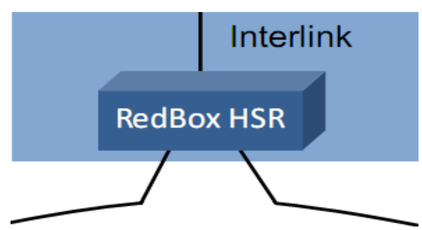


Figure-10 Red Box Ports

The non PRP nodes has single communication path without any redundancy.

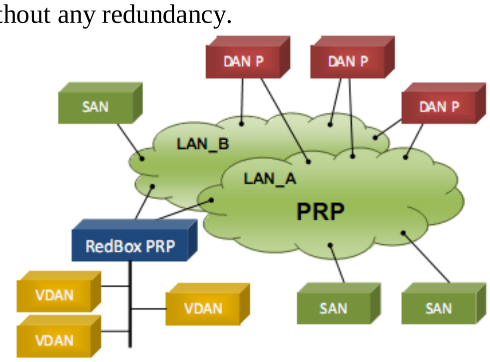


Figure 11. PRP and Non PRP network

Non-PRP nodes can be connected either via Redundancy box or directly to any of the two networks as shown in Figure 11.

PRP for the Station Bus

Station bus is the communication network used to communicate between the protection & control IEDs and a higher-level system such as a substation HMI or a gateway shown in figure-12. The Substation bus is also used to communicate between the IEDs within the substation.

As can be seen in table 2, the recovery times for the client-server communication between IEDs and gateways are quite forgiving. The communication between the IEDs using GOOSE can be more demanding as protection applications using GOOSE do have higher requirement on communication availability and shorter recovery times.

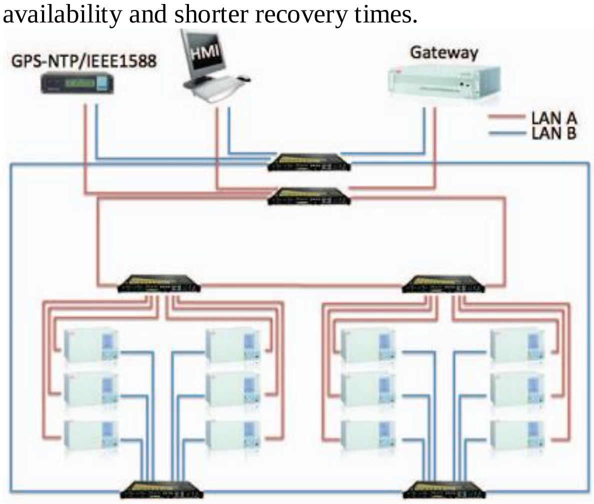


Figure-12 Typical Station bus architecture using PRP

In the system in Figure 8 there are two redundant rings, one for LAN A and another for LAN B. All the 12 IEDs in the system are connected to LAN A and LAN B. The Substation HMI, the Gateway to a SCADA system and the GPS clock are also connected to the two independent networks. This architecture can handle failure of any communication equipment without any communication interruption. The design using bridges (switches) with a relatively large number of ports also makes it possible to design the system with as few as possible bridge hops in between the IEDs in the system. When calculating performance of the system it shall be noted that each hop can add as much as 0.124 ms of delay to the message. The delay can be even greater depending on the performance and traffic load of the bridge. This means that the largest practical number of switch hops never shall exceed 5 in order not to delay the GOOSE messages with more than 0.6 ms. This is a requirement from [27]. Using bridges with fewer ports could potentially introduce a larger number of hops into the communication path.

There are two failure cases are possible but it cannot effect the communication of IEDs to the Server/Gateway.

Case-1 Failure of communication to an IED

The figure-13 shows the possibility of hardware failure of communication of single port but it will not affect the communication of IED to the network because 2[nd] port is healthy.

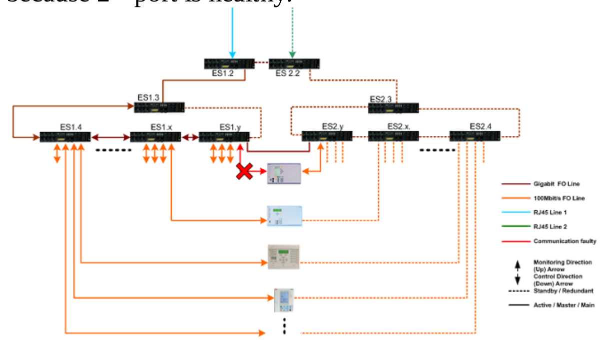


Figure-13 Failure of active communication port on IED

Case-2 Loss of an IED integration Switch

The below figure-14 shows that there are two possibilities.

- Hardware / Software Failure of ES 1.4.
- Double Fault Connectivity Loss at Station LAN Switch ES 1.4.

In this case also there will not be failure of IEDs communication to network because all IEDs already communicating to other LAN via Ethernet switch ES

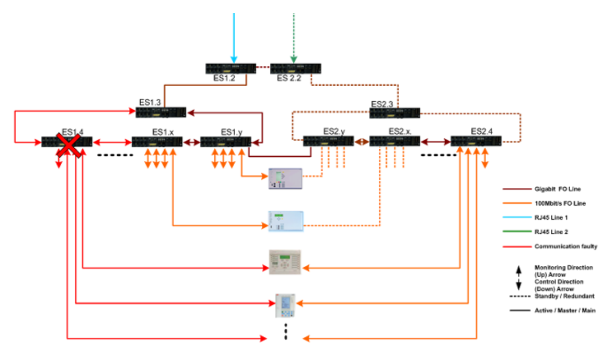


Figure-14 Loss of an Ethernet Switch in the Process Level Loop

High Availability Seamless Redundancy (HSR) Protocol (IEC 62439-3 Clause 5)

HSR applies the PRP principle of parallel operation to a single ring as shown in Figure-15. For each message sent, a node sends two frames, one over each port. Both frames circulate in opposite directions over the ring and every node forwards the frames it receives from one port to the other and

provides the loop suppression mechanism and HSR behaves like a roundabout frames in the ring have a higher priority than inserted frames The choice between these two protocols depends on the required functionality, cost and complexity [7].
HSR seamless, for voltage levels and process bus, rings and rings of rings requires nodes with dedicated hardware, but after this initial investment, provides a cost-effective redundancy. Allows ring and parallel topologies, but not mixing redundant and non-redundant devices on the same network (Red-Box is required).

Figure-15. HSR arrangement

- Effects of link failure in HSR

If any fiber optic link between the IEDs become failure as shown in Figure-16 the frame still get data from the opposite direction and no data lose with no delay in case of network failure.

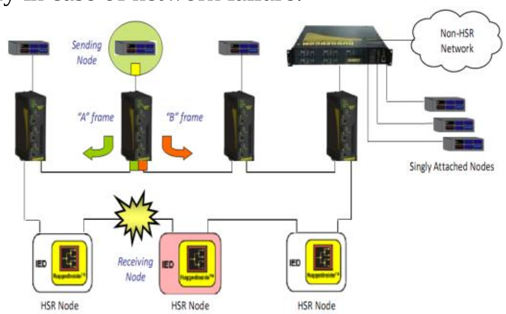


Figure 16 HSR Link Failure

Enhancement in HSR Protocol

The purpose of modification is to connect two networks through Quad-box in ring coupling arrangement to make the HSR network stronger to receive and send data through multiple inter ring communication between the IEDs and maintain complete redundancy. The Quad Box can be implemented using two standards Red Boxes HSR as mentioned in Figure-17 explain the hardware modification with Quad boxes to HSR node .the self-explanatory figure-18 shows the multiple sources for sending and receiving data.

The HSR has Reduce number of devices, elimination of switches, and reduced cost by converging critical and non-critical networks onto a single network. The
HSR can be overloaded if the quad box interlink got failure.

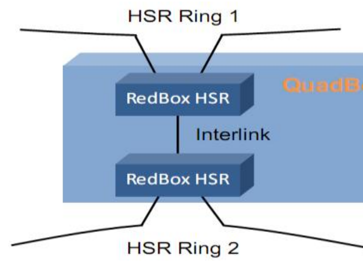


Figure-17 Quad Box arrangement

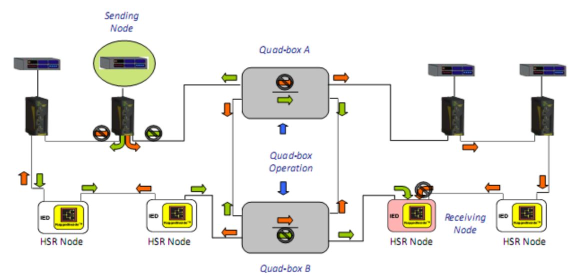


Figure-18 Enhancement in HSR through Quad Box

HSR Architecture (Rings of Rings)

The proposed SAS Architecture can be made by using Quad boxes rings of rings among IEDs up to station controller to HMI. The architecture is divided in three levels as mentioned in Figure-19 and no RSTP protocol is required any more(but can be used).The Architecture may be implemented for 380KV Networks.

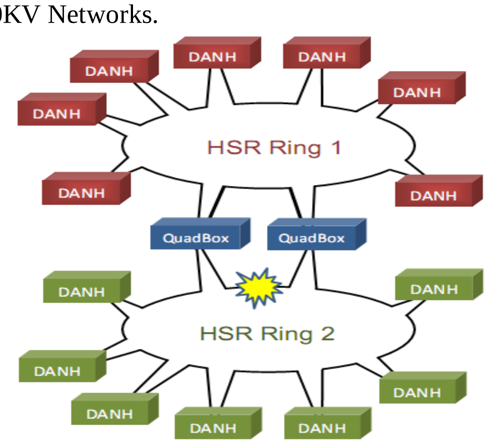


Figure-19 HSR enhanced Ring coupling

The Proposed architecture is to reduce cost and size of system is also shown in Figure-20[21].

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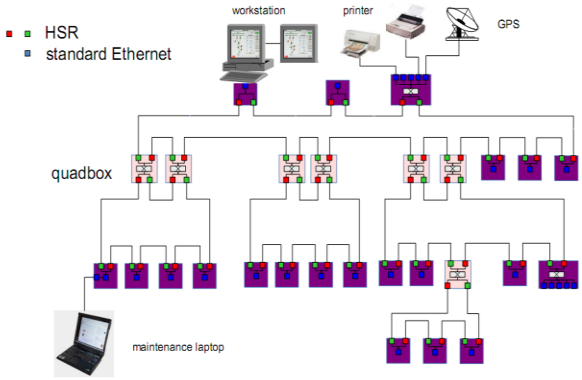

Figure-20 SAS Architecture by using Quad boxes

HSR for the Process Bus

The process bus application consists mainly of sampled values. a sampled value is the most sensitive application from a communication interruption point of view fewer components will lead to a better MTBF value for the complete system. By using HSR, the external switches can be eliminated. As the number of hops within a bay where HSR is being used will be limited, the additional delay introduced by each node in the ring will not sum up to an unacceptable big latency.

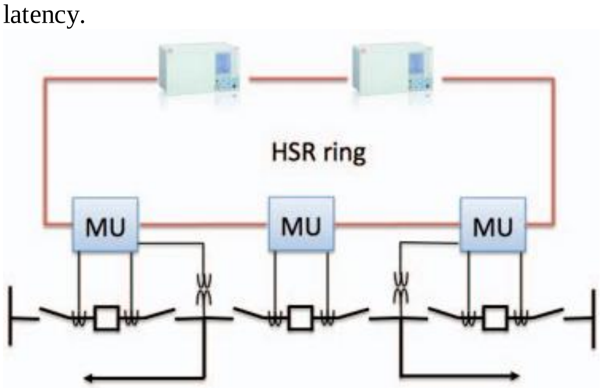

Figure-21 HSR applied at the process bus level.

The Merging Units acquiring data from the primary equipment are connected in a HSR ring to the protection and control IEDs for the bay. This creates a bumpless redundant path for the sampled values from the MUs to the IEDs are also shown in figure 21.

HSR approach and algorithm.

There are five new approaches and algorithm may be used for un-necessary traffic congestion problem in HSR network.

- Quick Removing (QR) Approach.
- Virtual Ring (VRing) Approach.
- Dual Virtual Paths (DVP) Algorithm.
- Removing the Unnecessary Redundant Traffic Approach.
- Port Locking (PL) Approach.

The amount of network traffic is used as a metric to compare the traffic performance of standard HSR protocol and all the approaches. This metric is a good candidate because the aim of new approaches is to reduce the unnecessary traffic in the network.

Ring traffic under standard HSR = T_{rsh}

$$T_{rsh} = \sum_{i=1}^{N} (N \times F_i \times D_f)$$

Ring traffic under the QR approach=T_{rqr}

$$T_{rqr} = \sum_{i=1}^{N} \left\{ \left[roundup\left(\frac{N}{2}\right) + 1 \right] \times F_i \times D_f \right\}$$

The traffic reduction percentage RP

$$RP = \left\{ 1 - \left(\sum_{i=1}^{N} \frac{[roundup\left(\frac{N}{2}\right) + 1] \times F_i \times D_f)}{N \times F_i \times D_f} \right) \right\} \times 100\%$$

Is proportional to the number of nodes in the ring N, which means that increasing the number of nodes will increase the number of links, and eventually, the path segments will become longer and make frames travel forward and backward through greater distances. Therefore, during the QR approach, those frames will stop circulating as soon as they reach, in the worst-case scenario, node number [roundup (N/2) + 1]. Almost half the traffic will be removed instead of travelling through the remaining links in both directions. Note that this number will increase [27].

Interconnection of PRP and HSR

Connecting Process and Station buses requires special considerations. The multicast sampled values are normally not allowed to propagate from the process bus to the Station bus. The main reason is the bandwidth that these messages consume. Sampled values would also load the communication processors/interfaces in the IEDs that do not require receiving the sampled value stream. One way to separate the Process and Station buses is by using multicast filters in the bridge connecting the two buses. This way sampled values can be blocked from entering the station bus. A benefit of having the two buses connected it that supervision and maintenance of the equipment in the process bus can be done from the normal HMI and substation gateway connected to the station bus. A RedBox in between the Station and Process bus provides bridging functionality between PRP and HSR. Figure 22 describes in detail how the bridging is done and how the redundant packages are handled.

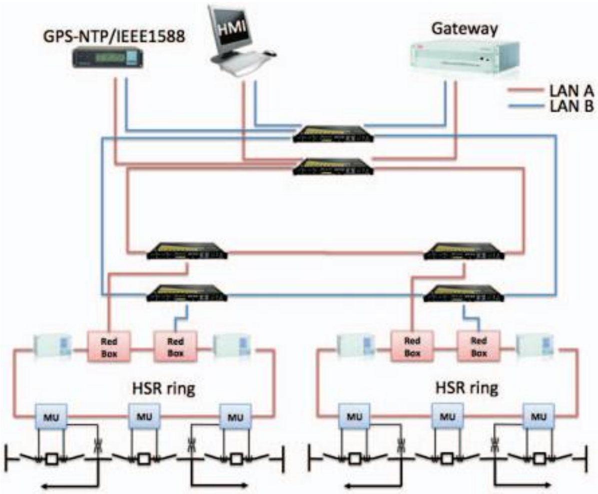

Figure-22 Interconnection of PRP and HSR

Detail Engineering

The result of the design process for IEC 61850 based systems can formally be described in an SCD (System Configuration Description) file as shown in figure-23, which contains the logical communication connections between IEDs within sub networks and routers between sub networks. The detail engineering on system level has to determine the communication addresses and the detailed data flow between the IEDs in terms of data sets and signal inputs to clients. This signal-level data flow engineering replaces to a big extent the engineering of the conventional wiring. The IEDs are to be tested and commissioned, then communication parameters are to be set, assign the required reports to be sent to HMI/Gateways normally each IED generates four reports for main and redundant servers/gateway or remote control center.

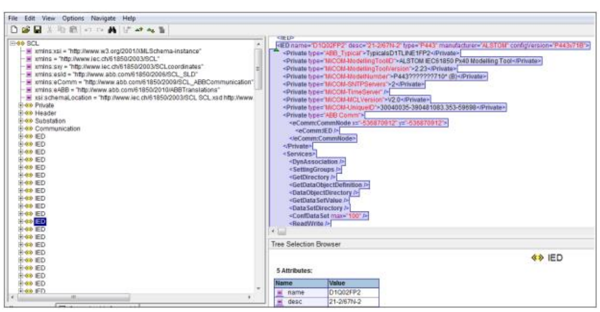

Figure-23 Shows the SCD File in SCL of Substation

The final system

The selected IEDs together with the communication architecture represent the final system, each IEDs CID file is imported to system configuration tool to be created SCD file and then filly exported to servers for configuration and next step is to select the engineering computers including servers, gateways ,GPS ,Ethernet switched and routers which all are depended on customers' requirements and price tag. Normally vendors use their own equipements but considering the cost effect some equipment may be from different vendors like Ethernet switches and GPS.

PROPOSED SUBSTATION AUTOMATION ARCHITECTURE

The practical approach for PRP and HSR may be used at EHV and HV (132 KV to 380/500 KV) while non PRP / SAN is used at LV and MV (11KV /13.8KV to 33KV) in substation automation system. The non PRP protocol is required when there is only IN/OUT arrangement from tertiary of the transformer for the purpose of substation auxiliary supply while HSR is required when there is complete 13.8KV /33KV network including bus raiser, bus coupler and outgoing feeders as described in figure-24. The disadvantage of the Non-PRP node is failure of one channel, the failure of communication from the IEDs but the advantage is reduction of redundancy and its cost. The figure-24 is proposed where the non–PRP/PRP protocol and HSR protocol are applicable. The figure depicts the general transmission substation 380KV/132KV/13.8KV/220V and describes the real time application of PRP, Non PRP & HSR. The EHV 380KV and HV 132KV is more important to be monitored 24 hours basis so the DANs have been used whereas In LV side (13.8KV) both SAN and VDAN may be used depending upon the client requirements. The PRP implements redundancy function in the end nodes rather than in network elements. This is one may or difference to protocols like RSTP or MRP. An end node is attached to two similar LANs of arbitrary topology, which are adjacent and parallel. The LANs named LAN-A and LAN-B, are identical and protocol MAC Level. In real time application, only Availability-Critical nodes need a double attachment while other do not. In order to meet the specific requirements, PRP defines different kinds of end nodes. The dual attached node (DAN) is connected to both LANS and used in because network is more important. Un critical node can be attached to only one LAN and are therefore called single attached node (SANs) that need to communicate with each other are on the same LAN,SAN and VDAN mostly used in LV side i.e 13.8KV,33KV & 66KV.There are following types upper level redundancy between station controller and gateways 380KV and 132KV side.

- HOT-Standby redundancy used between Station controller

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- HOT-HOT redundancy is used between Gateways
- HOT-Warm redundancy where data updating continuously in redundant one
- HOT-Cold redundancy where redundant one is switch off.

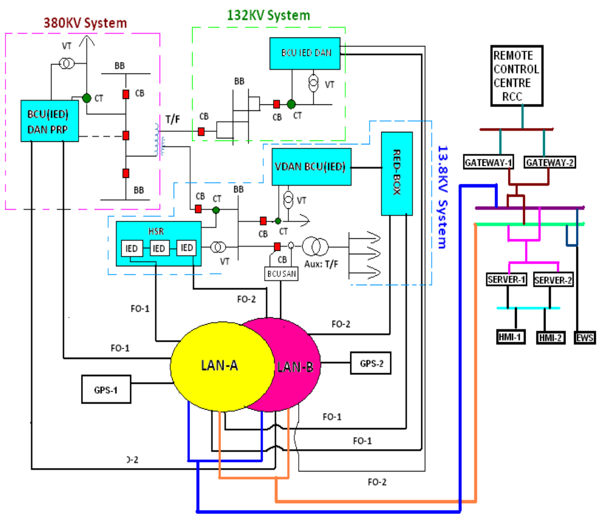

Figure-24 SAS Proposed Architecture with SLD using PRP ,Non-PRP & HSR Network.

It is recommended that once the software (GOOSE) interlock implemented for GIS LCC BCU so no need for hardwire interlock. The matching unit should be installed beside the CT box of GIS and then simple value SV could be sent to BCU and protection IED for accuracy class.

HMI Screens

Each station HMI should have two numbers of screens 30 Inch; one should be used for Station single line diagram including monitoring, control & SAS Overview and other screen of HMI should be used for Alarm/Event and Trends (Measurement of Powers, Frequency, Energy etc on graphical representation).

A 52 Inch wall mounted Screen is to be required to monitor the status of all single line diagram of substation with major measurements as shown in figure-25.

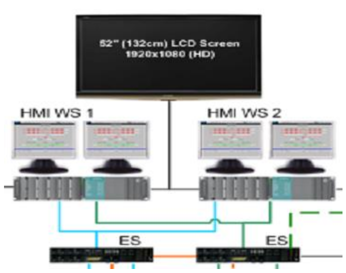

Figure-25 Station Level arrangement

System Overview

For the substation overview a single line diagram will be displayed. Considering the large number of feeders, not all details will be shown there. The general idea of the substation overview is to give a very clear and plain picture of the substation status. For that reason measurement and feeder information is reduced to a minimum i.e. the feeder status will be displayed with a compact selection of switching devices.

This figure-26 should cover complete Station SLD and no operation can be made by clicking on any DS/ES/CB at this screen and if you want to control any DS/ES/CB then you have to go in detail picture.

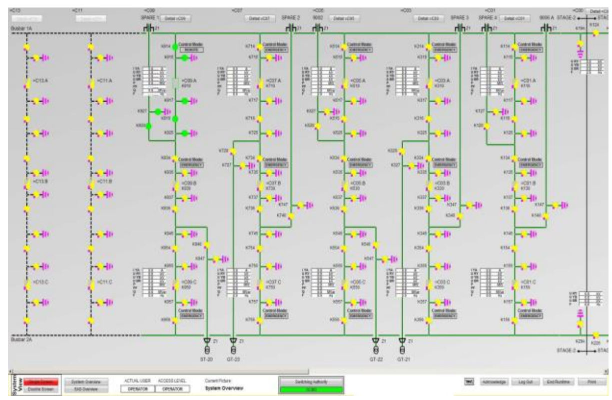

Figure-26 Proposed SAS System Overview.

Detail Picture of Dia/Bay and its function

In general the control areas of substation can be divided into 4 levels as shown figure-27.

- Level 1: LOCAL - from Local Mimic Display (LMD) in LCC
- Level 2: BCU - from BCU Mimic in LCC
- Level 3: REMOTE - from SAS HMI
- Level 4: SCADA - from SCADA Control Centre (SAS HMI set to SCADA, 4 Position switch at GIS LCC set to Remote.

The proposed detail picture shown in figure-28 depicts complete summary of GIS bay and can be controlled.

The following mentioned below advance functions are suggested for HMI detail picture for controlling, monitoring the system.

Bay Authority

The authority enables switching devices to control from HMI or Remote Control Centre(CRCC).The authority mode should be independent/separately for each Dia for safe and secure operation, If it is selected then no operation can be made from Local HMI.

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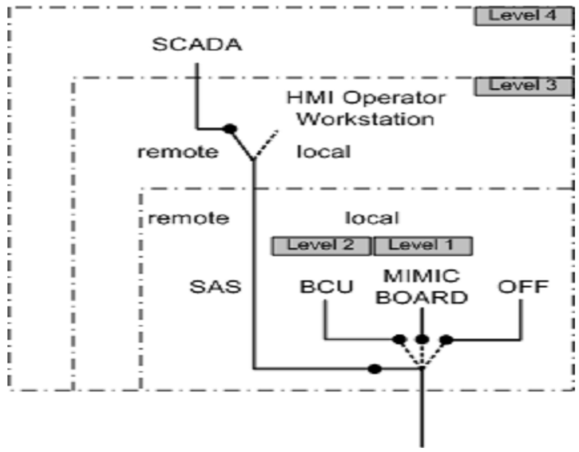
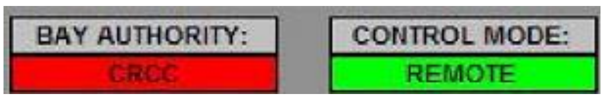


Figure-27 Control Authority Hierarchy.



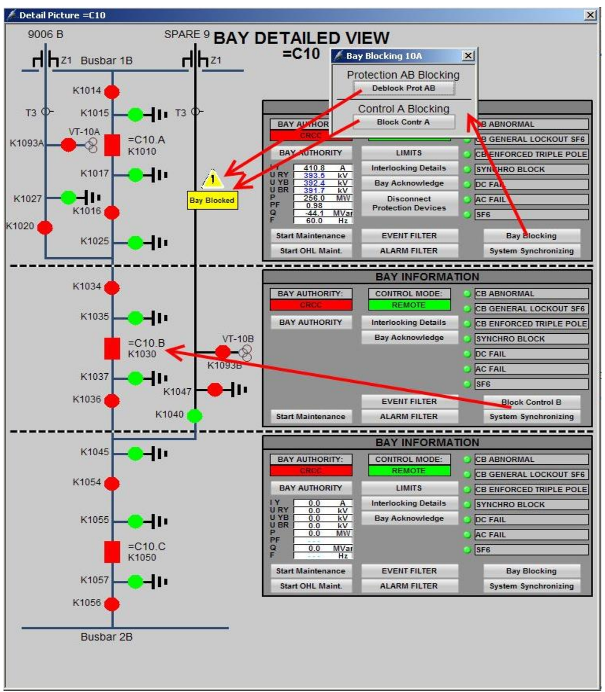


Figure-28 Proposed detail picture of HMI SLD

Dynamic Live interlock Table

The operation Authority of any Power company provides its substation interlock table so that no mall operation can be made and system working according to that philosophy. The approved interlocks with live status of DS/ES/CB,VT status and Protection Close block are required to be provided in Live dynamic detail matrix form in HMI as in figure-29 mentioned.

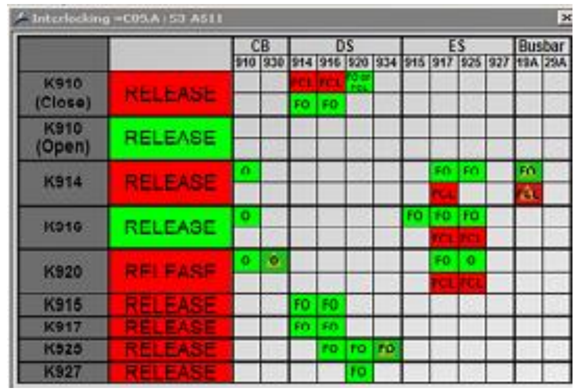
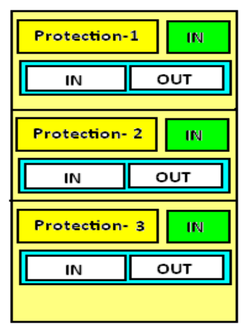


Figure-29 showing live dynamic interlock

Protection In/Out Commands and Back Indication

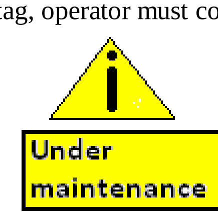
The function provides the status IN or OUT Protection, focuses the operator healthiness and active protection to be confirmed before energization of any circuits and transformers .if Protection is OUT then initiate the command selective "Protection IN" and energize the Circuit, no need to go at protection panels to make it IN. It commands for all Protection IEDs IN/Out, Auto-recloser IN/OUT,AVR Tap changer lower/rise commands from Operator Work Station and CRCC.



Under Maintenance Facility

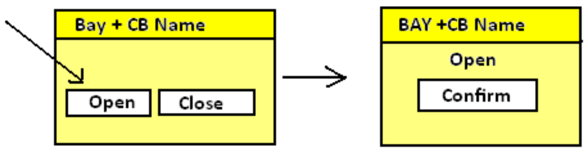
The Start/Stop maintenance function is required for each Circuit Breaker independently; the symbolic notation should be more attractive form and shall have facility to write any important notes.

The function is applicable when there is an outage works is going on and no one is authorized to remove this assigned Tags except same operator(shall be identified by Password) because PTW or LOA is issued on operator specific name and before removing this tag, operator must confirm clearance.



Select Before Excecute Command

When any commands executed from HMI, it should select then execute, while operation the command execution could be cancelled.



Synchrocheck Functionality

On the 380kV Voltage Levels, Synchrocheck function is utilized in the BCU to verify whether synchronization conditions of both partial networks (Line & Bus) have been fulfilled.

- Line side voltage (3-phase) is connected to the BCU
- A fourth voltage input at the BCU is connected to the bus voltage selection scheme
- The bus voltage selection scheme ensures that the correct bus voltage (dependent on Bus Coupler/ Section & disconnetor status is connected to the analog input of the BCU.

The same VT selection scheme logics are to be design for software and hardware interlocks. for closing of CB, the selectable voltage is required for BCU in hardwired and also in software logics which are in series.

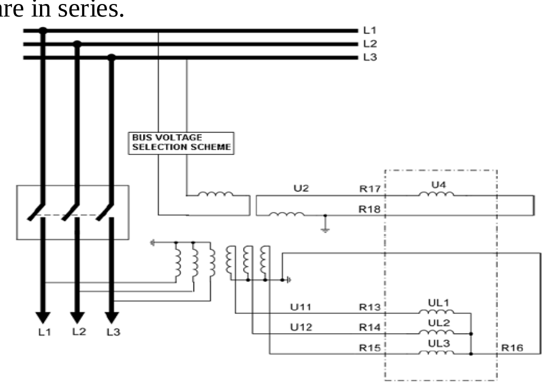
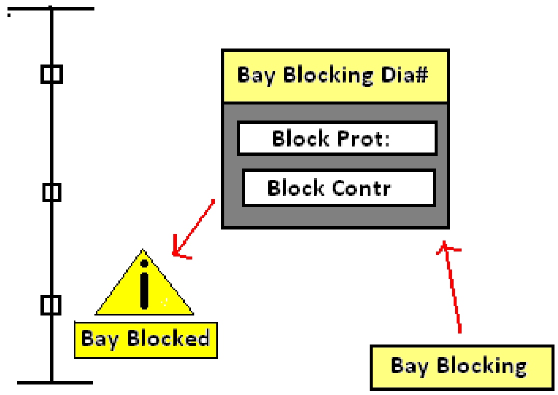


Figure-30 Synchrocheck (25M) functional diagram

The logics should be prepared in BCU after getting status of concerned Isolator, Voltage, VT MCB Trip status in software so that hardwire and software scheme should work together. Blocking of command under not allowed conditions are line and bus VT MCB trip, live line and live bus without synch conditions, line and bus disconnector opened.

Bay Blocking/De-Blocking

The purpose of bay blocking is to block the Protection and Control alarms for RCC for specified bay when any line or Transformer or Circuit Breaker is under maintenance/Outage/Testing & Commissioning. the different venders have different facilities for bay blocking at Bay level and Station Level(depends on Vender policy).The Logics of Bay Blocking is designed for both ½ CB scheme and double Bus bar(Used at EHV) & Single CB Scheme(Used at HV) is to be provided by considering protection logics.



Measurement Functionality

The HMI detail picture and main SLD should have facility to show the measurements as given below.

$$Error\% = \left[\frac{(expected\ value - measured\ reading)}{(expected\ value)}\right] \times 100\%$$

Proposed SAS HMI Overview

This display is shown in figure-31 the various components of SAS, their interconnection and health. The bay level devices are shown in sub-displays. The failure of any device itself or its interconnection with other system components is indicated by dynamic colour display of the frame around the device (red is failure).It should have all detail of Bay level to SCADA Level including all IEDs ,Ethernet Switches, Station Controllers, Gateways, HMI, Engineering PC,GPS and showing all connection. The Complete SAS Overview should be shown on one Screen and ES Detail connection with BCUs and relays should be provided on Ethernet Switch by Double click in detail. Each ES Switch should have Port number, SAS Panel name and in case of failure of any port should be red and get itself alarm port fail. The

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Detailed SAS System Network showing all connection from Bay level to SCADA Level.

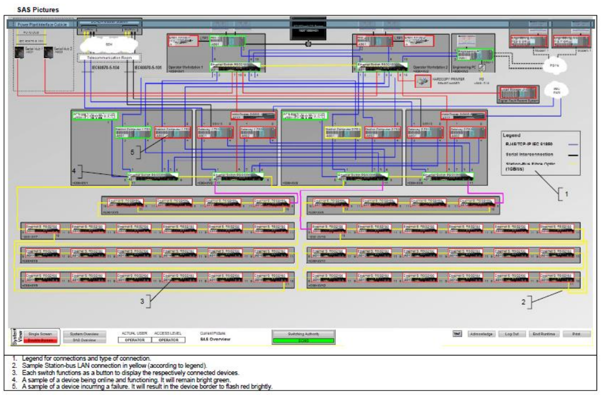

Figure-31 Proposed SAS Main Overview

By Double click on any Ethernet Switch will have to show detail of device/IEDs connected to that ES as mentioned in figure-32.

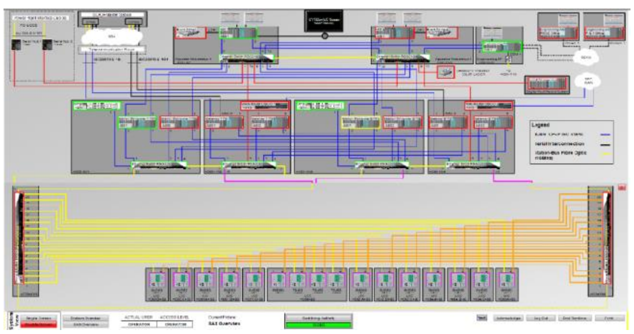

Figure-32 Detail Overview of connected IEDs to ES.

Proposed dynamic online GIS monitoring system

The basic switching, monitoring and measuring equipment (DS/ES/CB/CT/VT) arrangement insulated with SF6 Gas is known as GIS/Switchgear as shown in figure-33.The arrangement of these equipments are given as below.

- Single bus arrangement
- Single bus arrangement with by-pass bus
- Double bus arrangement
- Double bus arrangement with by-pass isolator
- 1½ circuit breaker arrangement
- Ring bus arrangement
- Main and transfer bus arrangement

The Most widely arrangements used in the system are double bus and 1½ CB scheme.

To monitor the arrangements of its equipments is crucial issue and important therefore it is proposed the solution which can monitor wide GIS dynamically and live in SAS HMI.

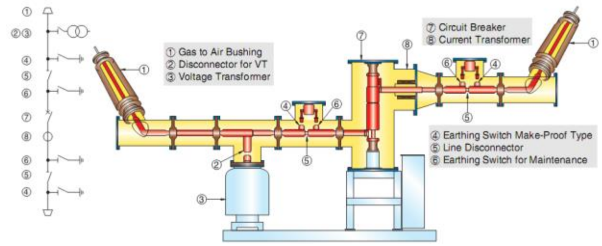

Figure-33 Proposed GIS Monitoring in HMI

The each controlling and monitoring equipments of GIS is monitored in SAS HMI in Events but proposed method can monitor the GIS by visualization in SAS overview as shown in above figure by RED if its failure. The following mentioned below items to be monitored continuously by means of gauges, internal failure, pressure low or high monitored by SF6 gauges ,supply is supervised by supervision relays. if any abnormality observed, the system extend the alarm for RCC and can be seen in HMI by means of events and visualization in HMI.

- GIS & CB gas pressure low stage 1 & 2
- GIS gas pressure rising alarm
- CB general lockout SF6 CH1 & CH2
- CB pole discrepancy operated.
- CB ABNL, motor & control voltage fail
- AC & DC supply fail
- DS/ES control and motor voltage fail
- LCC plug supervision
- BCU failure
- Synchronization error.

By above described method the operator can locate the exact fault point and take action immediately.

Online partial discharge monitoring systems

The PD Watch monitoring system is an online system which records and displays UHF signals produced by partial discharges in a GIS, dedicated specifically to GIS/GIB/GIL with pure SF6 gaseous insulation.

The GIS electric substations are known for their reliability. Many GIS are in function for 50 years and the failure rate remains poor. However, most often, the failure of this material type causes dramatic consequences (destruction by explosion, loss of exploitation), and heavy and expensive reparations.

Almost all of failures occurred are due to an isolating defect repairs between the high-voltage conductor and the protection GIS part, fatally causing, pursuant to some seconds, some days or some years duration, a flashover of the isolated system. There are five isolated defaults types could be identified.

- Free conductive particles
- Protrusions
- Electrodes to floating potential

- Fixed particles on insulator surface
- Void (Air cavity in insulating)

All these elements have the particularity, when they are submitted around to the presence of high voltage, to generate intermittent isolated defaults, called partial discharges and which can be measured by UHF electric method which measures electromagnetic waves in the low band of UHF, from 300MHz to 1800MHz.The PD can be measured online of running system as well as HV test before energization which helps to find out the flashover area quickly.

PD watch online architecture

The system PD Watch On-line is built around a network Ethernet, fiber optic or copper, through switches connecting the various components of the system shown in figure-34.

Application monitoring, remote or local, shall supervise the system PD Watch, using data from the ftp server. These data allow performing the monitoring of UHF sensors defined in a specific configuration for the office GIS to monitor.

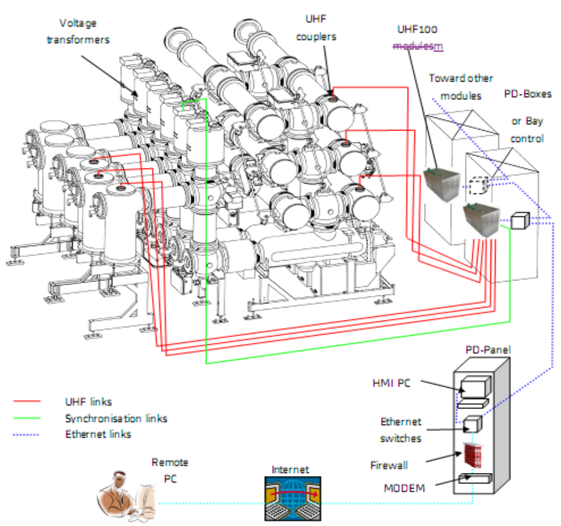

Figure-34 General architecture of PDWATCH online

They are displayed as trend curves, and data interpretation of sources of DP, and can trigger alarms. Acquisitions of instantaneous (real time) on the modules named in the application may be requested by the user. One or more modules (SYN) allow synchronizing the acquisition of UHF modules with parameters of amplitude, frequency and phase of the HV network.The monitoring system HMI is divided into two areas:

- The supervisor frame & window with a tab control to display supervisor data

All the SLD of substation with its sensor healthiness can be observed on tab view as given in figure.-35.

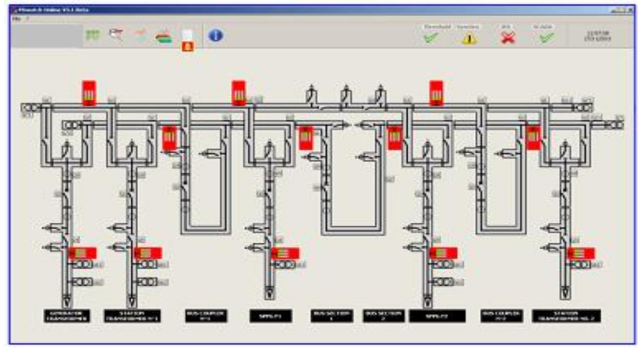

Figure-35 shows sensor allocation in GIS

The status overview displays all information about all IED (UHF module) and all sensors in figure-36

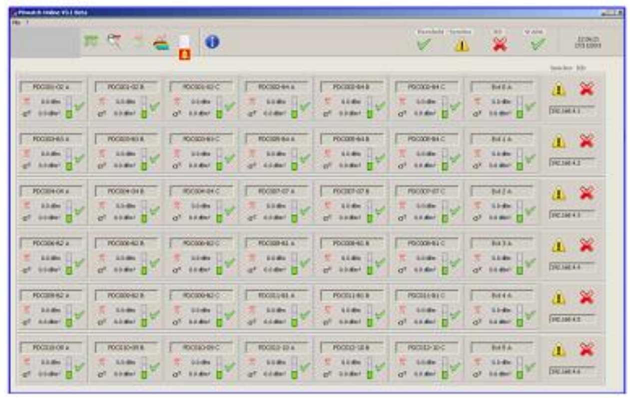

Figure-36 showing status of sensors

The variance of spectrum shows the evolution of the UHF signals level inside the GIS at short term and long term. It's useful for risk assessment.

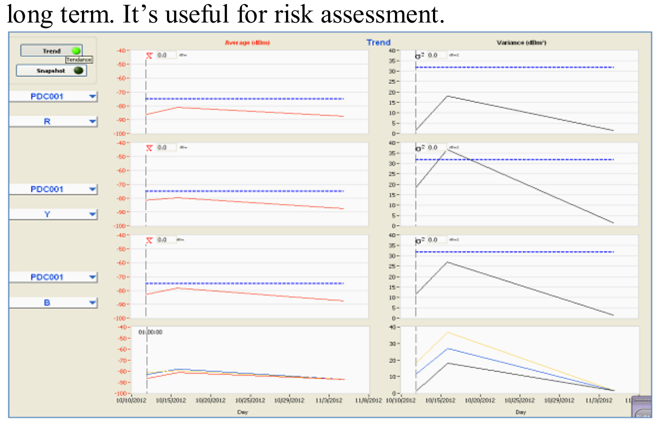

Figure-37 Graphical data of selected sensor

The real spectra acquired on the selected sensor and its associated sensors are shown in figure-38.

Figure-38 spectra acquired on selected sensor

Factory and Site Acceptance Testing (FAT, SAT)

The FAT verifies the complete system meets the specification specified by customer to delivery. Missing parts such as switchgear, RCC, etc. need to be simulated for typical feeders.

The Site acceptance test (SAT) verifies that all specification and requirements given by customers have been fulfilled before put into service.it includes all testing and commissioning from bay level (process level) to station level, all SAS equipments functioning, redundancy test for servers, Gateways, GPS, PRP, HSR and verification of specification.

Redundancy Testing & Diagnostic Function

The SAS Controller system is designed for double star configuration in order to check this functionality; the tests below will be performed all tests require observing.

- HMI SAS Overview
- HMI Alarm list/Event list
- Communication Online or not

Table 2.Substation Automation Redundancy test

Redundancy Test	Switch-Over Tolerated delay	SAT switch-Over Time
Main Station Controller to Redundant or vice versa	Less than 40 Sec	20 Sec
Main Gateway to Redundant or vice versa	Less than 40 Sec	3 Sec
Main HMI to Redundant HMI or vice versa	Both HMI data base is synchronized	0 Sec Switch Over
IED PRP Test by removing one channel at a time	Both channels are parallel working	0 Sec

Proposed SAS HMI User Access and Control

The given below table shows the accessible authority for different engineer/operators.

Table-3 control authority

Assessable function	View rights	Control Commands right	Alarm Acknowledgment and clear right	Adding Users right	Changing password right	Exit the HMI	Printing rights	Extracting and configuring reports from SOE	Desktop access
Monitor (Default)	X								
Operator	X	X					X		
Maintenance	X	X	X				X	X	
Engineer	X	X	X			X	X	X	X
Administrator	X	X	X	X	X	X	X	X	X

ROPOSED SAS OPTIMAL SCHEME SOLUTION

The purpose of this scheme is to be sent alarms to HMI/RCC in such a manner to compact the system wiring .In this proposed scheme, the following points are to be considered.

- All alarm which are taken through as Binary inputs through any nearby IEDs to be sent to HMI.The all IEDs faulty, DC/AC fail, Lockout relay operated should be taken as binary inputs to nearby IEDs not to SAS Common panels.
- The Device alarm as example Differential trip, R, Y, B, 3Ph, SOTF, DEF Operated should be taken through directly device itself.
- The SAS provides integration to reduce the hardwire, in order to achieve this goal, the tripping from Pole discrepancy stage-2,BB Trip and CBF Trip, TEE Protection should be taken as GOOSE (Generic Object Oriented System-wide Events).
- All Ethernet Switch faulty and its ports (FO/Ethernet cable) fails should be taken as internal supervision.
- All DC loops in SAS Common panels and within SCP should be supervised.

Optimal Solution SA Design

The following below factors plays significant rule in choice of the optimal solution, Geographical arrangement of the SA equipment's are to be installed nearby protection and control IEDs in order to save the cost of communication cable/ fiber optics, auxiliary supplies cable, most important for system performance and fault analysis., Existing or "homologated" devices to be used, Inclusion of 3rd party equipment such as for Main 1 or Main 2 being of different manufacture

- Requirements defined by utility company specification and practices. Examples are the levels of functional integration for protection panels to be used Main, back up and auto-reclosing IEDs in same panels, use single BCU for each bay and use all LAN-A/B adjacent panels with servers/gateways/GPS/Routers etc.

- Indications as to the use of serial communication being intended or imposed for all possible levels process bus, between bays for signal exchange (e.g. for station interlocking), for signal exchange between devices inside a bay (e.g. Between distance protection and recloser), for distributed functions such as synchrocheck or breaker failure protection.
- Arranged grouped alarms of SAS communication failure alarms to be sent HMI/Gateways via SAS interface panels.
- Use Multifunction IEDs which has all desired function to be used like distance, differential ,DEF, O/C, syncrocheck , UV, OV and Auto-recloser function.

OUTLOOK AND CONCLUSION

The existing substation automation system is not uniform and all application function varies vendor to vendors, integrated proposed Substation automation system architecture with interconnected HSR/PRP techniques IEC 62439-3 Clause 4 & 5, derived uniform advanced HMI functionality based on design engineering methodology and optimal solution according to customer requirements in this paper.

Implementation this advanced uniform HMI function leads to real cost reduction, easy for maintenance, trouble shooting, secured controlling of GIS equipment like DS/ES/CB and derived reliable performance.

The standard IEC 61850 covers all the aspects related to communication inside the substation which require to be implemented in advanced manners. It is recommended to have uniformed SA scheme and design for all vendors SA system in order to give more benefits and advantage to customer therefore it is suggested in this paper to implement only GOOSE interlocks among GIS equipment, merging units to be installed beside CT box in GIS to enhance the accuracy, merging online Partial discharge monitoring system to be included in SAS HMI and use same PC for HMI and gateway application and reduce the tripping and scheme alarms from hardwire to be shifted on GOOSE messages.

REFERENCES

[1] L. Andersson, K. P., Brand, and P. Reinhardt, “IEC 61850 meets Industrial IT”, ABB review, pp. 37 -43, 3rd march 2003

[2] S. Matsuda, Y. Watabe, I.I. Asrizal, S. Katayama, K. Okuno, and K. Kasuga, "Issues overcome in the design and application of IEC 61850-compliant substation automation systems," *Advanced Power System Automation and Protection (APAP), International Conference on* , vol. 1, pp. 198-202. IEEE, 2011

[3] K.P Brand, C. Brunner and W. Wimmer , “Design of IEC 61850 based substation automation systems according to customer requirements” *Indian Journal of Power and River Valley Development*, Vol.*61*(5),87.2011

[4] Dr. Alexander Apostolov “IEC 61850 Substation Configuration Languages and Its Impact on the Engineering of Distribution Substation Systems” CIDEL Argentina, USA, 2010.

[5] J. C. Tan, & W. Luan, "IEC 61850 based substation automation system architecture design," *Power and Energy Society general meeting, 2011 IEEE* , pp.1,6, 24-29 July 2011

[6] V. Skendzic, A.Guzma , "Enhancing Power system automation Through the Use of Real-Time Ethernet," Power systems *Conference: Advanced Metering, Protection, Control, Communication, and Distributed Resources, PS'06*, pp. 480-495. IEEE, 2006.

[7] De Oliveira, J. C., Varella, W. A., Marques, A. E., and Forster, G. “Real Time Application using multicast Ethernet in Power Substation Automation according to IEC61850” PAC World Journal 2007

[8] R. Tiwary “Substation Automation System: IEC61850 future perspective”, AREVA T&D, India

[9] The Institute of Electrical and Electronic Engineers, “CSMA/CD access method and physical layer specifications. IEEE Std 802.3”, 2005

[10] H. Kirrmann, K. Weber, O. Kleineberg, H. Weibel, "seamless and low-cost redundancy for substation automation systems (high availability seamless redundancy, HSR)," Power and Energy Society general meeting, pp. 1-7. IEEE, 2011.

[11] International Electro technical Commission, Geneva “IEC 62439 series: High Availability Automation Networks”, 2010

[12] H. Kirrmann, M. Hasson , and P. Muri, "IEC 62439 PRP: Bumpless recovery for highly available, hard real-time industrial networks," In *Emerging Technologies and Factory Automation, ETFA. IEEE*

Conference on, pp. 1396-1399. IEEE, September, 2007.

[13] H. D. Ngo, H. S. Yang. D. W. Ham, J. Rhee, Y. An, Han, Y. Lee, and N. Lee "An improved High-availability seamless redundancy (HSR) for dependable substation automation system," In *Advanced Communication Technology (ICACT), 16th International Conference on*, pp. 921-927. IEEE, 2014.

[14] G. Prytz, "redundancy in Industrial Ethernet Networks," Factory Communication systems, IEEE International Workshop pp.380-385, 2006

[15] H. Kirrmann, D. Dzung, "Selecting a Standard redundancy Method for Highly Available industrial networks," *Factory communication systems, 2006 IEEE International Workshop,* pp.386-390, 2006.

[16] A. Apostolov, "communications in IEC 61850 Based Substation Automation systems," *Power Systems conference: Advanced Metering, Protection, Control, Communication, and Distributed Resources, 2006. PS '06* , pp.51-56, 14-17 ,March 2006.

[17] M. Goraj, and R. Harada, "Migration paths for IEC 61850 substation Communication networks towards superb redundancy based on hybrid PRP and HSR topologies," *Developments in power systems protection,11th International Conference on* , pp.1-6, 23-26 , April 2012.

[18] J.; Starck, W.; Wimmer, and K., Majer, "Switchgear optimization using IEC 61850-9-2,"Electricity distribution , *22nd International Conference and Exhibition on* , pp.1-4, 10-13, June 213

[19] S. A., Nsaif, & J. M. Rhee, "Improvement of high-availability seamless redundancy (HSR) traffic performance for smart grid communications," *Communications and Networks, Journal of* 14, no. 6 ,pp. 653-661,2012.

[20] M.G. Jim , "Perspectives and priorities on Rugged Com Smart Grid Research IEC 61850 Technologies" July 23, 2010

[21] H, Kirrmann, "Seamless Redundancy", ABB Review, Special Report IEC 61850, pp,57-61, 2010.

[22] IEC 62439-1 (Ed.1.0): Industrial Communications Networks – High availability automation Networks – Part1: General concepsts and calculation methods, February 2010.

[23] J.A. Araujo, J. Lazaro, A. Astarloa, N. Moreira, and A., Garcia, "memory requirements analysis for PRP and HSR hardware implementations on FPGAs," *Industrial Electronics Society, 39th annual conference of the IEEE* , pp.2297-2302, 10-13 Nov. 2013

[24] Kirrmann, H.;Weber, K.; Kleineberg, O.; Weibel, H., "HSR: Zero recovery time and low-cost redundancy for industrial Ethernet (High availability seamless redundancy, IEC 62439-3),"Emerging technologies *& Factory Automation, IEEE Conference* , pp.1-4, 22-25 Sept. 2009

[25] D. Gunzinger, and H.D. Doran, "HSR performance evaluation; a pre-specification software implementation," Emerging Technologies *& Factory Automation, IEEE Conference on* , pp.1-4, 22-25 Sept. 2009

[26] J. A. Araujo, J. Lazaro, A. Astarloa, A. Zuloaga, and Garcia, A., "High Availability automation networks: PRP and HSR ring implementations," Industrial Electronics *(ISIE), IEEE International Symposium* ,pp.1197-1202, 28-31 May 2012

[27] C. Wester, M. Adamiak, and J., Vico, "IEC61850 protocol - practical applications in industrial facilities," Industry Applications *Society Annual Meeting (IAS), IEEE* , pp.1-7, 9-13 Oct. 2011

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