Empowering grid with digital substation

Asia Pacific Technology Forum 2024

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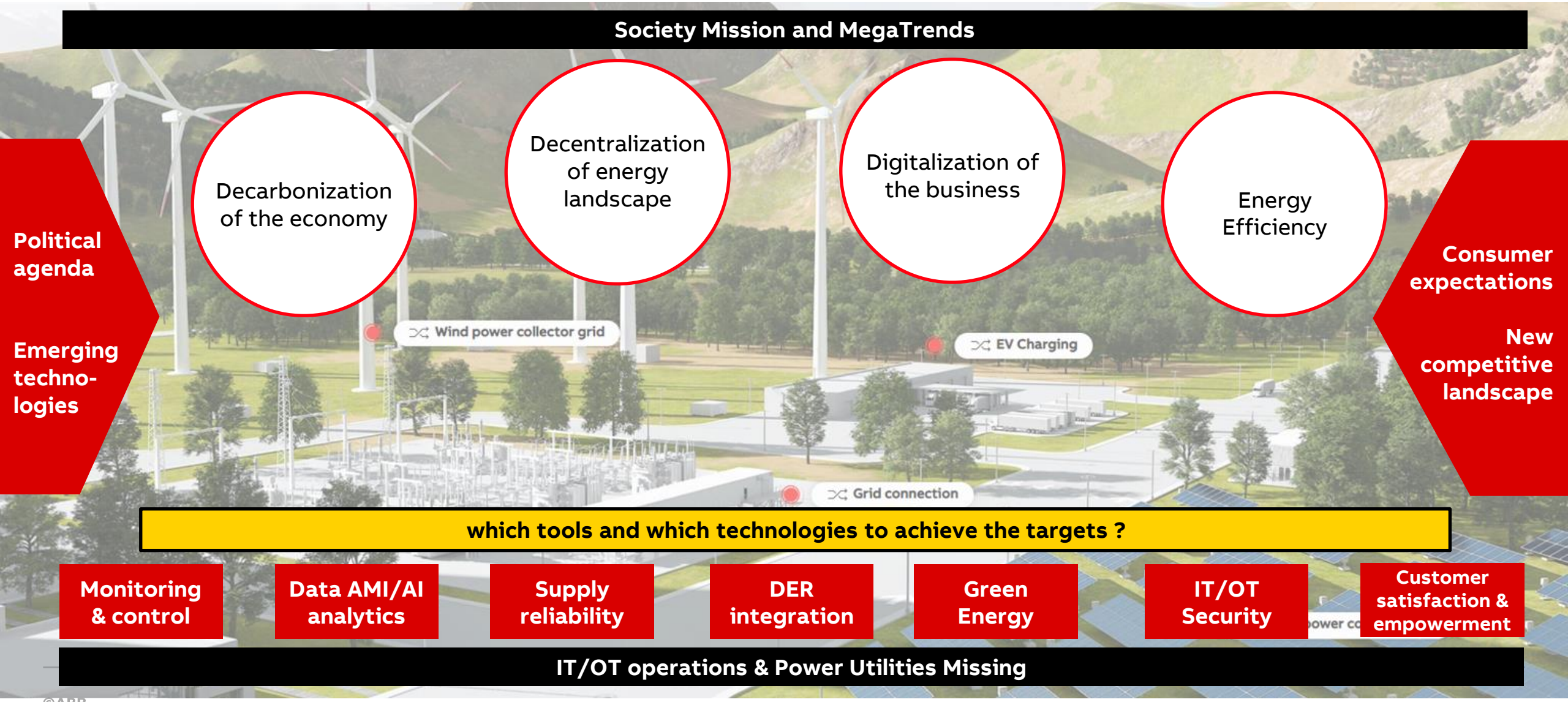
Centralized (SSC600) and Virtualized (SSC600SW)

Marco Nunes, 24.06.2024
ABB, Digital Substation Products
Electrification Division

Introduction Digital Substations deployment – Customer journey



The IT and OT operations are becoming more integrated, leading to IT/OT convergence.

ABB Electrification, Digital Substation Products

ABB Relion portfolio - Protection Relays for Distribution and Subtransmission

GRID EDGE & CLOUD

SSC600
SSC600 SW
SMU600

ADAM

- fleet mgmt
- datalake
- remote updates
- AI Fault Prediction
- AI Fault analysis

	Applications / Platform	Feeder Current	Feeder Voltage	Transformer 2 windings	Transformer 3 windings	Machines Motor	Machines Generator	Line protection Differential	Line protection Distance	Busbar differential	Capacitor	Petersen Coil	Recloser	Arc protection	PMU	Merging Unit SV	Station bus	Extra functions
basic range	605 series	REF601				REM601											Modbus, 61850 MMS, DNP3, IEC	self-powered REJ601 v1.5 REJ603 v3.0
	REX610 1.1	•	•			•								•			Modbus, 61850 MMS	
	611 series	REF611	REU611							REB611							Modbus	
mid range	615 series 5.1	REF615, REC615	REF630, REU615	RET615		REM615	REG615			REF615	REV615		RER615	•		all types + SMU615	Modbus, IEC103, DNP3 61850 MMS	
	620 series 2.0	REF620	REF620	RET620		REM620				REF620			RER620	•		all types	Modbus, IEC103, DNP3 61850 MMS	
	REX615 6.0	•	•	•		•	•	•		•	•		•	•	*2025/ 2026*	•	IEC 104, 61850 MMS	2 dimensions: standard + wide
high-end range	630 series 1.3	REF630	REF630	RET630		REM630	REG630										Modbus, IEC103, DNP3 61850 MMS	Load-shedding controller PML630
	REX640 1.3	•	•	•	•	•	•	•	•	•	•	•	•	•	*2025/ 2026*	•	Modbus, IEC103, DNP3 61850 MMS	High-speed busbar transfer HSBT
	SSC600 /SW	•	•	•		•		*06-2024*	•	•	•		•	•	*2025*	•	IEC 104, 61850 MMS	Centralized DR, Anomaly detector, SLD webHMI 30 bays protection

Electro-mechanical relays

Public Wireless ARCTIC family

Arc protection REA family

Remote IO/RTD RIO600 family

Configuration & Engineering tools

ABB Rxplore mobile app available on Android & iOS

Product Configuration Tool

Introducing next level - virtualization

Smart substation control and protection SSC600

Introducing Hybrid Protection and Control

Evolution of protection and control

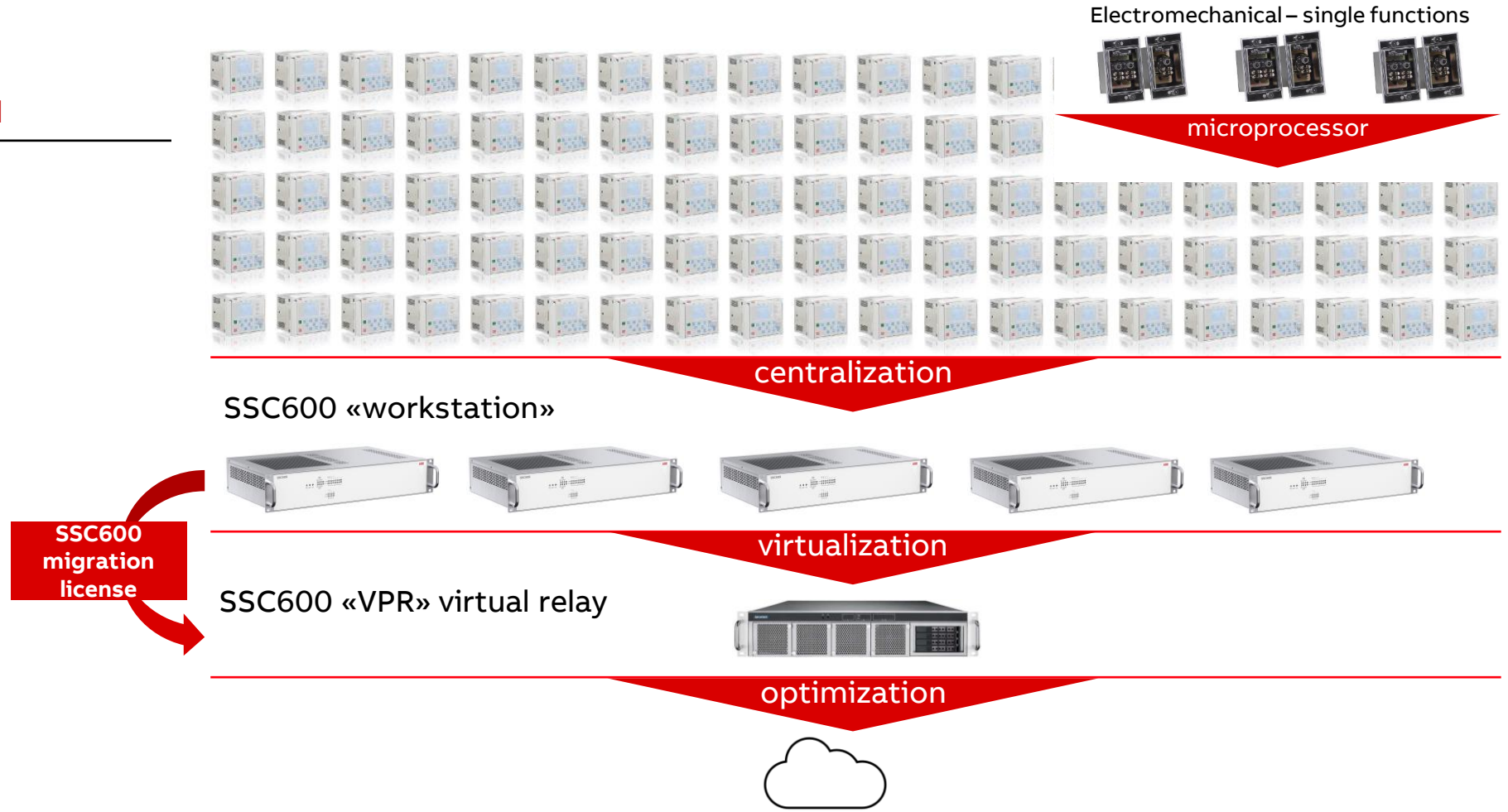
300-500 Electromechanical relays (single functions)

100 Microprocessor-based, multifunction relays

5 centralized protections

1 high-computing server, virtual machines-hypervisors

Cloud, 5G/6G



Introduction

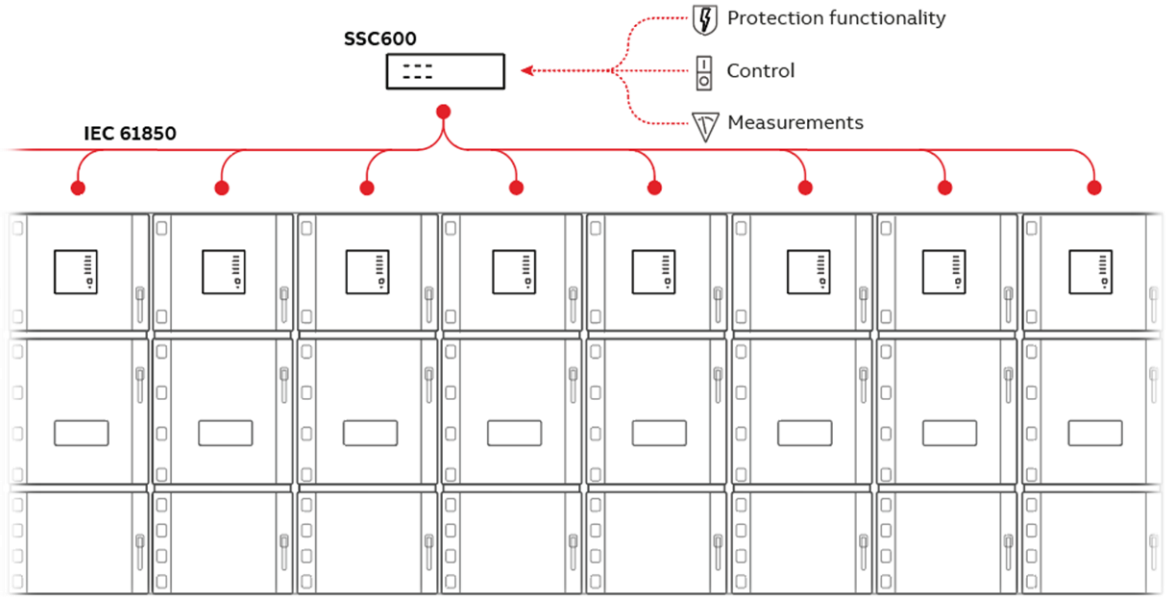
IEC 61850-compliant centralized protection and control

Customer need

- All settings, configurations and applications centralized in one device
- Dynamically allocate the applications per bay with the possibility to change or adapt at anytime depending on the substation evolution (for instance, a feeder needs to be converted into a transformer bay in a very short time)

Solution

- SSC600 combined with IEC 61850 merging units (MU)
- All settings, configurations and application in one device
- Any capable protection relay suitable as backup time master
- Substation gateway doubles up as human-machine interface (HMI)
- Combined or separated IEC 61850 network for process and station bus
- System visualization using SSC600 and its Web HMI (WHMI)
- Time synchronization via the IEEE 1588 v2 GPS (Global Positioning System) master



Centralized protection SSC600

Standards and communication

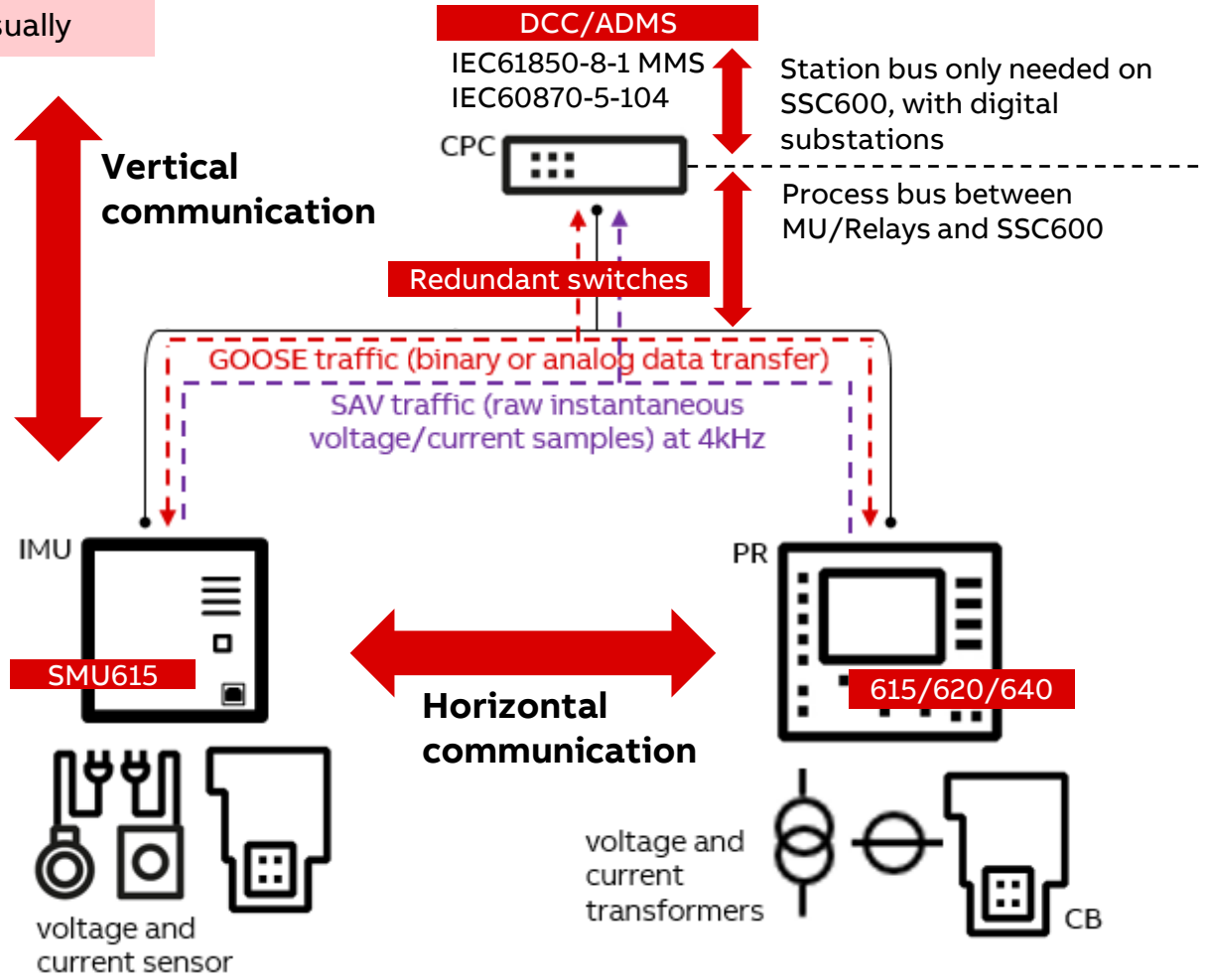
Time stamped Sampled values (1 us precision)

1 ms processing cycle on centralized protection vs 2.5/5 ms usually

- SSC600 has 8 Ethernet ports, incl. PRP/FO SFP
- SSC600 can combine or segregate process bus and station in the communication network.
- Network overload is not a problem, as 30 streams of SMV represent nly 15% network consumption on a 1Gb/s network

Open standards

- Time synch: IEEE 1588 v2 PTP (in addition to SNTP), according to IEEE C37.238-2011 Power Profile for high accuracy time synchronization.
- GOOSE: IEC 61850-8-1 Ed2, tripping type 1A, Class P1 (<=3 ms.)
- Process bus/sampled values: IEC61850-9-2LE
- Disturbances recorder: 60255-24 Comtrade files format
- Redundant communication: PRP as per IEC 62439-3 Edition 1 and 2
- Station bus: 61850 MMS + IEC60870-5-104
- Cybersecurity: ISO 2700x, IEC 62443, IEEE P1686 and IEC62351, NERC CIP and BDEW.
- WebHMI: HTTPS, FTPS, self-signed X.509 certificate, RSA key-pair with key-length of 2048 bits, RFC2617 HTTP Authentication
- EMC/LV: 60255-26 / 60255-1 / EN 60255-27
- Server certifications: CE, FCC, CCC, Electricity IV level for China, IEC-61850-3, IEEE-1613, UL, CB, LVD
- Environment: EU RoHS directive (2011/65/EU).

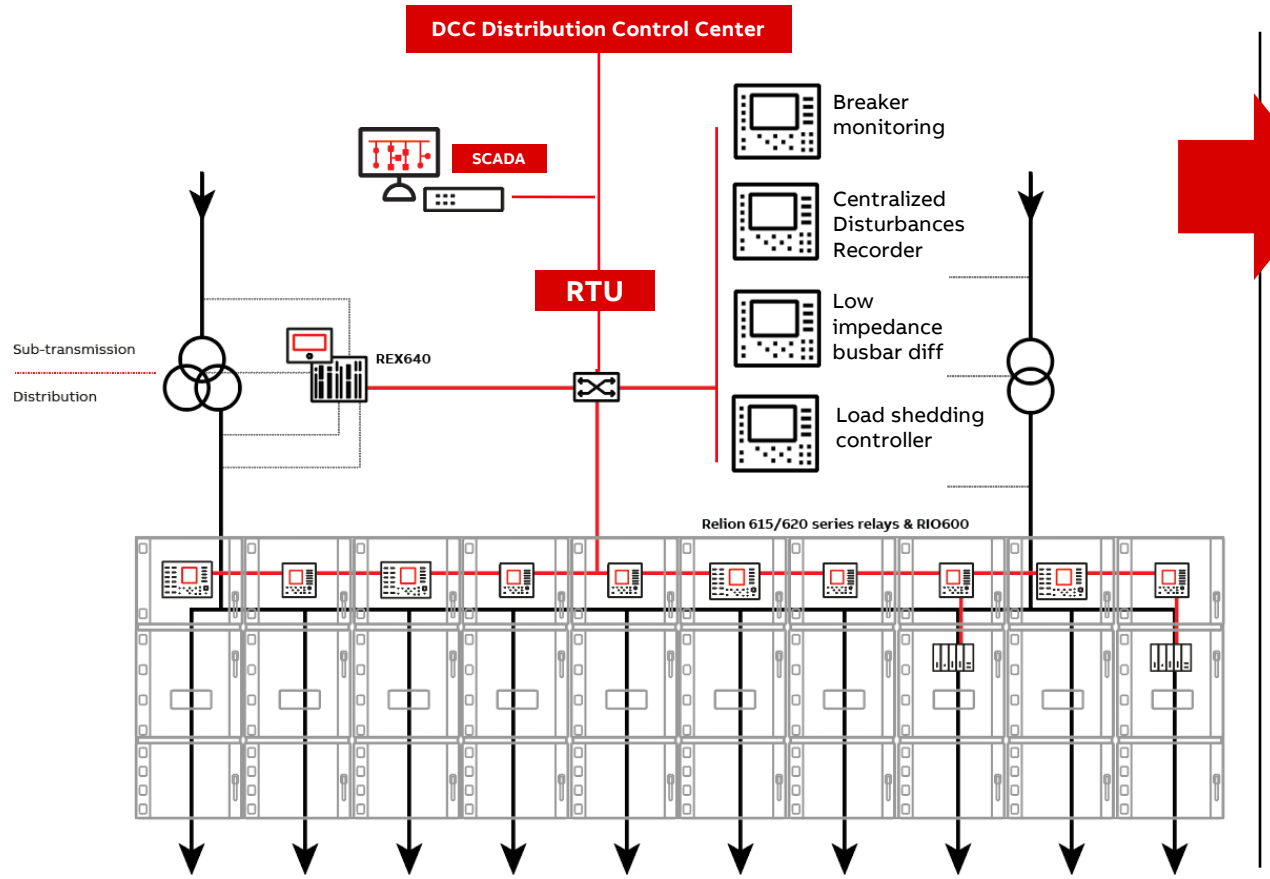


1) **Station bus: IEC61850-8-1, IEC60870-5-104, DNP3 (End 2023)**
2) **Sampled values, 4 kHz streams: IEC61850-9-2LE or IEC61869-9 (End 2024)**
3) **Goose messages (analog/binary – 500 ms): IEC61850 / GOOSE Trip: max 3 ms**

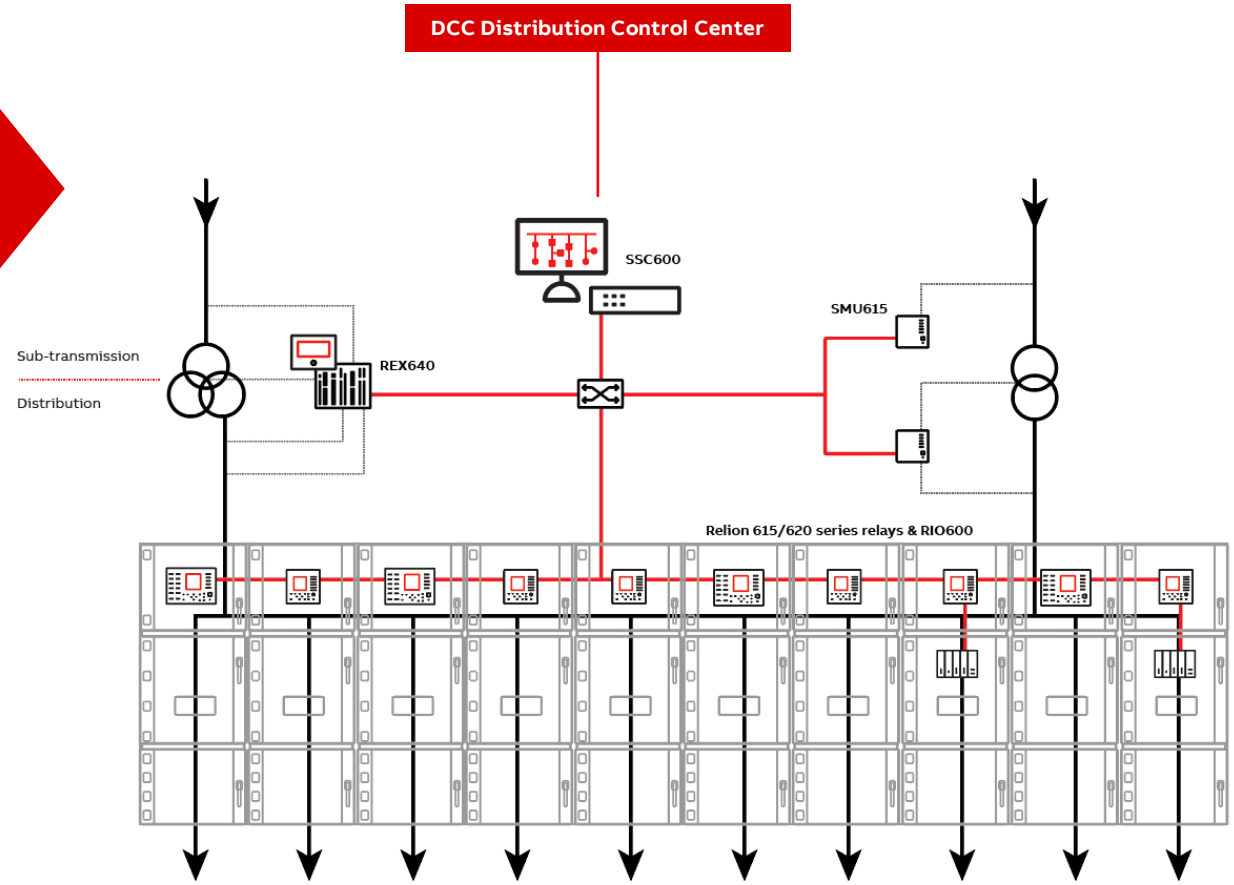
Smart substation control SSC600

Application feature: additional added-value

Conventional substations



Digital substation – centralized protection / SSC600



Centralized protection and control with SSC600/SW

Technology CPC (centralized 30 bays) or VPAC/VIED (virtual machines up to 150 bays)

- Substation HMI, Single Line Diagram
- Centralized Disturbances recording Fault recording
- Power Quality, Monitoring
- Abnormality recording (AI)
- AI Fault analysis & prediction (bundled with ABB ADAM)
- Gateway, 61850 MMS, IEC104
- Cybersecurity, Events log

- Basic Protection
- Advanced Protection (Distance, Busbar, ..)

Basic protection
Current protection_50/51
Earth-fault_50N/51N
3-phase undervoltage_27
3-phase overvoltage_59
Residual overvoltage_59N
Neg.seq. overvoltage_47O-
Pos.seq. undervoltage_47U+
Negative-sequence OC_46
Frequency protection_81
Fuse failure supervision_VCM,60
Three-phase inrush detect._68HB
Circuit-breaker failure_51BF
Master trip_94/86
Switch onto fault_SOTF
Load blinder_21LB

Cable/line application (5-10-15-20-30 bays)
Directional EF_67N
3-ph. direct. reverse power_32R/32O
Phase-discontinuity_46PD
Thermal protection_49F
Autoreclosing_79
Synchrocheck_25
Directional OC_67P

Advanced cable/line application (5-10-15-20-30 bays)
MF-admittance EF_67NYH
Admittance EF_21YN
Intermittent EF_67NIEF
Wattmetric EF_32N
Low-voltage ride-through protection_27RT
Fault locator_21FL
Direct. react. power underv._32Q/27

Transformer protection (0-2-4 bays)
Thermal overload_49/T/G/C
Transformer differential_87T
Low-impedance REF_87NL
3-phase underimpedance_21G
Tap-changer position indication_84M

Motor application (0-5-10-15-20-30 bays)
Thermal overload_49M
Neg.seq. OC for machines_46M
Loss of load supervision_37
Motor load jam_51LR
Motor startup supervision_49/66/48/51LR
Phase reversal 46R
Emergency startup_ESTART

Bay-level applications (for selected and available streams)
Tap-changer indication and control with voltage regulator
Distance protection_21P, 21N
Power quality • Current total demand and harmonic distortion (TDD and THD) • Voltage total harmonic distortion (THD) • Voltage variation • Voltage unbalance

Multi-bay level applications (up to 30 bays)
Load-shedding and restoration across 4 bus sections_81LSH
Low imp. busbar differential_87BL/87B
Arc protection_50L/50NL

Shunt capacitor protection
3-ph overload_51,37,86C
Current unbalance_60N
3-ph current unbalance_60P
Cap. bank switching resonance_55ITHD

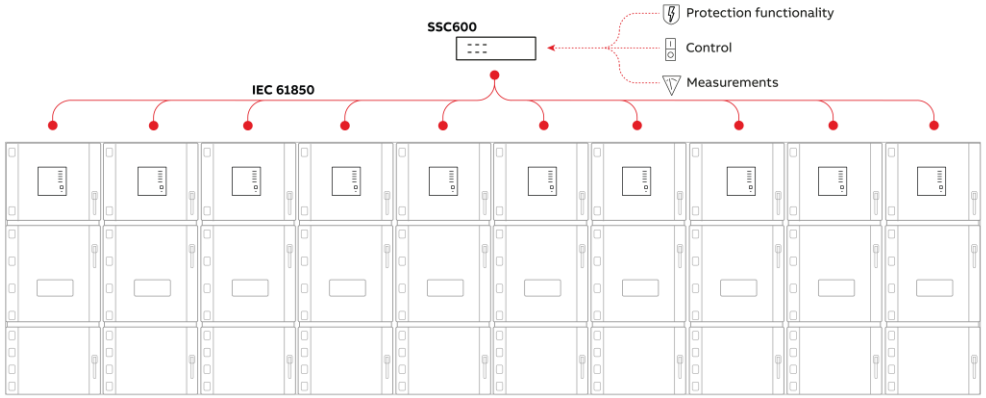
Optional packages & functions

Substation Automation and Management

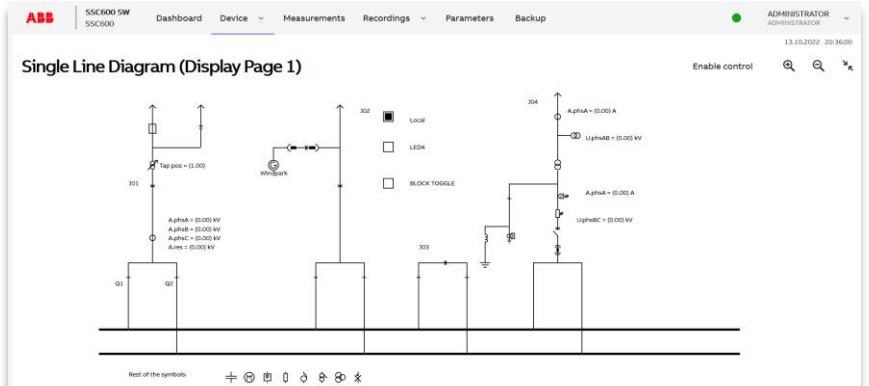
Substation Protection Functions

Centralized protection and control with SSC600/SW

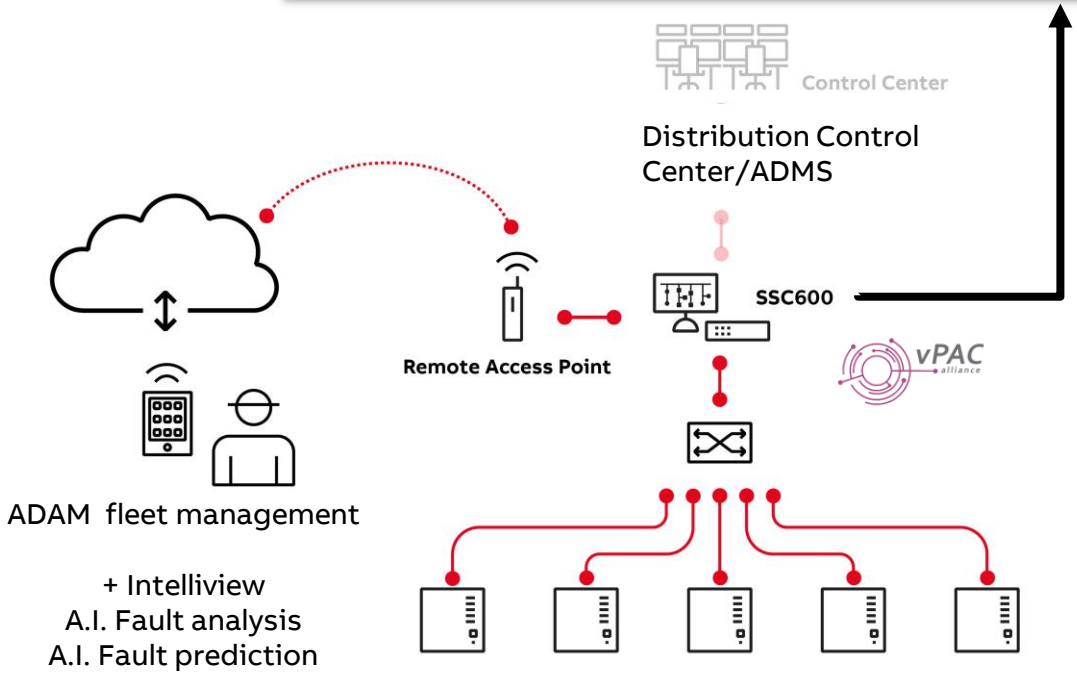
Technology CPC (centralized) or VPAC/VIED (virtual machine)



- Protection and control for primary substation
- Station HMI for the entire substation
- Full Protection and Control capabilities for up to 30 bays
- Merging units are the interface to the process
- Centralized Disturbances recording
- Busbar protection (low imp. busbar differential)
- Anomaly recording (AI), enabling Fault Prediction



Local / remote HMI on SSC600/SW
Single Line Diagram and monitoring



Protection virtualization technology

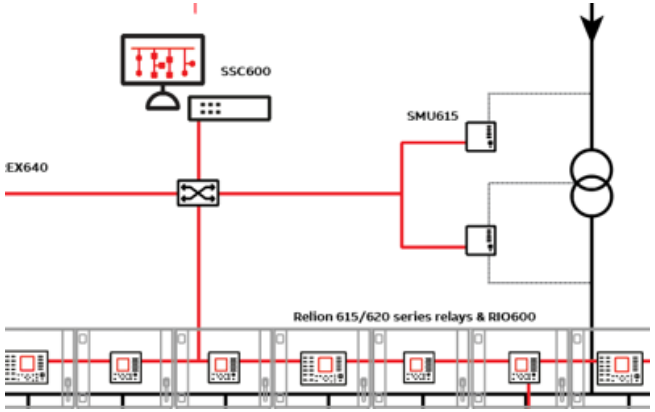
ABB Digital Substation: SSC600 CPC Workstation or SSC600 SW VPAC Virtual Machine

Centralized Protection and Control (CPC)

- ✓ All-in-one turnkey box, with full warranty and support from a single vendor
- ✓ The hardware, OS and applications have been type tested all together a turnkey solution
- ✓ Safe environment, one single engineering tool
- ✓ Native development on 61850 standard, and compatible with 61850-9-2LE 3rd party IED's
- ✓ Applicables flexibility, including station SLD, centralized recorders, fault recorder
- ✓ Hybrid architectures possible, with conventional IED's as bay backup merging units

ABB SSC600 workstation

Turnkey Centralized 61850-based platform.
Intel CPU 4 cores up to 30 bays.



Virtualized Protection and Control (VPR)

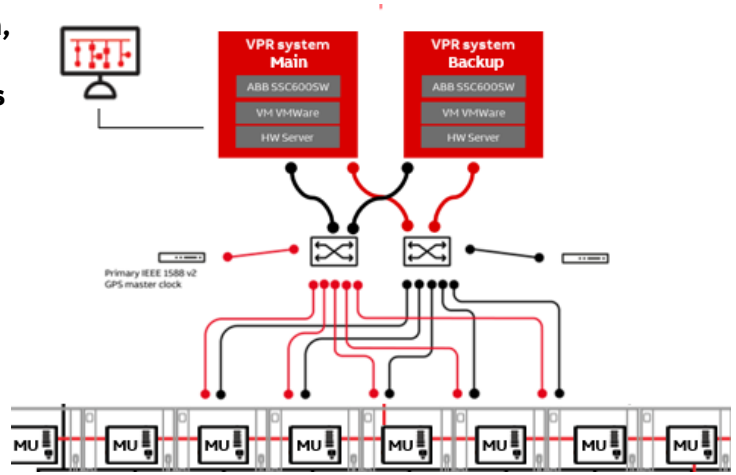
ABB SSC600 SW as Virtual Machine

XR-12

ECU-579

Centralized 61850-based platform, running on Virtual Machines.
Intel Xeon Gold CPU up to 24 cores up to 150 bays.

- ✓ Full scalability in terms of hardware and software
- ✓ Multi-vendor integration on same hardware platform
- ✓ Remote asset and apps management through VM centralized asset management tools
- ✓ Compatible with open-source and commercial vendors for the VM layer (hypervisor), KVM and VMWare
- ✓ Allow EPC's and Utilities to utilize always the same components worldwide, and customizing only the apps needed in the VM's/containers



Centralized/Virtualized protection and control features

Simplification of assets

Customer need

Minimize the number of devices in the network for reduced network complexity

Simplify spare device management

Concentrate on 1-2 devices that fit all applications

Solution

615/620 series devices as universal devices with basic backup functions

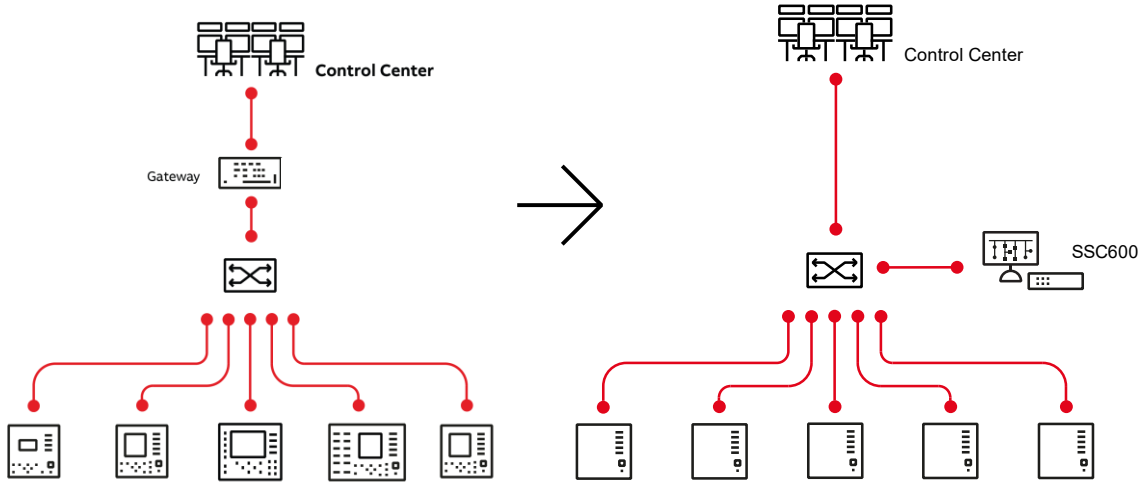
SSC600 as main protection with flexible high-end protection functionality

Reuse of templates with small changes to the main configuration for different substations

No need for additional gateway as IEC 60870-5-104 allows easy and direct connection to an upper-level system such as SCADA

Number of protection device variants reduced when using:

- SSC600 (one variant)
- SMU615 (one variant)



Centralized/Virtualized protection and control features

Redundancy of protection functionality via a hybrid installation

Customer need

Redundancy of protection and control functionality

Selective and reliable backup protection

Solution

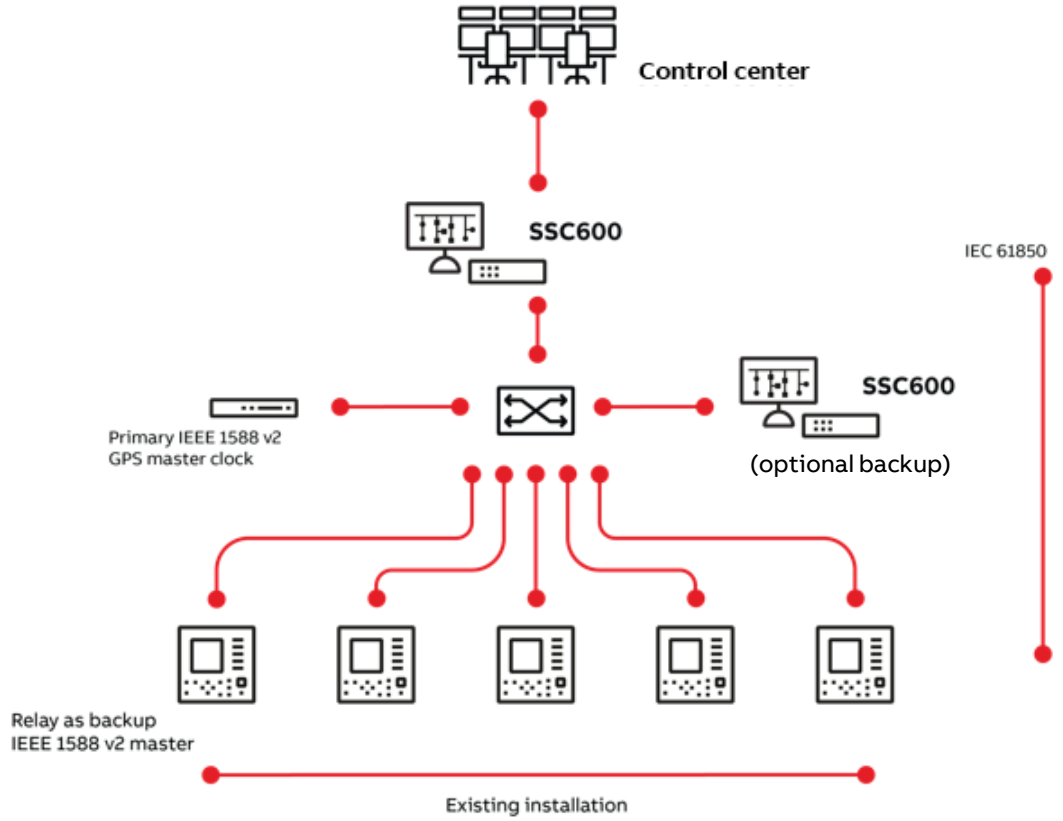
SSC600 added to existing installation as main protection, leaving existing relays and other protection devices as backup protection

Redundant communication with PRP Time synchronization via the IEEE 1588 v2 GPS master or a relay acting as backup time master

Substation gateway doubles up as HMI

Combined or separated IEC 61850 network for the process and station bus

Direct communication to the control center possible with IEC 61850 or IEC 60870-5-104, without an external gateway in between



Centralized/Virtualized protection and control features

Centralized protection and control with full redundancy

Customer need

Change to centralized protection with a redundant protection scheme

Complete greenfield or retrofit installation

Solution

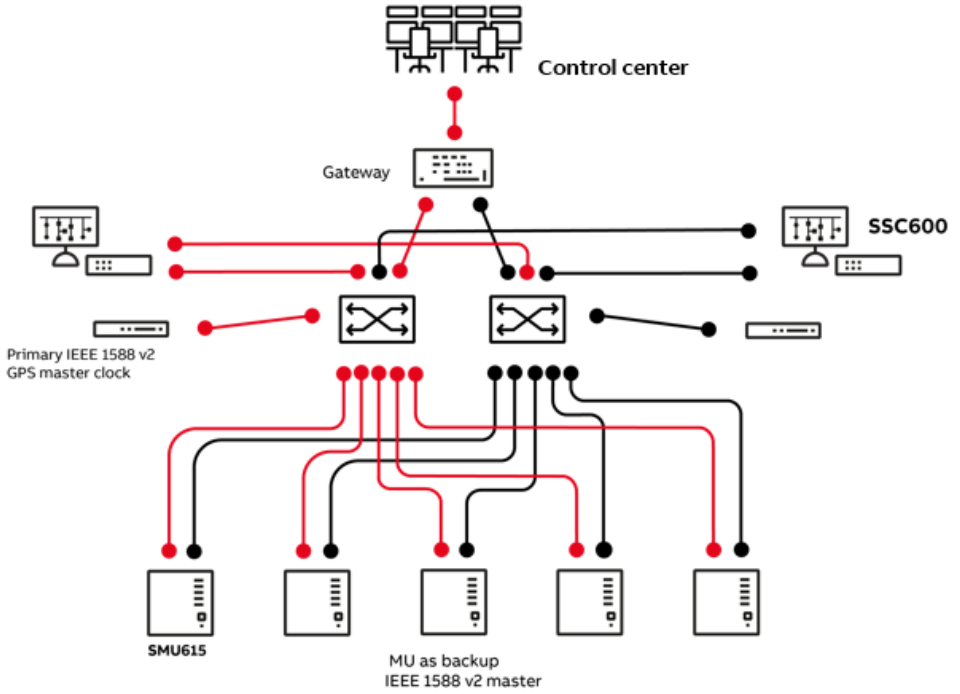
Two SSC600 devices and one gateway to the SCADA system

- Redundant power supply in SSC600
- Both SSC600 devices in hot-hot redundancy mode
- Redundant communication with PRP
- Time synchronization via the IEEE 1588 v2 GPS master and backup time master from MU or secondary GPS master

Substation gateway doubles up as HMI

Combined or separated IEC 61850 network for the process and station bus

Direct communication to the control center possible with IEC 61850 or IEC 60870-5-104, without an external gateway in between



Centralized/Virtualized protection and control features

Centralized protection with backup trip unit

Customer need

Failsafe redundant backup trip signal in case of relay or MU failure

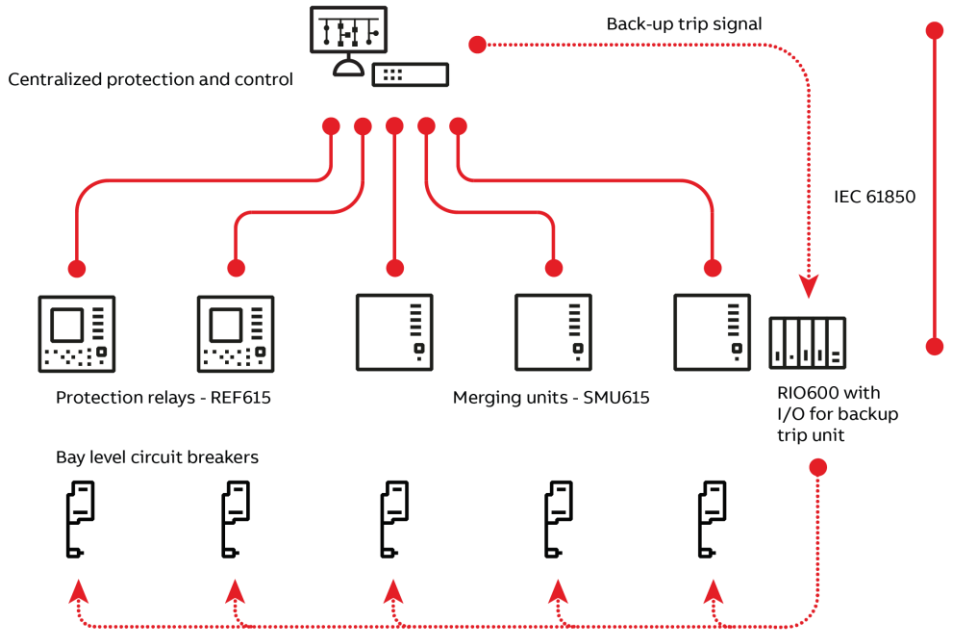
Solution

SSC600 combined with IEC 61850-capable devices with IEC 61850-9-2LE sending capabilities

SSC600 as main protection with flexible applications

SMU615 or basic REF615 feeder protection relay as backup protection

Remote I/O unit RIO600 added to facilitate backup trip signaling to bay-level circuit breakers



Centralized/Virtualized protection and control features

Simplified busbar protection

Customer need

Cost-efficient protection for busbar(s)

Different choices for implementation of busbar protection

Busbar protection without additional hardware

Solution

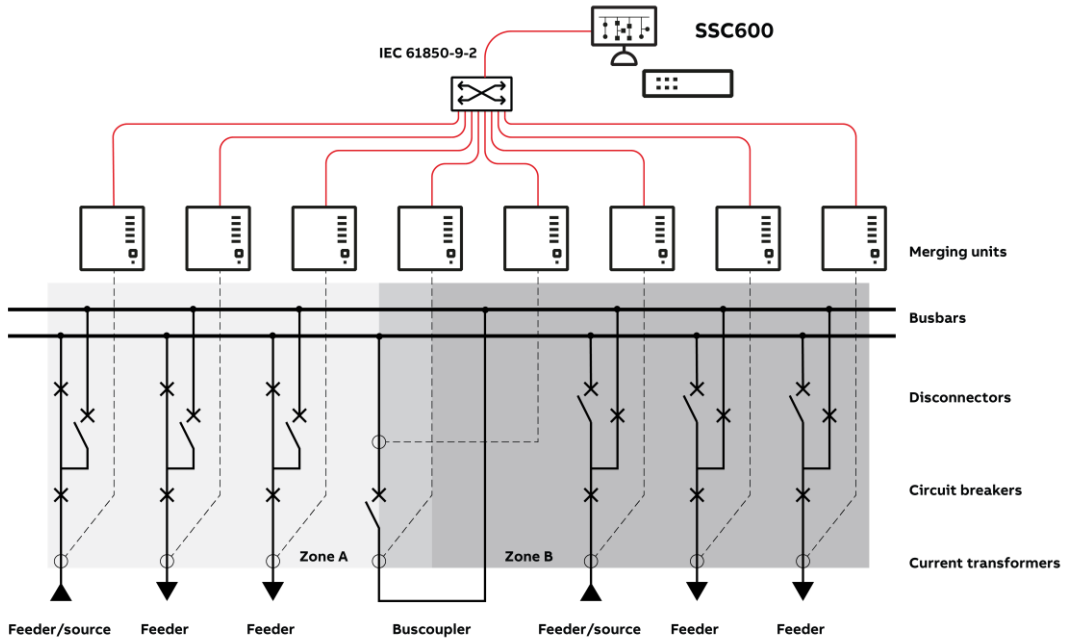
Arc flash protection

- MUs sense the light whereas SSC600 has the logic for selective tripping
- Easy-to-manage and engineer system with multiple sensors

Busbar differential protection

- Based on the low-impedance differential principle
- No need for extra equipment in addition to SSC600 and MUs
- Up to 30 bays
- 4 protection zones and a check zone
- For single and double busbars

On top of other substation protection, SSC600 can be used for busbar protection



Centralized/Virtualized protection and control features

Centralized substation-level HMI

Customer need

Centralized substation-level HMI

- Station-wide process visibility
- Annunciator functionality

Solution

Ability to monitor and control the whole substation via SLDs on the WHMI

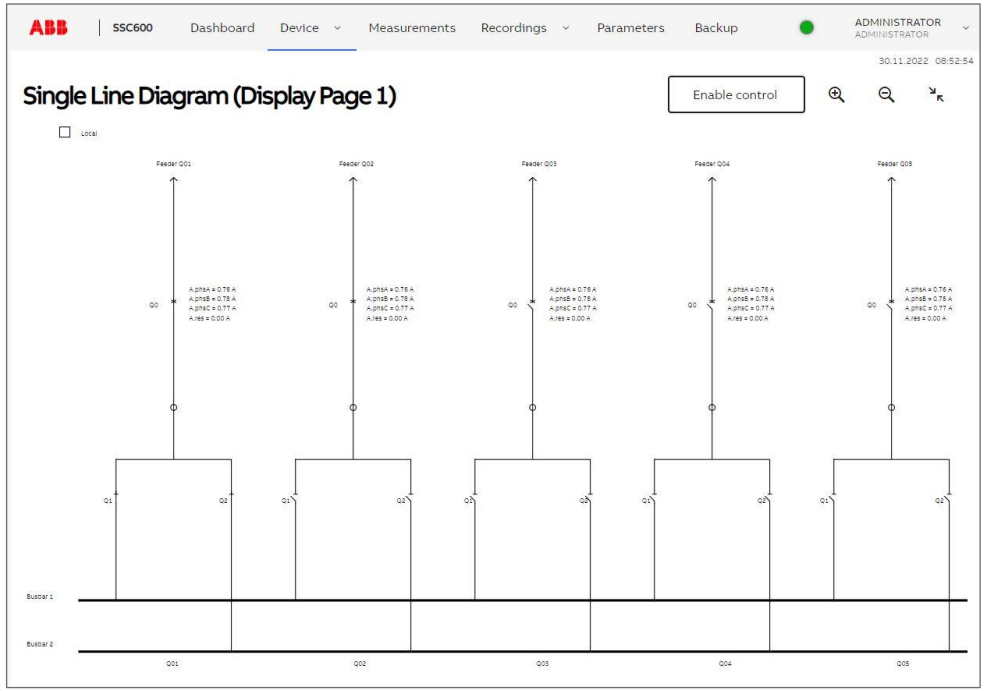
Easy access to events, fault records, disturbance recordings, settings and measurements

Alarm annunciator functionality with remote I/Os:

- Up to 100 alarm LEDS
- Capability to receive up to 1,600 GOOSE values and use them in logics

Possibility to add ZEE600 for a more comprehensive station HMI

- Full alarm handling with acknowledging
- Busbar coloring
- External logic processing (in addition to SSC600 logics)
- Data historian



SLD: Single Line Diagram
LED: Light Emitting Diode
GOOSE: Generic Object Oriented Substation Event
ZEE600: ABB zenon Electrification Edition ZEE600

Centralized/Virtualized protection and control features

Centralized fault analysis

Customer need

Substation-wide visibility with monitoring of network faults from a centralized point

All substation-related fault data in one place

Solution

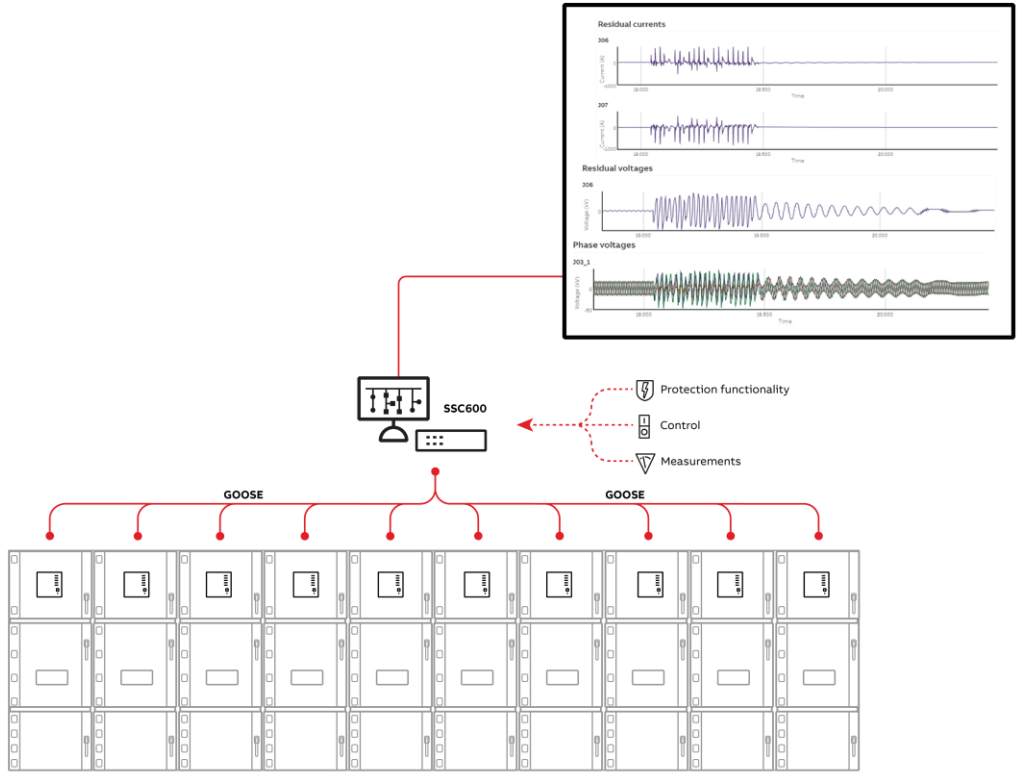
Disturbance recordings covering the whole substation

- Recordings of all received IEC 61850-9-2 LE sample streams with 80 samples per cycle (up to 30 streams)
- Recordings of up to 512 Boolean signals
- Storage space for thousands* of COMTRADE files
- Maximum recording length 60 seconds

Sequence of events (SOE) for the whole substation

Fault record data of all protection events

Trigger recordings with dedicated anomality detection function



*Depending on recording length

Centralized/Virtualized protection and control features

Centralized logics and configuration

Customer need

Flexibility to customize protection application for specific needs

Easy-to-use PLC engineering interface

Possibility to graphically troubleshoot and monitor programmable logics

Centralized place for large logics with protection class operation reliability and performance

Solution

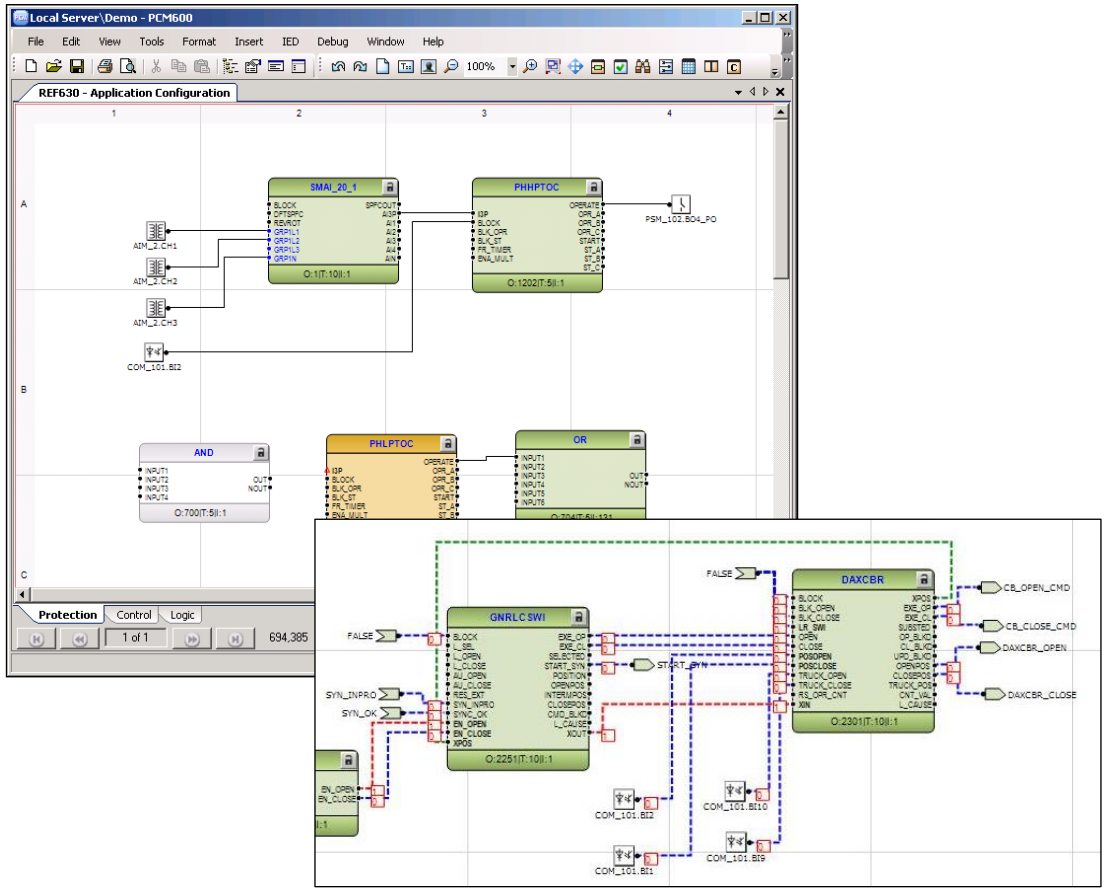
Extensive logical programming functionality with various logic functions

Easy-to-use graphical application configuration interface in PCM600

Online monitoring of the complete SSC600 application with PCM600

Ability to receive hundreds of statuses and use them together with thousands of logical gates for highly demanding applications

All station-level and bay-to-bay logics done centrally, for instance, interlockings in one single configuration



Introduction

ADAM fleet management solution

Cloud environment

- **Solution built around the software- and service-oriented approach to protection and control functionality in power distribution substations**
- **Added functionality** offered by utilizing cloud services
  - Fleet management
  - Remote updates
  - Remote diagnostics
  - Asset management

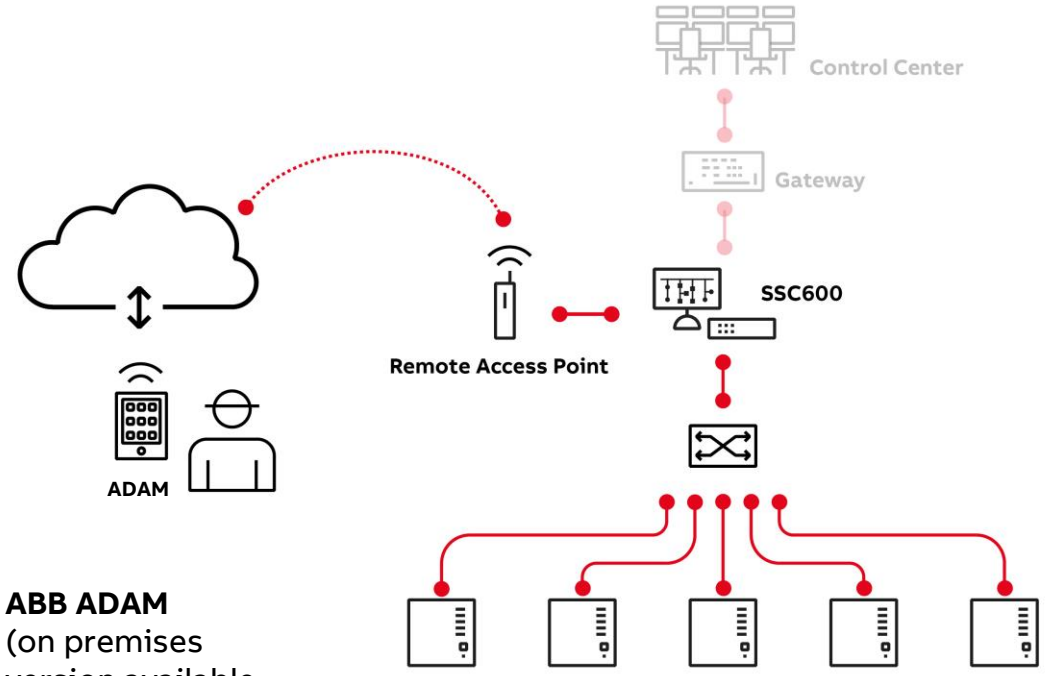
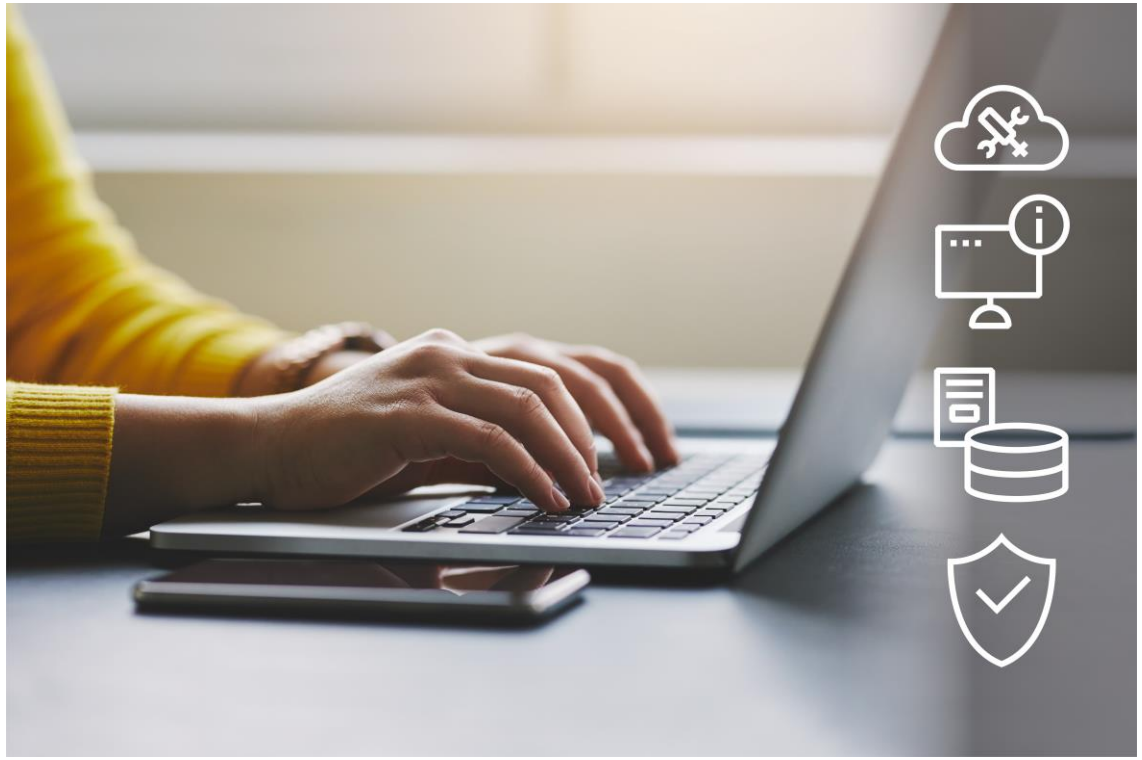


ABB ADAM
(on premises version available during Q1-2025)

Introduction

ADAM at a glance



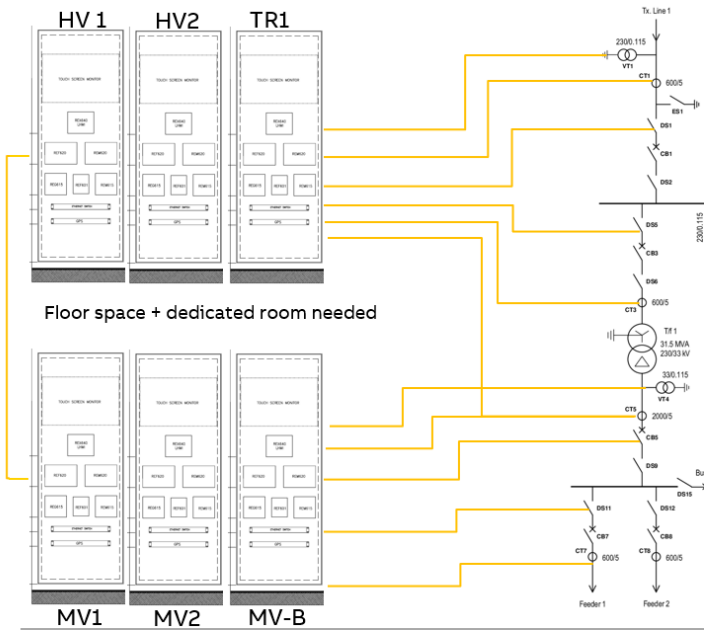
- Cloud-based fleet management
- Monitoring and management
- Gather records, events logs
- Cyber security
- Fault analysis
- Firmware updates
- Backup storage and versioning
- **A.I. / M.L based fault analysis and prediction (OPTION during Q1-2025)**

Smart substation control and protection SSC600

Migration from CONVENTIONAL → DIGITAL SUBSTATION

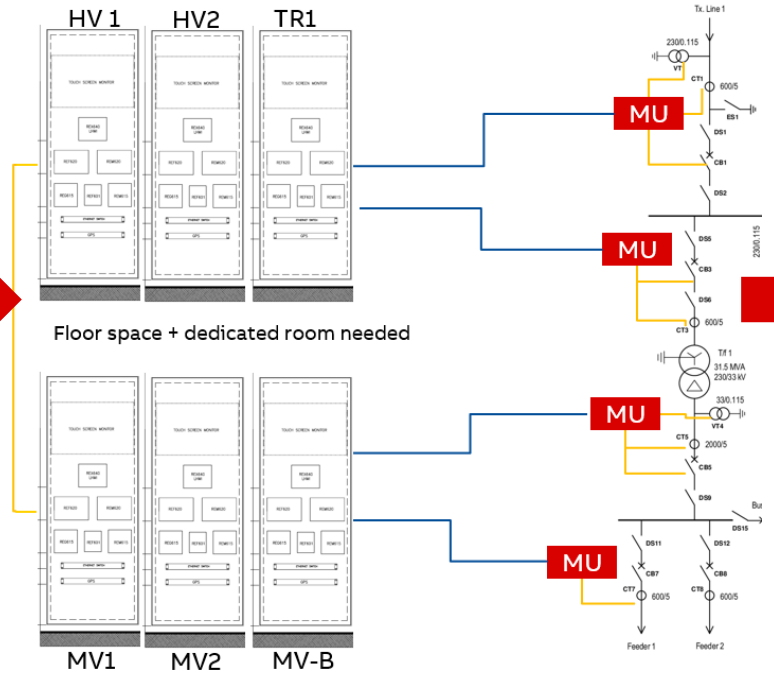
1 Conventional architecture (copper hardwiring – conventional IED's

Protection and Control



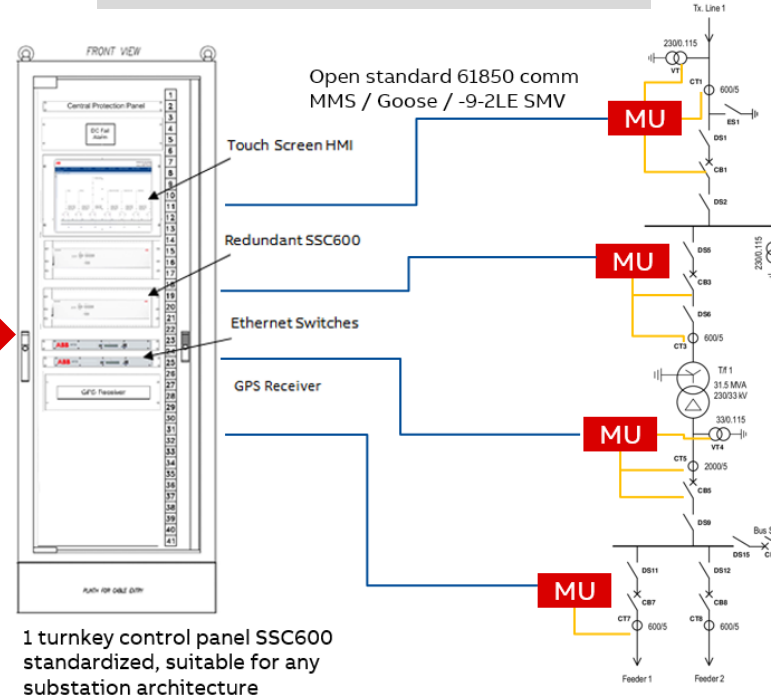
2 Digital Substation «light» hardwiring replaced by process bus FO

Protection and Control



3 Digital Substation «FULL» process bus FO + Centralized PACS

Protection and Control



copper FO

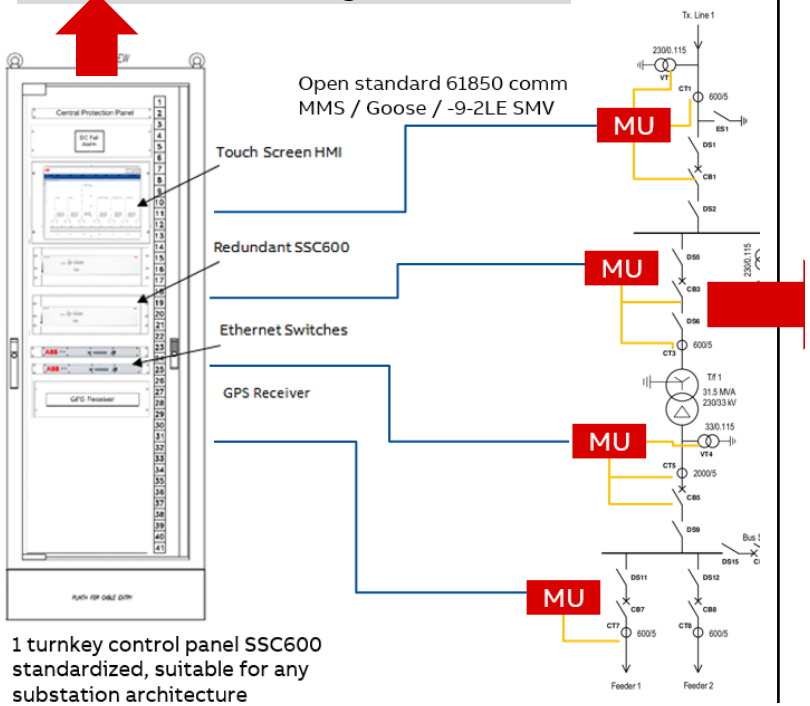
Smart substation control and protection SSC600

Migration from CONVENTIONAL → DIGITAL SUBSTATION

4

Digital Substation «FULL»
process bus FO + Centralized PACS

Backups/ Faults + anomalies recordings

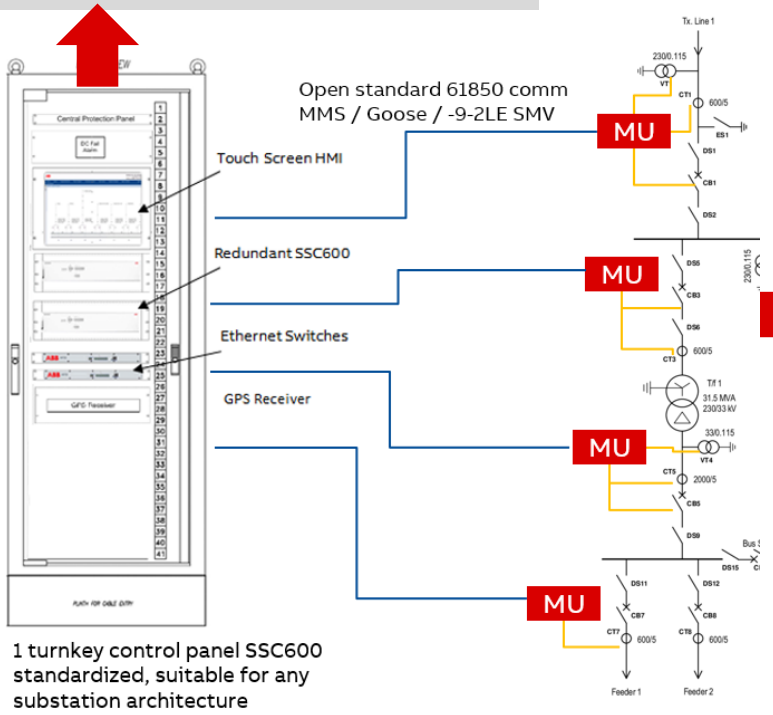


1 turnkey control panel SSC600 standardized, suitable for any substation architecture

5

Digital Substation «FULL»
process bus FO + Centralized PACS

A.I. Fault Analysis



1 turnkey control panel SSC600 standardized, suitable for any substation architecture

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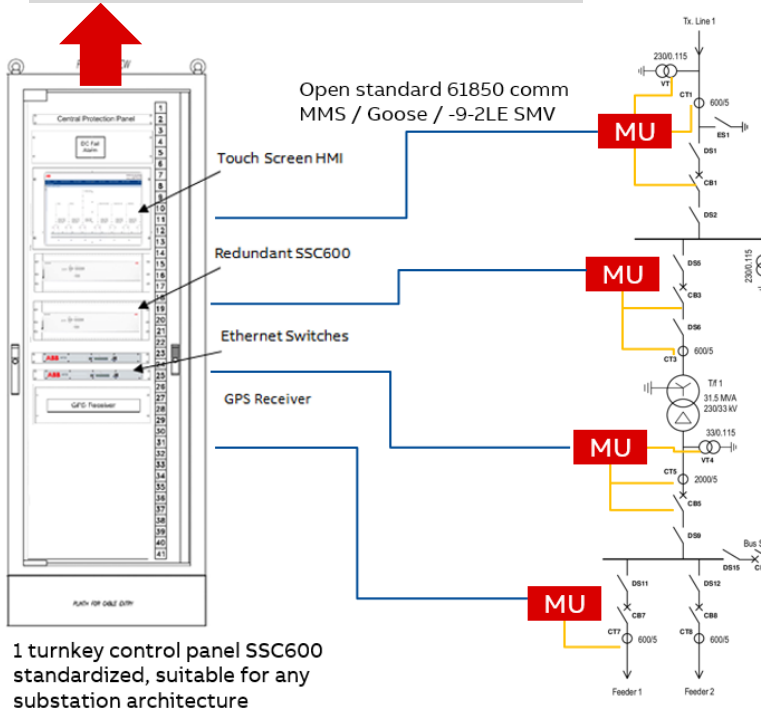
Digital Substation «FULL»
process bus FO + Centralized PACS

AI. Fault Analysis +
A.I. Fault prediction



1 turnkey control panel SSC600 standardized, suitable for any substation architecture

copper FO

Smart substation control and protection SSC600

User case: UK Power Network + PNDC

vPAC

- Full scalability of hardware and software
- Multi-vendor integration on the same hardware platform
- Remote asset and apps management through VM centralized asset management tools
- Compatible with open-source and commercial vendors for the VM layer
- Allow EPCs and utilities to utilize the same components worldwide and customize only the apps needed in the VMs/containers

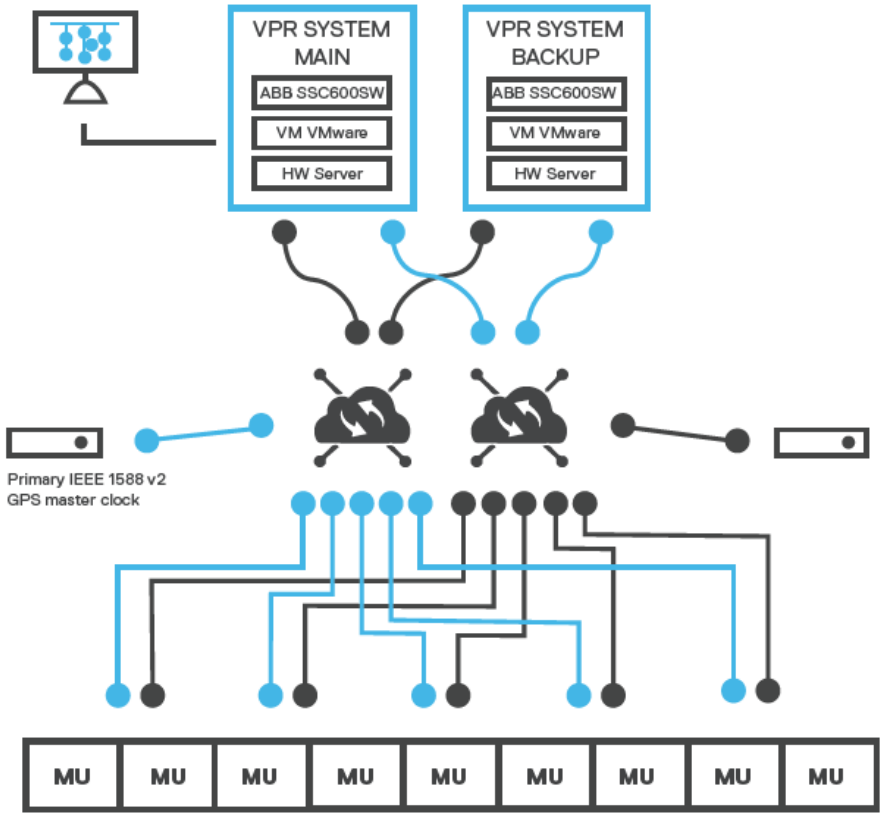


ABB SSC600 as Virtual Machine

Centralized 61850-based platform running on virtual machines with Intel® Xeon® Gold CPU up to 24 cores up to 150 bays

In partnership with:

Source: DELL (2022)

Application packages

SSC600/SSC600SW Feature Pack 4, up to 30 61850-9-2LE streams (30 x 4 currents/4 voltages)

Base functionality (always included)

Substation management

Functionalities
Web HMI with station SLD
Breaker monitoring
Measurements_3I/3V/In/Vn/f/…
Fault recorder
Disturb. recorder (centralized)
IEC61850-9-2LE SMV receiving
IEC61850 GOOSE/ R-GOOSE/MMS
Advanced logics
Alarms
Events and audit log
PRP redundant communication
Redundant power supply
Time synch. with IEEE 1588 v2
IEC 60870-5-104
Anomaly detector ANOGAPC

Basic protection functions

Basic protection
Current protection_50/51
Earth-fault_50N/51N
3-phase undervoltage_27
3-phase overvoltage_59
Residual overvoltage_59N
Neg.seq. overvoltage_47O-
Pos.seq. undervoltage_47U+
Negative-sequence OC_46
Frequency protection_81
Fuse failure supervision_VCM,60
Three-phase inrush detect._68HB
Circuit-breaker failure_51BF
Master trip_94/86
Switch onto fault_SOTF
Load blinder_21LB

Optional packages & functions

Cable/line application (5-10-15-20-30 bays)

Directional EF_67N
3-ph. direct. reverse power_32R/32O
Phase-discontinuity_46PD
Thermal protection_49F
Autoreclosing_79
Synchrocheck_25
Directional OC_67P

Advanced cable/line application (5-10-15-20-30 bays)

MF-admittance EF_67NYH
Admittance EF_21YN
Intermittent EF_67NIEF
Wattmetric EF_32N
Low-voltage ride-through protection_27RT
Fault locator_21FL
Direct. react. power underv._32Q/27

Transformer protection (0-2-4 bays)

Thermal overload_49/T/G/C
Transformer differential_87T
Low-impedance REF_87NL
3-phase underimpedance_21G
Tap-changer position indication_84M

Motor application (0-5-10-15-20-30 bays)

Thermal overload_49M
Neg.seq. OC for machines_46M
Loss of load supervision_37
Motor load jam_51LR
Motor startup supervision_49/66/48/51LR
Phase reversal 46R
Emergency startup_ESTART

Bay-level applications (for selected and available streams)

Tap-changer indication and control with voltage regulator
Distance protection_21P, 21N
Power quality • Current total demand and harmonic distortion (TDD and THD) • Voltage total harmonic distortion (THD) • Voltage variation • Voltage unbalance

Multi-bay level applications (up to 30 bays)

Load-shedding and restoration across 4 bus sections_81LSH
Low imp. busbar differential_87BL/87B
Arc protection_50L/50NL

Shunt capacitor protection

3-ph overload_51,37,86C
Current unbalance_60N
3-ph current unbalance_60P
Cap. bank switching resonance_55ITHD

SSC600 applications and features, available in 3 variants

SSC600 FP4 workstation (including 61850-3 server)

SSC600 SW (FP4) (software VM for Linux KVM)

SSC600 SW (FP4) (software VM for Vmware 7.x)

On the way to intelligent and autonomous networks

Conclusion

- Turnkey & flexibility
- Reliability
- Reduction of assets
- Interoperability
- Security Remote patching
- System savings OPEX/CAPEX
- Backups and asset management
- Life cycle management

Reduced cabling costs
-90%

Reduction of engineering costs
-20%

Reduction in construction costs of the HV/MV substation up to
- 1 MUSD

Reduced deployment time for Substation automation systems
50% faster

Reduction of operational costs
- 25%

Total Savings for the Substation Automation System
- 30%

Use of technology GRID EDGE & AI for an AUTONOMOUS network

Simplification of standards and Assets

Greater visibility of current and upcoming events