

# FACTORY ACCEPTANCE TEST (FAT)/ FACTORY SYSTEM TEST (FST)/FUNCTIONAL PERFORMANCE TEST (FPT) PROCEDURE

## STANDARD FACTORY ACCEPTANCE TEST (FAT) PROCEDURE FOR SAS AND CONTROL & PROTECTION

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## 1 GENERAL:

This document is used as a standard test protocol of all tests to be done at the Factory Acceptance Test (FAT) for the typical Substation Automation System (SAS) and Control & Protection system of every substation.

Aim of the Factory Acceptance Test (FAT) is to demonstrate equipment and functionality as well as the approval of the system-parameterization by Employer to reduce the change requests during commissioning at site. The general philosophy shall be to deliver a system to site only after it has been thoroughly tested and its specified performance has been verified, as far as site conditions can be simulated in a test lab. During FAT, the entire Sub-station Automation System including complete control and protection system to be supplied shall be tested for complete functionality and configuration in factory itself. The extensive testing shall be carried out during FAT. The purpose of Factory Acceptance Testing is to ensure trouble free installation at site. No major configuration setting of system is envisaged at site.

This document details the equipment and functions under test and the corresponding test methods as well as the test documentation.

## 2 TEST CONFIGURATION:

**2.1 Equipment:** For the FAT configuration the following equipment will be present:

Computer type:	Quantity (complete SW installed)			
(Make e.g. Advantech)	Engineering / DR PC	Server PC	Client/HMI PC	Gateway PC
(Model)				

Network components:	Quantity			
	Station Level		Bay/Dia Level	
	Make/Model	Nos.	Make/Model	Nos.
Ethernet Switch				
GPS Time server				
Router cum Firewall				
Networking Panel				
Auxiliary BCU Panel				
Protection & Relay Panels	NA	NA		

Peripheral	Quantity	
	Make/Model	Nos.
Event Printer		
DR Printer (Color)		
Logbook Printer		
Auto-Changeover switch for redundant UPS supply		
UPS (5 kVA)		

Note: These equipment quantities shall be verified w.r.t. Engineering approved SAS Architecture and Bill of material (BOM).

S. No.	IEDs	Used For Functions	IED Make	IED Model	Quantity
1.	Main-1 Distance Relay	21M1			
2.	Main-2 Distance Relay	21M2			

3.	Transformer Differential Relay	87T			
4.	Transformer REF Relay	64			
5.	Reactor Differential Relay	87R			
6.	Reactor REF Relay	64R			
7.	Bay Control Unit	BCU			
8.	Bus Bar Differential Relay	87CU/MCU			
9.	Bus Bar Peripheral Unit	87PU/ BU			
10.	LBB Relay	50BF			
11.	Backup Impedance Relay	21R			
12.	Master Trip relay	86A/B			
13.	Auto-reclose Relay	79			
14.	Stand-alone DR	21DR			
15.	TEED Differential Relay				
16.	Over Flux Relay (if separate)				
17.	Controlled Switching Device				
18.	Transformer B/U O/C				

Note: Typical units will be present which can be loaded with different configurations

For an overview drawing of the equipment installed for the FAT please refer to the Appendix.

## 2.2 Engineering documents

### Purpose:

This test verifies that the correct manufacturing drawings and documentation for the equipment/system under test will be used during the Factory Acceptance Test.

### Procedure:

1. Verify that approved drawings (printed and soft copies) of all assembled equipment are present.
2. Verify that the detailed signal list for SCADA as per Employer specimen signal list is available with IEC 61850 addresses and display text as per the list.
3. Verify that the detailed GOOSE matrix with publisher and subscriber details are available.
4. Verify all required hardware and software manuals are present.
5. Guaranteed Technical Particulars (GTPs) as approved by Employer are included in Appendix A for reference.
6. Copy of Customer Technical Specification for reference is made available in the FAT room.

### Drawing Verification Log:

Cubicle	Document Title	Approved Drawing/ Doc. No.	Checked
	Overall System Architecture		<input type="checkbox"/>
	Standard General Technical Particulars for SAS		<input type="checkbox"/>
	Functional Design Specification		<input type="checkbox"/>
	Signal List for SCADA		<input type="checkbox"/>
	Matrix for GOOSE messages (with publisher & subscriber details)		<input type="checkbox"/>
	GA & Scheme of Networking Panel		<input type="checkbox"/>
	Bill of Quantity		<input type="checkbox"/>
	Server 1		<input type="checkbox"/>
	Server 2		<input type="checkbox"/>
	Gateway 1		<input type="checkbox"/>
	Gateway 2		<input type="checkbox"/>
	Operator Workstation 1		<input type="checkbox"/>

	Operator Workstation 2		<input type="checkbox"/>
	Engineering/DR PC		<input type="checkbox"/>
	ICT Feeder		<input type="checkbox"/>
	Line Feeder		<input type="checkbox"/>
	Line Reactor Feeder		<input type="checkbox"/>
	Bus Reactor Feeder		<input type="checkbox"/>
	Tie Bay of all type		<input type="checkbox"/>
	Bus Coupler		<input type="checkbox"/>
	Bus Sectionalizer		<input type="checkbox"/>
	Bus-bar		<input type="checkbox"/>
	GPS		<input type="checkbox"/>
	UPS		<input type="checkbox"/>
	Other applicable drawings (not listed above)	Attach the list as annexure	<input type="checkbox"/>

### Hardcopy & Softcopy Manuals Verification Log:

Cubicle	Document Title	Doc. No.	Checked
	Signal List for SCADA		<input type="checkbox"/>
	Matrix for GOOSE messages (with publisher & subscriber details)		<input type="checkbox"/>
	Operation and Technical Guide of BCU, Gateway, Server/Client Software		<input type="checkbox"/>
	Relay Configuration Software for Main-1		<input type="checkbox"/>
	Relay Configuration Software for Main-2		<input type="checkbox"/>
	NMS Software		<input type="checkbox"/>
	Ethernet Switch		<input type="checkbox"/>
	Time Synchronizing Equipment		<input type="checkbox"/>
	Router cum Firewall		<input type="checkbox"/>
	UPS		<input type="checkbox"/>

### 2.3 Station level equipment:

Soft and hardware components are checked to ensure required functionalities. Versions are recorded for later support purposes.

#### i. Hardware Component

The following hardware equipment are to be present during FAT:

- All Bay Control Units as per approved BOQ.
- All Protection Relays as per approved BOQ.
- HMI/Redundant HMI system consisting of redundant servers.
- Time Synchronizing Equipment consisting of GPS Receiver Unit, Antenna, Time Display Unit.
- Substation Controller/Gateway Subsystem
- Color Printer
- LAN switch equipment
- Auxiliary Panel
- UPS

The above equipment are to be as per approved standard GTP.

#### Purpose

To verify that all hardware equipment required in the contract are available in the FAT room for testing.

### Procedure

1. Visually inspect units and individual modules for cleanliness and ensure that they are free from damage.
2. Visually inspect the units for correct wiring practices and ensure that they are free from insulation damage.
3. Ensure the equipment is configured for proper point capacity as per approved drawings.
4. Ensure all modules, terminations and cables have the proper location labels as per approved drawings.
5. Ensure that all earth ground and shield connections are correctly bonded in the panels.
6. Ensure all equipment is free from all foreign material (Dust, Solder, droppings etc.)

### Hardware Visual Inspections Log:

S. No.	Equipment	Hardware Specification (CPU/RAM/HDD)	Serial No.	Checked
1	Server Workstation-1			<input type="checkbox"/>
2	Server Workstation-2			<input type="checkbox"/>
3	Operator Workstation-1			<input type="checkbox"/>
4	Operator Workstation-2			<input type="checkbox"/>
5	Gateway #1			<input type="checkbox"/>
6	Gateway #2			<input type="checkbox"/>
7	Disturbance Recorder PC			<input type="checkbox"/>
8	Color Laser jet Printer	NA		<input type="checkbox"/>
9	Dot Matrix printer	NA		<input type="checkbox"/>
10	GPS Receiver Unit	NA		<input type="checkbox"/>

### Panel Visual Inspections Log:

S. No.	Equipment	Serial No.	Circuit Name	Quality of Wiring	Checked
1.	Networking Panel		Networking Panel		<input type="checkbox"/>
2.	Aux. Panel		Aux. Panel		<input type="checkbox"/>
3.	Inverter				<input type="checkbox"/>
4.	Modem				<input type="checkbox"/>

### ii. Software Components:

The Software to be used will include the following applications:

- The BCU/IED with IEC 61850 (Server/Client) capability.
- HMI & Server with latest Version with IEC 61850 (Client) capability.
- Gateway with latest Version with IEC 60870-5-101 & 104 capability.

Configuration files shall be downloaded prior to commencement of tests and shall be the actual configuration files for individual S/S.

### a. Firmware Verification

#### Purpose

To verify and record that the Equipment Firmware used in the FAT.

#### Procedure

Using Device Display verify all BCU/IED equipment firmware version.

### Firmware Verification Log.

S. No.	Equipment	Model	Operating System/Firmware	Checked
1	HMI-1			<input type="checkbox"/>
2	HMI-2			<input type="checkbox"/>

3	DR PC			<input type="checkbox"/>
4	Color Laser JET Printer			<input type="checkbox"/>
5	Dot Matrix Printer			<input type="checkbox"/>
6	Gateway-1&2			<input type="checkbox"/>
7	Ethernet Switches			<input type="checkbox"/>
8	Voltage Level BCU Bay No.			<input type="checkbox"/>
9	Voltage Level IED's (IEC61850 Compliant) for Dia			<input type="checkbox"/>

### SCADA Devices - IP Addresses

Will be checked at each device user interface.

### System Devices

Designation	N/W Name	GOOSE ID	IP Address				Checked
Server 1			172	16	55	1	<input type="checkbox"/>
Server 2							<input type="checkbox"/>
OWS1							<input type="checkbox"/>
OWS2							<input type="checkbox"/>
EWS/DR PC							<input type="checkbox"/>
SDC1							<input type="checkbox"/>
SDC2							<input type="checkbox"/>
Gateway1							<input type="checkbox"/>
Gateway2							<input type="checkbox"/>
GPS Time Server 1							<input type="checkbox"/>
GPS Time Server 2							<input type="checkbox"/>
Ethernet Switch 1							<input type="checkbox"/>
Ethernet Switch 2							<input type="checkbox"/>
Event Printer							<input type="checkbox"/>
Color Laser jet Printer							<input type="checkbox"/>
Router cum Firewall 1							<input type="checkbox"/>
Router cum Firewall 2							<input type="checkbox"/>
19 Port Managed LAN Switch							<input type="checkbox"/>

Relay's Name	N/W Name	GOOSE ID	IP Address				Checked
P444 __LINE	#01_21M1		172	16	55	101	<input type="checkbox"/>
							<input type="checkbox"/>
							<input type="checkbox"/>
							<input type="checkbox"/>

### 2.4 Test Equipment:

The following equipment are required to conduct the test.

- EWS/DR PC to be used for Configuration Applications for different IEDs.
- Hand-held Digital Multimeter suitable for AC/DC with peak-hold and continuity tester.
- Digital Clamp-on Meter suitable range for secondary current measurement.
- Three phase injection KIT (Relay Test Kit) for supplying 3 phase current and voltage.
- 4-20 mA Injection Kit.
- Protocol Analyzer as applicable.

#### i. Test Equipment Inspection

### Purpose

To ensure that the Test Equipment to be used is operational and have valid calibration.

### Procedure

Visual inspection of calibration stickers and certificates. Power up and verification that units are operational.

#### Test Equipment Inspection Log:

S. No.	Equipment	Calibration Check	Device Power On	Checked
1	3 Phase Injection Kit			<input type="checkbox"/>
2	Precision Hand-held Digital Multi Meters			<input type="checkbox"/>
3	Digital Clamp-on meter			<input type="checkbox"/>
3	Insulation Resistance Tester			<input type="checkbox"/>
4	220V DC Source for powering up all SAS Panels			<input type="checkbox"/>
5	4-20 mA Injection Kit			<input type="checkbox"/>

### 2.5 Power Checks:

#### Purpose

To ensure that the SAS equipment installed in the panels & control rooms are operating when connected to the nominal specified power supply (220V AC/DC).

#### Setup/Program

Perform the steps below to confirm correct operation of all equipment connected to the power supplies.

#### Procedure

1. Verify that all 220V AC/DC equipment are powered at the nominal AC/DC supply voltage input. Using a Digital Multimeter verify that the nominal AC/DC supply voltage is present.
2. Verify that there are no abnormalities seen when the equipment is turned ON.

#### Power Checks Log:

S. No.	Panel	Equipment	Device Power ON	Checked
1	NA	Server-1		<input type="checkbox"/>
2	NA	Server-2		<input type="checkbox"/>
3	NA	HMI-1		<input type="checkbox"/>
4	NA	HMI-2		<input type="checkbox"/>
5	NA	DR PC		<input type="checkbox"/>
6		Gateway-1		<input type="checkbox"/>
7		Gateway-2		<input type="checkbox"/>
8	NA	Laser Jet Printer		<input type="checkbox"/>
9	Networking Panel	Auxiliaries (Lighting etc.), LAN Switches, Gateway		<input type="checkbox"/>
10	Relay Panel	Relays and Wiring diagram		<input type="checkbox"/>

### 3 FUNCTIONAL TESTING:

General Substation Automation System (SAS) is a combination of different bay control units and protection devices with a central operator placed as Human-Machine-Interface (HMI) and central data storage and acquisition. These components and their connections are shown in the System Architecture. For SAS-FAT a configuration is selected to check the basic system functions and the cooperation between the different components. The test procedure will show the proper function of the system in general. All decentralized I/O devices (bay control units and protection devices)



are provided for this test. A complete test of all I/O signals (see SAS signal list) is objective of this test. All modules are tested by type tests in general and by test routines during manufacturing.

### 3.1 Start-up and SAS system availability

For following equipment, the start – up times are measured to check the performance. The timing of the station controllers starts with switching on the power supply and finishes after reaching the working condition “RUN”. The timing of the Operator Workstation starts with switching on the power supply. The computer will then start - up automatically without registering to Windows or manual start of any software. The timing finishes after reaching the start picture of the application software where the user has to register with his password. The timing of the Engineering PC and Protection Interface PC starts with switching on the power supply and finishes after successful achievement of the working condition.

System Start-up	checked	Time	Comments see log sheet no.
Server-1	<input type="checkbox"/>		
Server-2	<input type="checkbox"/>		
Operator Workstation 1	<input type="checkbox"/>		
Operator Workstation 2	<input type="checkbox"/>		
Engineering/DR PC	<input type="checkbox"/>		
Gateway 1	<input type="checkbox"/>		Data Transmission to RCC/RLDC should resume automatically
Gateway 2	<input type="checkbox"/>		Data Transmission to RCC/RLDC should resume automatically
Complete system start up	<input type="checkbox"/>		Black Start

After start-up of all devices the error free operation, communication and time synchronization of components is checked on the SCADA displays.

S. No.	System Start-up	Checked
1.	Time synchronization of Substation controllers / PCs	<input type="checkbox"/>
2.	Time synchronization of connected IEDs	<input type="checkbox"/>
3.	Communication to Bay Control Unit	<input type="checkbox"/>
4.	Communication to Protection Devices	<input type="checkbox"/>
5.	Event list printer	<input type="checkbox"/>
6.	Hardcopy color/ Logbook printer	<input type="checkbox"/>
7.	Communication with remote control centers	<input type="checkbox"/>

### 3.2 Monitoring and control

#### i. BCU – displays and handling.

General layout, handling, and control of typical feeder BCUs is demonstrated and checked under this chapter. The displayed SLD is cross checked against the approved SLD/ Mimic SLD.

BCUs for ____kV Level	checked	Comments see log sheet no.
Basic/control display for OHL Feeder	<input type="checkbox"/>	
Basic/control display for Transformer Feeder	<input type="checkbox"/>	
Basic/control display for Line Reactor Feeder	<input type="checkbox"/>	
Basic/control display for Bus Reactor Feeder	<input type="checkbox"/>	

Basic/control display for Tie Bay/TBC	<input type="checkbox"/>	
Basic/control display for Auxiliary System		
Basic/control display for Bus Coupler	<input type="checkbox"/>	
Basic/control display for Bus Section	<input type="checkbox"/>	
Event list	<input type="checkbox"/>	
Alarm list	<input type="checkbox"/>	
Analogue measurement list	<input type="checkbox"/>	
Metering list	<input type="checkbox"/>	
Alarm limits	<input type="checkbox"/>	
Handling of displays, control and menu	<input type="checkbox"/>	
Changing V,I,f – limits: - current >limit 1 - current >limit 2 - voltage >limit 1 - voltage <limit 1 - frequency >limit 1 - frequency <limit 1	<input type="checkbox"/>	
BCUs for _____ kV Level	<input type="checkbox"/>	

## ii. HMI – modes of operation and user management

A multi-level login is implemented in SCADA. There are 4 different levels of access. Without login, there is no possibility to open any display. The different access levels are implemented as shown in following table:

### Purpose

To verify that the OWS/HMI system has Security Classes, that are enabled and configured properly.

### Setup

1. Ensure that the HMI Servers are running.
2. Start Client, by default the user will be logged in as blank.
3. Verify that this user class has proper access level as per HMI Security Classification.
4. Go to any bay detail screen. Verify if access to tool bar and object controls are according to that allowed in the access level logged in.
5. Repeat steps 1 to 3 for the other HMI Usernames (Operator, Protection, Administrator)
6. Repeat steps 1 to 4 for the other Workstations.
7. Function is tested by clicking on the corresponding buttons or switching devices and checking of SCADA “No permission” – notifications.

### HMI Access Level:

Access Level	Monitor	Operator	Engineer	Administrator	Checked	Comments see log sheet no.
Display System Status & View Screens	Yes	Yes	Yes	Yes	<input type="checkbox"/>	
Controls – CB, Isolators	No	Yes	Yes	Yes	<input type="checkbox"/>	
Acknowledge/Clear Alarms	No	Yes	Yes	Yes	<input type="checkbox"/>	
Change HMI Config.	No	No	No	Yes	<input type="checkbox"/>	
Create/Disable/Delete User Account	No	No	No	Yes	<input type="checkbox"/>	
Change User	No	No	No	Yes	<input type="checkbox"/>	

Profile/Access Level						
Maintenance mode	No	No	Yes	Yes	<input type="checkbox"/>	
Reset lockout relay	No	Yes	Yes	Yes	<input type="checkbox"/>	
Interlocking bypass	No	No	Yes	Yes	<input type="checkbox"/>	
Sync. Check Bypass	No	No	Yes	Yes	<input type="checkbox"/>	
Auto-reclosure	No	No	Yes	Yes	<input type="checkbox"/>	
Auto sequence	No	No	No	Yes	<input type="checkbox"/>	
Shut down the system	No	No	Yes	Yes	<input type="checkbox"/>	

### iii. HMI – Displays and Handling

Check that the displays are in accordance with Employer’s requirements. General layout and handling is demonstrated and checked. Overview and control pictures are cross-checked against the approved substation SLD.

#### Purpose

To verify that the Single Line Diagram and Bay Detail Screens on the OWS system are configured properly and are in correct operating condition.

#### Setup

1. Ensure that the HMI Servers are running.
2. Log in as an “Operator”.

#### Procedure

1. Verify the layout of each SLD on the OWS.
2. Verify the device number, device description and device symbol for each device.
3. Verify all displayed analog and digital values on the detailed bay view screens.
4. Click on each device object and confirm that the respective popup screen or bay/view detail screen is displayed.
5. Repeat steps 1 to 4 for each SLD / Detailed Bay View.

	Checked	Comments see log sheet no.
Handling of screen/picture selection	<input type="checkbox"/>	
Display for Station overall SLD	<input type="checkbox"/>	
Display for _____kV overview:	<input type="checkbox"/>	
- _____kV substation overview	<input type="checkbox"/>	
- _____kV single line diagram view	<input type="checkbox"/>	
Display for _____kV overview:	<input type="checkbox"/>	
- _____kV substation overview	<input type="checkbox"/>	
- _____kV single line diagram view	<input type="checkbox"/>	
Display of Measurement Trends (Real-time and Historical)	<input type="checkbox"/>	
Display of maintenance mode	<input type="checkbox"/>	
Display of safety tagging	<input type="checkbox"/>	
Display of Operations counter for PLCC & CB	<input type="checkbox"/>	
Display of Network/LAN overview	<input type="checkbox"/>	
Display of typical bay communication (Ring)	<input type="checkbox"/>	
Display for Auxiliary System views	<input type="checkbox"/>	
Display of event list	<input type="checkbox"/>	
Display of alarm list	<input type="checkbox"/>	

Handling of screen/picture selection	<input type="checkbox"/>	
Basic/ Control display for Kiosk Air Conditioning System	<input type="checkbox"/>	
Basic Control display for Online Monitoring System for Transformers & Reactors	<input type="checkbox"/>	
Basic /Control display for Control Switching Device	<input type="checkbox"/>	
CVT/CT Monitoring	<input type="checkbox"/>	
Visual Monitoring System	<input type="checkbox"/>	
Transformer Bank with Tap changer Operation	<input type="checkbox"/>	

**In case of extension packages, the existing make SCADA system of the substation where extension is proposed shall be used to carry out the validation of extension bays signals, control commands, etc., with the extension bays configured as the only bays that exist in the substation.** For this purpose, the existing SCADA system can be installed in a laptop. Further after completion of FAT, the verified SCADA configuration shall be used for addition into the existing SCADA at site.)

#### iv. Inspections of HMI typical bay screens

##### Validation of electrical views

##### Purpose

To verify that the Single Line Diagram and Bay Detail Screens on the OWS system are configured properly and are in correct operating condition.

##### Setup

1. Ensure that the HMI Servers are running.
2. Log in as an “Operator”.

##### Procedure

1. Verify the layout of each SLD on the OWS.
2. Verify the device number and device description for each device.
3. Verify all displayed analog and digital values on the detailed bay view screens.
4. Click on each device object and confirm that the respective popup screen or bay/view detail screen is displayed.
5. Repeat steps 1 to 4 for each SLD / Detailed Bay View.

Bay screens _____kV Naming, SCADA numbers, status indications, measurement items to be checked	Checked	Comments see log sheet no.
_____kV Line Feeder	<input type="checkbox"/>	
_____kV Transformer Feeder	<input type="checkbox"/>	
_____kV Bus Reactor	<input type="checkbox"/>	
_____kV Line Reactor	<input type="checkbox"/>	
Bay screens _____kV Naming, SCADA numbers, status indications, Measurement to be checked		
_____kV Line Feeder	<input type="checkbox"/>	
_____kV Transformer Feeder	<input type="checkbox"/>	
_____kV Bus Reactor	<input type="checkbox"/>	
_____kV Line Reactor	<input type="checkbox"/>	

## Validation & Verification of Signals on SCADA HMI

### Purpose

To verify that the signals as per the specimen signal list provided by Employer has been correctly configured and are appearing on SCADA HMI as desired.

### Setup

The Detailed signal list based on which the SCADA configuration has been prepared shall be taken and each signal shall first be validated (e.g. appearance of “Valid”, Reset/ Set/operated/Healthy, etc. status as per the appearance of on-screen validity shall be checked). Any signal appearing as “unknown” / “invalid” shall be flagged and configuration shall be modified for proper validation.

After validation of signals under SCADA configuration, various protection functions and appearance of the desired signals on SCADA HMI shall be verified.

For certain signals (having Integer type attribute), the on-screen display of text displayed depends on the value fetched from IED, (e.g. Auto-reclose status from function RREC wherein the value of ‘AutoRecSt’ 1 denotes ready, 2 denotes Auto-reclosure in-progress, etc.). All types of text displays with different inputs shall be verified by simulation of the state.

For all the IEDs subscribing to GOOSE messages from other IEDs (e.g. BCUs), which are used to perform logical actions, the appearance of ‘GOOSE fail’/‘GOOSE trouble alarm’ shall be configured and verified by making one of the GOOSE message absent, to which the IED subscribes.

The Voltage selection logics for ICTs & Rector feeders, utilizing GOOSE messages shall also be verified by simulating various switchgear status, which change the selected voltage.

## Validation of Historical Trend

### Purpose

To verify that the Trending in the OWS system are configured properly and are in correct operating condition.

### Setup

1. Ensure that the HMI servers are running.
2. Go to Trend Screen.

### Validation of Historical Trend on OWS

S. No.	Activity	Checked
1.	Verify all Analog signals on trend screen.	<input type="checkbox"/>
2.	Verify that the trend curve on HMI screen for different analog signal has different colors.	<input type="checkbox"/>
3.	Verify that the Time Scale for trend curves are user settable.	<input type="checkbox"/>
4.	Verify that EHV Lines have Predefined trend of active and reactive power, ICT have Predefined trend of current, active and reactive power. Bus have Predefined trend of voltage and frequency.	<input type="checkbox"/>
5.	Data archive retrieval is to be checked for proper display of old records	<input type="checkbox"/>

## Validation of Reports Function

### Purpose

To verify that the Reports Functions (Historical Report) in the OWS/HMI system are configured properly and are in correct operating condition.

### Setup

1. Ensure that the Client & Server is running.

### Procedure

#### Historical Event Report

1. Generate some Digital / Analog events in BCU.
2. Click on the Reports button present on the HMI Screen.
3. Select the Range of date by selecting the Start Date and End Date.
4. Verify whether the same generated events have been produced in the Historical Report.

#### Daily Report (Hourly Instantaneous Value of Analog Data Points)

1. Inject Voltage & Current through 3 Phase Injection Kit to any BCU.
2. Verify the values on the detailed view of the selected BCU.
3. Select the daily Report Button of line BCU.
4. Verify the daily Report have produced Hourly instantaneous Value of the selected BCU. The Maximum and minimum instantaneous value of each selected parameter (with time) shall also be included in the report. This time-tagged max and min data shall be generated from the Trend data of the BCU.
5. Data archive retrieval is to be checked for proper display of old records.

#### Operation Reports:

Apart from Historical and trend reports of analog values, reports in specified formats as per the requirement of Employer system operation are also to be generated in the standard format provided by Employer. The reports will be periodic logging (01 hourly/ 04 hourly/ 08 hourly etc.) of analog/digital values and mainly cover the EHV feeder, Transformer & Reactors temperatures, AC & DC Auxiliary supply system, Battery chargers, CB operation counter readings, PLCC counter readings etc.

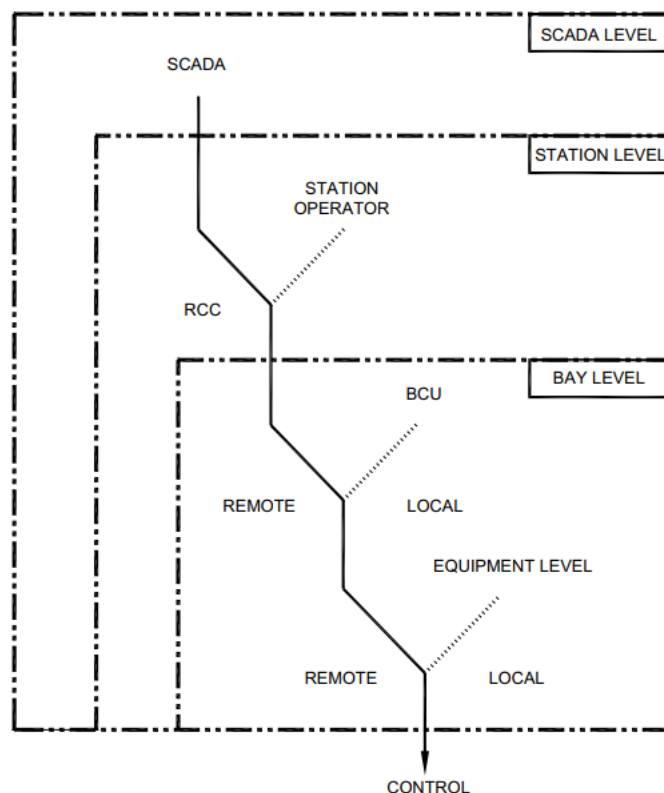
#### v. SCADA connection:

In this chapter the communication to SCADA via IEC 104/IEC 61850 will be checked. Detailed information test (control authority, command, and indication) will be done in the chapter following this. SCADA interface is simulated with test program IEC-Test running on two laptops. With the test program the protocols IEC 104 as well as IEC 61850 can be simulated. Detailed redundancy tests will be performed under chapter [2.2.20.4/3.2.20.5](#).

	Checked	Comments see log sheet no.
Communication check for		
- spontaneous information	<input type="checkbox"/>	
- general interrogation		
- time stamping of indications	<input type="checkbox"/>	

#### vi. Control tests:

Control is possible from Relay Panel/MIMIC Board, BCU, Operator Workstation (1 or 2) and CCR/Backup CCR. During the test, all check back indications from switchgear devices will be simulated by an I/O simulation box. Pre-conditions for controls are correct switching conditions (synch-check and interlocking). Switching the relevant local/remote switch will be displayed in event list.



	Checked	Comments see log sheet no.
A. Control from mimic board The mimic board is implemented in the cubicle	<input type="checkbox"/>	
B. Control from BCU Changing status of local/remote switch on BCU raises an event-on-event list. Control from BCU is only possible if local/remote switch on BCU is in local position and local/remote switch on mimic board is in remote position. In this position no control from Operator Workstation and SCADA is possible.	<input type="checkbox"/>	
C. Control from Operator Workstation (Local) Changing status of local (SCADA) / remote (SCC/ECC) button on Software screen raises an event-on-event list. Control from Operator Workstation is only possible if control is switched to local position and local/remote switch on BCU and mimic board is in remote position. In this Position, no control from SCADA is possible.	<input type="checkbox"/>	
D. Control from SCADA (Remote) Control from SCADA is only possible if all local/remote switches per bay (on bay and station level) are in remote position. SCADA interface is simulated with test program IEC Test.	<input type="checkbox"/>	

### vii. Control method:

Control of switchgear shall be done from the detailed bay display diagrams in OWS. The method of man machine dialogue shall be a multi-stage procedure with verification to ensure security of control.

	Checked	Comments see log sheet no.
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- Selection of switching device	<input type="checkbox"/>	
- Appearance of selected device control window	<input type="checkbox"/>	
- Selection of switching direction (open/close)	<input type="checkbox"/>	
- Change of the selected device symbol (flashing in selected control direction)	<input type="checkbox"/>	
- Execution of the control	<input type="checkbox"/>	
- Possibility of cancellation at any time	<input type="checkbox"/>	
- Time out of control mode if operator fails to respond	<input type="checkbox"/>	
- Source of control appearance in event list	<input type="checkbox"/>	
- Double object control blocking function for control from HMI/ SCADA level	<input type="checkbox"/>	

### viii. Control of dummy circuit breaker:

	Checked	Comments see log sheet no.
- Check of dummy circuit breaker function	<input type="checkbox"/>	

### ix. Control of circuit breaker:

“CLOSE” and “OPEN” operation of 765/400kV typical circuit breaker is tested by giving a command from BCU or HMI and checking of the command execution. At the same time, the respective check back indication of switching position is checked at the BCU and HMI. The correct registration in the event list will also be tested. All the bays for each voltage level will be checked. Furthermore, some faults will be simulated (e. g. control authority, CMD interlocked, CMD monitoring time). SCADA-interface is simulated with test program IEC-Test.

	Command	Checked typical				Comments see log sheet no.
		701-52	702-52	703-52	704-52	
765kV	Circuit breaker					765kV
	Control/Display BCU					
	Control/Display HMI	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	Control/Display SCADA	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	HMI/SCADA Display event list	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
400kV	Circuit breaker					400kV
	Control/Display BCU					
	Control/Display HMI	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	Control/Display SCADA	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	HMI/SCADA Display event list	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

### x. Synch-check:

Synchro check-function is parameterized in the BCU. Therefore control is demonstrated from bay control unit for functionality-check. Positions of bus bar voltage transformer disconnecting switch are simulated by an I/O simulation box and bus bar voltage by a test set (e.g., Relay Test Kit).

#### Purpose

To verify that Incoming and Running (Reference) voltages are within the synchronizing range before the circuit breaker can close. The circuit breaker will not close if any of the limiting parameters is not within the check synchronizing range. For practical reasons this FAT will not include the testing of Running Voltage selection for the Synchronization.

#### Setup



1. Set up the BCU to check synchronizing ranges as follows:
  - Phase Differences Specification requirement states Phase Difference shall not exceed 30° (1° Hysteresis).
  - Voltage Difference Specification requirement states Voltage Difference shall not exceed 10% (2% Hysteresis) for 400kV and below system and 7.5% (1% Hysteresis) for 765kV system.
  - Frequency difference 0.1 Hz (Connected System).
2. Set up the 3 Phase Injection Kit to supply the Running Voltage & Selected Voltage to BCU TMU card (CT/VT card).
3. Set up the 3 Phase Injection Kit to the following test cases:

#### Check Synchronization Test Settings

Test Case	Voltage Difference in pu	Phase Angle Difference in Degrees (°)	Expected Sync Close Results	Checked
1	0.20	40.0	No	<input type="checkbox"/>
2	0.12	40.0	No	<input type="checkbox"/>
3	0.10	40.0	No	<input type="checkbox"/>
4	0.11	20.0	No	<input type="checkbox"/>
5	0.09	17.0	Yes	<input type="checkbox"/>
6	0.10	16.0	Yes	<input type="checkbox"/>
7	0.10	15.0	Yes	<input type="checkbox"/>
8	0.05	10.0	Yes	<input type="checkbox"/>

#### Procedure:

1. Select a BCU and corresponding Circuit Breaker to Test.
2. Using the 3 Phase Injection kit, inject the Running & Selected Voltage to the BCU and apply the differences as shown in the above table.
3. Open the Detailed view of the selected Bay on the HMI and verify the voltage references.
4. Initiate the CB Close Request.
5. Verify that the Circuit Breaker closes only when the configured settings are satisfied.

CB	CB Condition	Checked
765KV Circuit Breakers		
		<input type="checkbox"/>
		<input type="checkbox"/>
		<input type="checkbox"/>
400KV Circuit Breakers		
		<input type="checkbox"/>
		<input type="checkbox"/>
		<input type="checkbox"/>

The above check sync verification is to be carried out for all possible voltage selection logics for synchronization (e.g, for main bay breaker connected to Bus 1 in one and half scheme, Bus 1 Voltage- Bus 2 Voltage, Bus 1 Voltage - Feeder 1 Voltage, Bus 1 Voltage – Feeder 2 voltage, as may be required in the scheme). These possible voltage selection conditions are required to be simulated either by simulated switchgear or by simulating GOOSE messages published by other BCUs, which are required in the selection logic.

#### Dead Source Condition

## Purpose

To verify that when the following conditions are met, the Synchro check logic permits the Immediate closure of the Circuit Breaker.

- Dead Line-Dead Bus
- Dead Line-Live Bus
- Live Line-Dead Bus

## Dead Bus Setup

1. Set up the BCU to check synchronizing settings as follows:
  - Presence of Line Voltage (Param1) – 70%
  - Absence of Line Voltage (Param2)– 30%
  - Presence of Bus Voltage (Param3)– 70%
  - Absence of Bus Voltage (Param4)– 30%

## Procedure

The absolute values of the two voltages ( $V_{line}$  and  $V_{bus}$ ) must be above or below settable thresholds, to permit the circuit breaker closing. The following voltage controls are available:

- not  $V_{line}$  and not  $V_{bus}$  – (Dead Line-Dead Bus)
- not  $V_{line}$  and  $V_{bus}$  – (Dead Line-Live Bus)
- $V_{line}$  and not  $V_{bus}$  – (Live Line-Dead Bus)
- $V_{line}$  and  $V_{busbar}$  – (Live Line-Live Bus)

With  $V_{line}$  and  $V_{bus}$  TRUE if the measured voltage is above the threshold  $V>$  (param 1 and param 3), and  $V_{line}$  and  $V_{bus}$  FALSE if the measured voltage is below the threshold  $V<$  (param 2 and param 4). These thresholds are given in % of the nominal voltage value.

The selection of the voltage control is made during the configuration phase.

Test Case	Description	Expected Sync Close Results	Checked
DL-DB	In case of the absence of both voltages i.e. not $V_{line}$ and not $V_{bus}$ .	Yes	<input type="checkbox"/>
DL-LB	In case of the absence of one of the two voltages i.e. not $V_{line}$ and $V_{bus}$ .	Yes	<input type="checkbox"/>
LL-DB	In case of the absence of one of the two voltages i.e. $V_{line}$ and not $V_{bus}$ .	Yes	<input type="checkbox"/>
LL-LB	In Case of the presence of both voltages i.e. $V_{line}$ and $V_{bus}$ , Set beyond ranges	No	<input type="checkbox"/>
LL-LB	In Case of the presence of both voltages i.e. $V_{line}$ and $V_{bus}$ , Set within ranges	Yes	<input type="checkbox"/>

	Checked	Comments see log sheet no.
Displaying and handling - BCU	<input type="checkbox"/>	
- HMI	<input type="checkbox"/>	

	Checked	Comments see log sheet no.
Dead line – Dead bus	<input type="checkbox"/>	
Dead line – Live bus	<input type="checkbox"/>	
Live line – Dead bus	<input type="checkbox"/>	
Live line – Live bus with unfulfilled sync conditions ( $V_{diff}$ , $f_{diff}$ , $angle_{diff}$ )	<input type="checkbox"/>	

Live line – Live bus with fulfilled sync conditions ( $V_{diff}$ , $f_{diff}$ , $angle_{diff}$ )	<input type="checkbox"/>	
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#### xi. Control of isolator and earthing switch:

“CLOSE” and “OPEN” operation of high voltage switching devices are tested by giving a command from BCU or HMI and checking of the command execution. At the same time, the respective check back indication of switching position is checked at the BCU and HMI. The correct registration in the event list will also be tested. One bay for each voltage level will be checked (400kV-station: ‘401’ and for 220kV-station: ‘201’). Furthermore, some faults will be simulated (e.g. control authority, CMD interlocked, CMD monitoring time).

SCADA-interface is simulated with test program IEC-Test.

#### xii. Interlocking (bay and station based):

Control of switchgear devices is only possible if all interlocking conditions are fulfilled. Interlocking conditions are shown in circuit manuals of local control cubicles (For drawing nos. see chapter 2.2). Generally, for demonstration of interlocking the control can be done from bay control unit. As the complete feeder interlocking is checked during SAT of BCU together with primary switchgear, only some selected general functions are shown. Positions of relevant breakers/isolators are simulated by a hardwired I/O simulation box. The interlocking logic and status for each switchgear should be visible to the operator-on-operator HMI beforehand while operating the respective switchgear. The validation of interlock condition shall be performed based on the interlock logic visible on the screen.

	Checked	Comments see log sheet no.
Maintenance mode	<input type="checkbox"/>	
Switchgear interlocking	<input type="checkbox"/>	
HMI – display of interlocking conditions along with signals for each switchgear device	<input type="checkbox"/>	

#### xiii. Switching sequences:

Switching sequences are initiated and controlled from Station Controller. The preconditions for switching sequences are parameterized in BCU. The interruption of the switching sequence can occur due to missing one of the preconditions, either synch-check or interlocking. Correct switching and the corresponding feedback indications will be checked. Randomly, some interlocking conditions will be done in such a way that the switching sequence will be interrupted. The effect will be that the system will wait for the command running time to terminate. In the event list negative feedback will be recorded indicating the reason for not executing the command.

Connect OHL Feeder To BB1:		
closing of Isolators & CB		
Connect OHL Feeder To BB2:		
closing of Isolators & CB		
Disconnect OHL Feeder (Bay):		
opening of CB & Isolator		
Change Busbar:		
closing/opening of Isolators		
Close Bus Coupler:		
closing of Isolators & CB		
Open Bus Coupler:		

#### xiv. Digital RTCC Functions (if applicable):

The Digital RTCC Functions view shows information about the tap position of transformer feeder (ICT1-ICTn) of the station. Using the control button a tap position control window will appear. It can be chosen between the automatic and manual mode. The tap position of each transformer feeder can be changed with the top/down slider by using the manual mode. The exit button closes the window.

Properties of Digital RTCC	Checked	Comments see log sheet no.
- Selection of transformer feeder	<input type="checkbox"/>	
- Appearance of selected window	<input type="checkbox"/>	
- Selection of control mode (auto/manual)	<input type="checkbox"/>	
- Send TAP rise/ lower command in manual	<input type="checkbox"/>	
- Checking of Master-Follower/ independent mode	<input type="checkbox"/>	
- Checking of Other RTCC Functions	<input type="checkbox"/>	

#### xv. Event processing:

Events are displayed in chronological order in event list. All events have date and time tag. Selection of event list on Operator Workstation will show the latest page with the newest event on top. Event list shows all events including the alarms. **Events are colored in white.** The creation of a reduced list is possible by filter function. Transient conditions (i.e.00/11) will not generate an event, unless a time delay is exceeded.

##### Purpose:

To verify that the Events Points are configured properly and in correct operating condition.

##### Setup:

1. Ensure that the HMI Servers are running.
2. Display the Event Screen.

##### Procedure:

1. Select a Digital Input Point from one of the BCUs configured as an Event.
2. Change the state of the Selected Input
3. Verify that an Event is displayed on the Event Screen with proper description and Time Stamp.
4. Acknowledge this alarm.
5. Go to Event Screen and verify that this alarm is displayed in the list.
6. Repeat Steps 1 to 6 for the several Digital Input

#### Validation of the Events and Alarm Management on OWS:

S. No.	Activity	Checked
1	Verify that separate logs are available for alarm and events	<input type="checkbox"/>
2	Verify that suitable filters (sorting by date, time etc.) are provided for both alarms and events	<input type="checkbox"/>
3	Verify that an Alarm and Event is displayed in the Alarm and Event Screen with proper description and Time Stamp	<input type="checkbox"/>
4	Verify the alarm acknowledgement facility and verify that their display changes in alarm viewer according to the alarm status	<input type="checkbox"/>

	Checked	Comments see log sheet no.
Event processing - BCU	<input type="checkbox"/>	
- HMI	<input type="checkbox"/>	
Time tagging - BCU	<input type="checkbox"/>	
- HMI	<input type="checkbox"/>	
Filter function - date/time	<input type="checkbox"/>	
- message group	<input type="checkbox"/>	
- message text	<input type="checkbox"/>	
- alarm group	<input type="checkbox"/>	
Check naming convention of one typical feeder according signal list		
- hierarchical name	<input type="checkbox"/>	
- signal name	<input type="checkbox"/>	

#### xvi. Alarm processing:

Alarms are displayed in chronological order in alarm list. Selection of alarm list on Operator Workstation will show the latest page with the newest alarm on top of the line. **Coloring depends on alarms status (raised, cleared, and acknowledged)**. Acknowledgement of alarms depends on permissions level (see 3.2.ii “HMI – modes of operation and use)

#### Purpose

To verify that the Alarms are configured properly and in correct operating condition.

#### Setup

1. Ensure that the HMI Servers are running.
2. Display the Alarm Screen.

#### Procedure

1. Select a Digital Input Point from one of the BCUs configured as an Alarm.
2. Change the state of the Selected Input
3. Verify that an Alarm is displayed in the Alarm Screen with proper description and Time Stamp.
4. Acknowledge this alarm.
5. Repeat Steps 1 to 6 for the several Digital Input

	Checked	Comments see log sheet no.
Alarm processing - BCU	<input type="checkbox"/>	
- HMI	<input type="checkbox"/>	
Time tagging - BCU	<input type="checkbox"/>	
- HMI	<input type="checkbox"/>	
- Time stamp quality field	<input type="checkbox"/>	
Filter function - date/time	<input type="checkbox"/>	
- message group	<input type="checkbox"/>	
- message text	<input type="checkbox"/>	
- alarm group	<input type="checkbox"/>	
Permission of acknowledgement	<input type="checkbox"/>	
Alarm raised: Yellow Flashing	<input type="checkbox"/>	
Alarm cleared: Green	<input type="checkbox"/>	
Alarm acknowledged: Yellow	<input type="checkbox"/>	

Alarm list filtering function (Date & Time, Bay No.)	<input type="checkbox"/>	
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### xvii. Analogue measurement handling

Correct displaying of analogue values is checked on the screens of BCU and HMI. A change of analogue quantity is reported to the SCADA master system. Correct displaying of power flow convention is defined and checked. Measurements will be tested from BCU (in feed by a relay test set) as well as from BCU:

	Checked	Comments see log sheet no.
Displaying of analogue values - BCU - HMI	<input type="checkbox"/> <input type="checkbox"/>	
Power flow convention	<input type="checkbox"/>	
Real time trends	<input type="checkbox"/>	

Measurement of each Bay: For e.g. Checked

CT Ratio: 3000/1 A \* ☐

VT Ratio: 400/0.11 kV \* ☐

### Current Measurement:

Injected second Current	Expected measured value	Dead band	Indicated Value					
			R		Y		B	
			BCU	HMI	BCU	HMI	BCU	HMI
0.0A								
0.05A								
0.5A								
1.0A								
1.1A								

### Voltage Measurement:

Injected second. Voltage	Expected measured value	Dead band	Indicated Value					
			R		Y		B	
			BCU	HMI	BCU	HMI	BCU	HMI
6.35V								
31.75V								
63.5V								
70V								
110V								

### Frequency Measurement:

Injected Frequency	Dead band	48Hz		50Hz		52Hz	
		BCU	HMI	BCU	HMI	BCU	HMI
Indicated Value							

Comments see log sheet no.

\*CT & PT Ratio as per approved drawing

Injected Value	Phase Angle V with ref. to I	Active Power				Reactive Power				Power Factor			
		Calculated Value	BCU	HMI	Err. (%)	Expected Value	BCU	HMI	Err. (%)	Calculated Value	BCU	HMI	Err. (%)
I = U =	0°									1			
	60°									0.5			
	90°									0			
	120°									-0.5			
	-120°									0.5			
	-60°									-0.5			

### Transformer Measurement Values

Injected	Measured			Checked
	HMI	Error (%)	Remote Control Center	
Oil Temperature ..... °C				
Winding Temperature HV..... °C				
Winding Temperature IV ..... °C				
Winding Temperature LV ..... °C				
Oil Temperature ..... °C				
Winding Temperature HV..... °C				
Winding Temperature IV ..... °C				
Winding Temperature LV ..... °C				
..... °C				
..... °C				

### General Station Analogue Values

Injected	HMI	Measured Supervisory		Checked	Comments see log sheet no.
	Display	Error (%)	Transmitted		
Outside Temp.....°C				<input type="checkbox"/>	
Outside Humidity.....%				<input type="checkbox"/>	
SCADA Room Temp.....°C				<input type="checkbox"/>	
Telecom Room Temp.....°C				<input type="checkbox"/>	
Battery Room Temp.....°C					
SPR... Temp.....°C					
SPR... Temp.....°C					

Injected		HMI	Measured Supervisory	Checked		Comments see log sheet no.
		Display	Error (%)	Transmitted		
Current 220V DC-1 O/P .....	A				<input type="checkbox"/>	
Voltage 220V DC-1 O/P .....	V				<input type="checkbox"/>	
Current 220V DC-2 O/P .....	A				<input type="checkbox"/>	
Voltage 220V DC-2 O/P .....	V				<input type="checkbox"/>	
Current 48V DC-1 O/P .....	A				<input type="checkbox"/>	
Voltage 48V DC-1 O/P .....	V				<input type="checkbox"/>	

Current 48V DC-2 O/P .....	A				<input type="checkbox"/>	
Voltage 48V DC-2 O/P .....	V				<input type="checkbox"/>	
Diesel Generator Voltage ....	V				<input type="checkbox"/>	
Diesel Generator Current ....	A				<input type="checkbox"/>	

#### xviii. Changing of alarm limits:

For supervising the analogue values each measured value shall have high and low alarm limits available. It shall be possible to set each limit independently at the BCU stage. When an alarm limit is detected as having been transgressed an alarm shall be generated and the value displayed on the VDU shall be identified as in alarm status by use of color or other means to the approval of engineer.

	Set point	Checked	Comments see log sheet no.
Voltage	- upper limit: 107% of nominal value	<input type="checkbox"/>	
	- lower limit: 95% of nominal value	<input type="checkbox"/>	
	- processing of alarm limits (color)	<input type="checkbox"/>	
	- hysteresis	<input type="checkbox"/>	
	- alarm dead band	<input type="checkbox"/>	
Current	- first upper limit: 1000A for 400 & 765kV level	<input type="checkbox"/>	
	- second upper limit: 1500A for 400&765kV Level	<input type="checkbox"/>	
	- processing of alarm limits (color)	<input type="checkbox"/>	
	- hysteresis	<input type="checkbox"/>	
Frequency	- upper limit: 105% of nominal value	<input type="checkbox"/>	
	- lower limit: 95% of nominal value	<input type="checkbox"/>	
	- processing of alarm limits (color)	<input type="checkbox"/>	
	- hysteresis	<input type="checkbox"/>	

#### xix. Redundancy/Availability and diagnostic function:

The SAS system is designed for a hot/hot configuration. In order to fulfil this functionality following test will be performed:

##### A. SAS – SERVER Redundancy

##### Purpose

In case of server failure, the connected HMI operator workstations must switch to the healthy server.

##### Setup

Ensure setup as per approved SAS Architecture Drawing.

##### Procedure

1. With both Servers operational, verify that Clients are connected with their respective servers & can perform normal functions i.e. open different screens, alarm & trend screen.
2. On OWS-1 (Server1), Close the Server1 Application.
3. Check that Alarm appears on the client.
4. Observe that Client1 are now connected with Server2.
5. Start the Server1 application on OWS1, observe that Client1 are now connected with the OWS1 after some defined period of interval.
6. On OWS-2 (Server2), Close the Server2 Application.



7. Observe that Client2 are now connected with Server1.
8. Check that Alarm appear on the client.
9. Start the Server2 application on OWS2, observe that Client2 are now connected with the OWS2 after some defined period of interval.

## Shutdown & Startup of Servers

## Purpose

To verify that the HMI Redundancy is operational during the shutdown of the active server.

## Setup

Ensure setup as per approved SAS Architecture Drawing.

## Procedure

1. With both Servers operational, verify that Clients are connected with OWS-1.
2. Shutdown OWS-1. Observe that Client is now connected with the OWS-2 and receives communications from the remote devices.
3. Startup OWS-1. Observe that there is no interruption to the Bay Level Devices. Restart the Client.
4. Observe that Client is now connected with the OWS-1 (Primary Server) and receives communications from the remote devices.
5. Shutdown OWS-2. Observe that Client is still connected with OWS-1.
6. Startup OWS-2. Observe that there is no interruption to the Bay Level Devices.

Voltage Level substation controller/Servers	Checked	Switch over time	Comments see log sheet no.
Server1 faulty: Disconnect Server1 from LAN and generate new inputs (events and alarms) on BCU. Initiate control of any switching device. <ul style="list-style-type: none"> <li>• Check switchover of connected HMIs to SC 2</li> <li>• Check updating of information event/ alarm/ analogue appearance on HMI 1&amp;2.</li> <li>• Check execution of command</li> <li>• Check event/alarm appearance on dot printer.</li> <li>• Check fault indication of SC 1</li> </ul>	<div><input type="checkbox"/></div> <div><input type="checkbox"/></div> <div><input type="checkbox"/></div> <div><input type="checkbox"/></div> <div><input type="checkbox"/></div>		
Server2 faulty: (Server1 healthy again) Disconnect Server2 from LAN and generate new inputs (events and alarms) on BCU. Initiate control of any switching device. <ul style="list-style-type: none"> <li>• Check switchover of connected HMIs to Server 1</li> <li>• Check updating of information event/ alarm/ analogue appearance on HMI 1&amp;2.</li> <li>• Check execution of command</li> <li>• Check appearance on dot printer.</li> <li>• Check fault indication of Server 2</li> </ul>	<div><input type="checkbox"/></div> <div><input type="checkbox"/></div> <div><input type="checkbox"/></div> <div><input type="checkbox"/></div> <div><input type="checkbox"/></div>		

### B. SAS– HMI Operator workstation redundancy

Each HMI operator workstation is independent of the other operator workstation and in case of failure the second workstation remains operational.

HMI operator workstation	Checked	Switch over time	Comments see log sheet no.
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HMI 1 faulty Disconnect HMI1 from LAN and generate new inputs (events and alarms) on BCU. Initiate control of any switching device. <ul style="list-style-type: none"> <li>• <i>Check updating of information on HMI 2</i></li> <li>• <i>Check execution of command</i></li> <li>• <i>Check appearance on dot printer</i></li> <li>• <i>Check fault indication of HMI 1</i></li> </ul>	<input type="checkbox"/>    <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/>		
HMI 2 faulty (HMI 1 healthy again) Disconnect HMI2 from LAN and generate new inputs (events and alarms) on BCU. Initiate control of any switching device. <ul style="list-style-type: none"> <li>• <i>Check updating of information on HMI 2</i></li> <li>• <i>Check execution of command</i></li> <li>• <i>Check appearance on dot printer</i></li> <li>• <i>Check fault indication of HMI 1</i></li> </ul>	<input type="checkbox"/>    <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/>		
HMI 1 and HMI 2 healthy again <i>Check database synchronizing</i>	<input type="checkbox"/>		

### C. SAS – Network redundancy

Reliability and security of the redundant LAN configuration will be checked.

## Purpose

To verify that

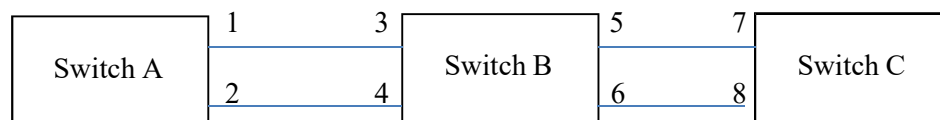
- Ethernet connections in the Substation Automation System are functional and running.
- LAN Switch Redundancy is functional.

To establish that in the event of a loss in communications, the SAS device are OFFLINE. When communications link is restored, the SAS device are automatically back to ON-LINE.

### Typical Procedure:

## Ethernet LAN Redundancy Check

1. Choose a Switch in the LAN. Let it be Switch B in below fig having switches A & C adjacent to it. There are two ports, 3 & 4 of switch B connected to two ports, 1 & 2 of switch A. Similarly, there are 2 other ports in switch B, 5 & 6 connected to ports 7 & 8 of switch C (as shown in figure).



2. On switch-B Disconnect port 3 LAN cable. Verify that no device in the entire system fails to communicate.
3. On switch-B Disconnect port 4 LAN cable. Verify that no device in the entire system fails to communicate.
4. On switch-B Disconnect port 5 LAN cable. Verify that no device in the entire system fails

5. On switch-B Disconnect port 6 LAN cable. Verify that only those devices, which are connected to switch B, fail to communicate.
6. Restore the LAN cables in reverse order and check that communication of the devices above gets restored.
7. Repeat the above for all other switches in the Redundant Ring LAN.

## LAN Communication Functional Check Test Results Log

S. No.	Panel	Equipment	Communication check	Redundancy check
1	___KV BCU (Bay 01/02/03---)			
2	___KV BCU (Bay 01/02/03---)			
3	Networking Panel			

	Checked	Comments see log sheet no.
<p>Checking <b>Station Ethernet ring</b></p> <p>Checking functionality in case of disconnecting and connecting the ring at several points.</p> <p>Initiate control of any switching device.</p> <ul style="list-style-type: none"> <li>• Check redundancy.</li> <li>• Check fault indication from adjacent units.</li> <li>• Check appearance on HMI 1 &amp; 2</li> <li>• Check execution of command</li> <li>• Check dynamic animation of SCADA pictures (Communication ports status etc.)</li> </ul>	<div style="text-align: center;"> <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/> </div>	
<p>Checking <b>Bay Ethernet ring</b></p> <p>Checking functionality in case of disconnecting and connecting the ring at several points.</p> <p>Initiate control of any switching device.</p> <ul style="list-style-type: none"> <li>• Check redundancy.</li> <li>• Check fault indication from adjacent units.</li> <li>• Check appearance on HMI 1 &amp; 2</li> <li>• Check execution of command</li> <li>• Check dynamic animation of SCADA pictures (communication ports status etc.)</li> </ul>	<div style="text-align: center;"> <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/> </div>	
<p>Checking the <b>communication of switches</b></p> <p>Checking functionality in case of disconnecting and connecting the Ethernet switches and router at several points. Initiate control of any switching device. (1x optical, 1x electrical, 1x 1GB port)</p> <ul style="list-style-type: none"> <li>• Check redundancy.</li> <li>• Check fault indication from adjacent units.</li> <li>• Check appearance on HMI 1 &amp; 2</li> <li>• Check execution of command</li> <li>• Check dynamic animation of SCADA pictures (communication ports status etc.)</li> </ul>	<div style="text-align: center;"> <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/>   <input type="checkbox"/> </div>	

**D. Gateway redundancy (IEC 104 Ports)**

The redundancy of the IEC 104 communication interface from the Gateways will be checked. As the real SCADA system is not available 2 Laptops with the IEC TEST – Software are used to simulate the RCC& RSCC.

#### E. Time synchronization redundancy

Redundancy of GPS time synchronization is tested. One clock will be disconnected from the network. It is checked that the various devices are still time synchronized (i.e. by changing the time manually for a device and check that it gets synchronized again).

Time synchronization redundancy	Checked	Comments see log sheet no.
Disconnect GPS time server 1 from the network. Check availability of correct time synchronization Reconnect GPS time server 1 and disconnect time server 2 (any one of the IED/OWS internal clock) from the network. Check availability of correct time synchronization	<input type="checkbox"/>	

#### F. Safety tag facility

It is checked that safety tag facility is realized in SCADA. A triangle with exclamation mark is set on the respective switching device.

	Checked	Comments see log sheet no.
Processing of safety tag facility	<input type="checkbox"/>	
Properties of safety tagging - 3 different types of safety tags - notebook facility (date, time, user, ...) - prevent of SCADA control	<input type="checkbox"/>	
Display on the - overview picture. - individual bay display	<input type="checkbox"/>	
Check appearance on redundant server/operator	<input type="checkbox"/>	

#### G. Maintenance mode

It is checked that individual feeders can be set into maintenance mode. No control is possible, and no alarms/events can come up during the feeder is in maintenance mode, which is indicated by annunciation “MAINTENANCE MODE.”

	Checked	Comments see log sheet no.
Feeder is in “Maintenance Mode”	<input type="checkbox"/>	
Check appearance on HMI Display	<input type="checkbox"/>	
Check control blocking	<input type="checkbox"/>	
Check suppression of data transmission	<input type="checkbox"/>	

#### H. Import and export of archived process data

The backup/ archiving function will be checked under this chapter. Data, which was outsourced as backup files will be imported into the runtime and displayed in the event list in conjunction with the filter function. During import mode, no changes of any other archive type or date is possible. The “Archive” button starts blinking when an import succeeded. Afterwards the imported messages can be saved into a readable format (as \*.csv or \*.txt). The export button function will remove the backup database from the event-list and the “Archive” button stops blinking.

	Checked	Comments see log sheet no.
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Import from archive	<input type="checkbox"/>	
Export data to readable format to Excel (*.csv or *.txt)	<input type="checkbox"/>	
Export to archive	<input type="checkbox"/>	

### I. Additional Tests:

In this chapter the remote access to bay control unit and protection relays will be checked. In addition, some protection tests will be simulated for checking information recording in SAS-system.

	Checked	Comments see log sheet no.
Remote access to IED devices via DR PC: - Password security - Access/Load function with ability to change relay settings. - Download of fault records - Automatic download of DR (Built-in & Stand- alone) fault record with necessary S/w - Evaluation of Fault records with evaluation S/w - Connection to 3rd party relays	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
Remote access to BCUs and via DR PC: - Password security - Access/Load function with ability to change relay settings	<input type="checkbox"/> <input type="checkbox"/>	
Information recording in SAS system - Reset of trip lockout relay - Auto-reclosing ON/OFF selection - Reporting of fault location	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
- Hardcopy print (to paper and file)	<input type="checkbox"/>	

### J. Remote Desktop:

The remote desktop function is a feature of Windows. It is shown as an icon on the desktop of all PCs of this station. Press this button and a window will appear. Choose the desired PC by selecting its IP address; the remote desktop function opens the desktop of the desired PC. It is mainly used for configuring the station controllers and HMI servers from the Engineering PC.

Remote desktop	Checked	Comments see log sheet no.
Remote desktop functionality	<input type="checkbox"/>	

### K. Time synchronization:

The time synchronization is checked under this chapter. The antenna of the GPS clock is disconnected. An alarm should be generated. Then the times of the devices is changed by hand for a few minutes only. Connect the antenna again. The devices have to synchronize again by themselves after some minutes and the alarm has to disappear. The time synchronization test shall be performed by making GPS as the master clock for synchronizing all IED's present on ring network.

### Procedure

1. Disconnect the GPS Receiver Antenna. Set the GPS Receiver to send Local Time.
2. Confirm that the External Time Display Unit displays this local time.
3. Confirm that IEDs Operator Workstations and Substation Gateway Times match this local time. This confirms that the SNTP packets are broadcast by the GPS receiver.

4. Confirm that GPS Receiver unsynchronized alarm is received in the workstations.
5. Power off the GPS receiver.
6. Verify that all IEDs are synchronized with any of the IED/OWS designated as redundant Time server.
7. Power on the GPS receiver.
8. Connect the GPS receiver Antenna. Verify that the GPS receiver is locked with satellite and GPS is updated to satellite time.
9. Confirm that the External Time Display Unit, The IEDs, Operator Workstations and the Substation Gateway are updated to the correct time of GPS.

Time synchronization	Checked	Comments see log sheet no.
OWS-1 & Server-1	<input type="checkbox"/>	
OWS-2 & Server-2	<input type="checkbox"/>	
DR PC	<input type="checkbox"/>	
Auxiliary System	<input type="checkbox"/>	
Time synchronization of connected IEDs	<input type="checkbox"/>	
Bay Control Unit	<input type="checkbox"/>	
Event list printer/ Hardcopy/ Logbook printer	<input type="checkbox"/>	

## xx. Validation of OWS Memory and Disk Utilization:

### Purpose

To verify that the OWS have Memory and Disk Usage and allocation those are within the specification requirements.

### Setup

Ensure that the Servers are running and functioning properly.

### Validation of OWS Memory and Disk Utilization

Computer	Physical Memory	Hard Drive Free Space	PASS/FAIL
Server-1			
Server-2			
OWS-1			
OWS-2			
DR/EWS PC			
Gateway-1			
Gateway-2			

## 3.3 EWS TEST

### i. Setting and configuring of BCUs

#### Purpose

To verify that the BCU database is configured in necessary software and download is possible. Settings of BCU like Change of IP Address etc. are possible.

#### Setup

1. Ensure that DR PC is running.

**Procedure**

1. Change some parameters in S/W for the BCU to test. Compile the Database for which parameters have been changed.
2. Run S/w on the DR and select the compiled Database. Connect the BCU for which the parameters have been changed.
3. Upload the database.
4. Verify that the download is successful and check the DB version on the BCU.

**ii. Network Monitoring System****Purpose**

To verify that the Network Monitoring System (NMS) application software can perform the following functions on the LAN devices:

1. Configuration Management
2. Fault Management
3. Performance Monitoring

Note that the Network Management System is based on Simple Network Monitoring Protocol (SNMP). Some background on this protocol is needed to understand how the application software works.

**Procedure**

1. Verify that NMS software monitors LAN devices statistics and present these using displays.
2. Verify that it maintains connectivity and device status, issues alarms on errors conditions. This can be verified in the OI client screens.
3. Verify that it has tools for maintenance of addressed and links.

**3.4 Auto Reclose Test:****i. Test for Auto-Reclose Successful case:**

1. Select the Circuit Breakers of Main & Tie on which Auto reclose has to be tested.
2. Ensure that the Circuit Breakers are in closed condition and Auto-recloser is in ON state and all interlock conditions for closing the breaker are satisfied.
3. Simulate 1-Phase trip, ensure that the corresponding phase of the Main & tie breakers open.
4. Ensure that the Main Circuit Breaker Auto recloses first with predefined dead time (1sec) and Tie breaker auto recloses once the main breaker reclose cycle is completed. (2sec)
5. Ensure that once Auto-recloser is successful for main, the respective reclaim timer starts and Auto- reclose State goes back to Normal once the reclaim time is over and the same is applicable for Tie Bay.
6. Put Auto-recloser of main CB in off position. Repeat steps 1 to 3. In this case ensure that Main CB does not go for Auto-reclose and tie CB Auto-reclosers without priority. (1 sec)
7. Check that Auto-reclose does not take place for CB which are already in open condition. Check this for both Main & Tie CB.
8. Check that A/R does not take place for CB having A/R lockout condition (SF6 gas pressure/Oil pressure/spring discharge). The healthy CB associated with the feeder shall be A/R successfully.

**ii. Test for Auto-Reclose Failure case:**

1. Repeat steps 1 to 5 of successful case, Once the reclaim time starts, simulate another 1-Phase trip.
2. Ensure that the Auto-reclose enters Locking State and a 3-Ph tripping is issued to the both Main and Tie Breaker and all the 3-phases of the breaker open.
3. Repeat steps 1 to 3 of successful case, Once the Auto-recloser cycle starts, before the dead time is over and close command is issued to the Main and Tie Breaker, Simulate another 1-ph trip in other phase. In this case also Auto-recloser enters Locking State and a 3-Ph



tripping is issued to the both Main and Tie Breaker and all the 3-phases of the breaker open.

4. Repeat steps 1 to 3 of successful case, Once the Auto-recloser cycle starts, before the dead time is over and close command is issued to the breaker, simulate the AR blocking signal (SF6 gas pressure/Oil pressure/spring discharge), Ensure that the Auto-reclose does not take place and Auto-recloser goes back to its Initial state.

### 3.5 Setting of Protection Relays

#### i. Setting of Main-1 Protection Relays

##### Purpose

To verify that the Setting of Main-1 Protection Relays can be changed via the Rear Port of Protection Relays.

##### Setup

1. Ensure that DR PC is running.
2. Relay Configuration software is properly installed on DR PC.

##### Procedure

1. Verify that Protection relays rear Port for which test to be performed are connected via rear port.
2. Run Relay Software on DR PC and open the Protection relay file. Verify that the connection is successful.
3. Extract the settings from the connected Protection Relay. After extracting, select the parameter that needs to be modified. Upload the changes to the connected relay.
4. Verify that the parameter is changed again by opening the setting file of Protection Relay from DR PC.

#### ii. Setting of Main-2 Protection Relays

##### Purpose

To verify that the Setting of Main-2 Protection Relay can be changed via the Rear Port of Protection Relays.

##### Setup

1. Ensure that DR PC is running.
2. Relay software is properly installed on DR PC.

##### Procedure

1. Connect the Ethernet cable between Ethernet switch and Protection relay for which test to be performed.
2. Run software and connect with the Protection relay. Verify that the connection is successful.
3. Extract the settings from the connected Protection Relay. After extracting, select the parameter that needs to be modified. Upload the changes to the connected relay.
4. Verify that the parameter is changed by using the front display of Protection Relay.

### 3.6 DR Configuration:

Check DR is configured as per TS as per following-

- i. Analog triggering level
- ii. Signal name and order
- iii. Pre-& Post fault time (Pre-fault time: min 500ms)
- iv. Triggering Channel
- v. Re-trigger option etc.

### 3.7 Disturbance File Retrieval



**Purpose**

To verify that the automatic disturbance file is uploaded to DR PC when the disturbance is created.

**Setup**

1. Ensure that DR PC is running.
2. System Software should be running on the DR PC.

**Procedure**

1. Create the Disturbance on Main-1 &2, Verify that the disturbance has been created in the relay.
2. Observe that the Disturbance File (.cfg/.dat etc.) is automatically created in the DR PC.
3. Open the Disturbance file with DR software.

Testing of Typical Relays & BCU (One number of each type and function) is to be verified in Factory Acceptance Test.

#### 4 BCU INPUT/OUTPUT DATA RETRIEVAL

The following are the procedures in the BCU I/O Data retrieval. The individual BCU Test result logs are to be filled up in the following sections.

**Digital Input Retrieval****Purpose**

To verify that the change of state of Digital Input points are updated in the BCU MMI, the Operator Workstations and Master Station Simulator.

To verify that the Digital Inputs are mapped correctly as per the approved drawing.

**Setup/Program**

1. Connect the test jig to the BCU under test.
2. Go to the BCU MMI Digital Inputs Display screen.
3. On the OWS-1 go to relevant HMI screen.
4. On the OWS-2 go to Alarm/Event list. Procedure
5. Select a Digital Input point on the BCU under test.
6. Change its state from 'OFF' to 'ON' (single points) or from 'OPEN' to 'CLOSED' (double points) by toggling the corresponding jig.
7. Verify that the state of this point in the BCU MMI and HMI is changed correctly.
8. Verify that the state of this point in the OWS-2 event list screen is changed correctly.
9. For points configured with alarm, verify that alarms are displayed in the Alarm Screen of the OWS- 2 with correct time stamp.
10. For points considered in the IEC 60870-101 List, verify that the state of this point in the Master Station Simulator is changed correctly with correct time stamp.
11. Change its state from 'ON' to 'OFF' (single points) or from 'CLOSED' to 'OPEN' (double points) by toggling the corresponding jig.
12. Repeats step 3 to 6
13. Repeat 1 to 8 for all Digital Input points to be tested on this BCU.
14. Repeat steps 1 to 9 for all BCU's.

**Digital Output****Purpose**

To verify that digital output operations are successfully executed.

To verify that the Digital Output points are mapped correctly according to the approved drawings & Data List.

**Setup/Program**

1. Connect the test jig to the BCU under test.

2. Go to the BCU MMI Digital Outputs Display screen.
3. On the OWS-1 go to relevant HMI screen.
4. On the OWS-2 go to Alarm/Event list.

#### Procedure

1. Choose a BCU to test. From the HMI workstation initiate digital output requests.
2. Verify that the corresponding output activated.

### Software Interlock Logic

#### Purpose

To verify that software interlock logic for CBs and Isolators are operational based on simulated conditions.

Note: Since not all interlock conditions can be tested during FAT, other interlock inputs shall be simulated by shorting auxiliary contacts at the terminal blocks of the panels.

#### Setup

1. Set up the test jig to simulate software interlock positive and negative test conditions.
2. Set up shorting links to simulate other auxiliary contacts.
3. Refer approved drawings.

#### Procedure

1. Select a BCU to test.
2. Refer to the interlock conditions for testing. First set up a negative condition. Attempt to operate controls related to the interlock logic being tested. Verify that the interlock is successful.
3. Set up for a positive test condition. Verify that interlock is successful when control operation is performed on related to the interlock logic being tested.

CB/ Isolators	CB/Isolators Interlock Negative Test Result	CB/Isolators Interlock Positive Test Result	CB/Isolator Condition	Checked

Interlock involving GOOSE signal shall also be checked. **It shall be ensured that absence of required GOOSE signal does not enable any interlocking condition.**

Spare switching arrangement for Single phase reactor and transformer banks shall be verified by simulation and software interlocks to be verified.

## 5 SUBSTATION CONTROLLER DEVICE REPORTING

#### Purpose

To verify that the Substation Controller (Server/Client) is successfully communicating with the bay level devices using IEC 61850 protocol.

#### Setup

1. Ensure that the Server/Clients are running.
2. Go to the System Architecture Screen on Client.

#### Procedure

1. On the System Architecture screen, verify that the bay device status is Normal.
2. Go to a remote device and disconnect the LAN cable, verify that the System Architecture screen shows the bay device is Failed.

3. Connect the LAN cable. Monitor the communication between Server and remote device and verify that the IEC 61850 packets between the two TCP/IP addresses are passing through.
4. Verify that the System Architecture Screen shows that the device is Normal.
5. Repeat the above procedures for other devices.

### **5.1 IEC 60870-5-104 Data Retrieval**

#### **Purpose**

To perform preliminary verification that the IEC 60870-5-104 Communication Ports are functional.

#### **Setup/Program**

- Ensure that the test equipment is in FAT room.
- Use a Protocol Analyzer Test set to simulate an IEC 60870-5-104 Master Station polling with General Interrogation and data changes. Use the Protocol Analyzer Test set to Monitor IEC 60870- 5-104 datagram on the redundant serial communications links.

#### **Procedure**

1. Verify that communication is established with the simulator Protocol Analyzer Test set.
2. Verify that the simulator is sending request on the primary channel and that the SAS Gateways is responding on both the primary (Main) and the secondary (Standby) channels.
3. Disconnect the simulator from the primary channel and connect it to the secondary channel; verify that the SAS Gateway will respond on both channels to requests received on the secondary channel.
4. Verify that data present at HMI should be same at Protocol Analyzer Test also.
5. Verify that all the configured required data points are sent by the gateway to the simulator.

### **5.2 Master Digital Inputs Retrieval**

#### **Purpose**

To verify that the Substation Gateway is polled for Digital Input data correctly by the Master Simulator.

#### **Procedure**

1. Inject digital input changes to single point and double point inputs.
2. Verify change of the state in the Gateway Machine and Protocol Analyzer.

## **6 MASTER ANALOG INPUTS RETRIEVAL:**

#### **Purpose**

To verify that substation gateway is polled for Analog Input data correctly by the Master Simulator.

#### **Procedure**

Inject Analog Inputs and verify that the Analog data are correctly received by the Master Simulator.

## **7 STATEMENT OF SYSTEM ACCEPTANCE:**

Upon satisfactory completion of all applicable tests specified in this document and the proper disposition of all properly documented and witnessed discrepancies resulting from tests specified in the procedure, the system, tested and witnessed by the Employer is functionally accepted by Employer.

## **8 DURATION OF FACTORY ACCEPTANCE TEST:**

The duration of Factory Acceptance Testing will be mutually agreed depending upon the size of the substation (normally one to two weeks).

## 9 COMMENTS:

Any comments should be added in “log sheets”; a pattern is attached on next page.

## SAS-FAT LOG SHEET

No.	Reference	Author	Date
Description			

## 10 GLOSSARY:

BCU: Bay Control Unit  
DR: Disturbance Recorder  
EWS: Engineering Workstation  
FAT: Factory Acceptance Test  
FPT: Functional Performance Test  
FST: Factory Simulation Test  
GTW: Gateway  
GPS: Global Positioning System  
IED: Intelligent Electronic Device  
NMS: Network Management (Monitoring) System  
OWS: Operator Workstation  
RCC: Remote Control Centre  
RSCC: Regional System Co-ordination Centre  
SAS: Sub-station Automation System  
SAT: Site Acceptance Test  
SCADA: System Control & Monitoring System

Verify by:	Verify by:
Employer's Representative	Manufacturer's Representative
Signature:	Signature:
Name:	Name:
Date:	Date: