APPROVED FOR EXTERNAL USE

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Digital switchgear concepts for MV applications

Safety and simplicity

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Learning objectives

- Introduction to digital switchgear
- Governing standards
- Key digital switchgear components
  - Current and voltage sensors
  - Protection and control relays with LEA inputs
- Benefits of digital switchgear
  - Examples
- Asset health monitoring
- Installations
- Appendix

What is digital switchgear?

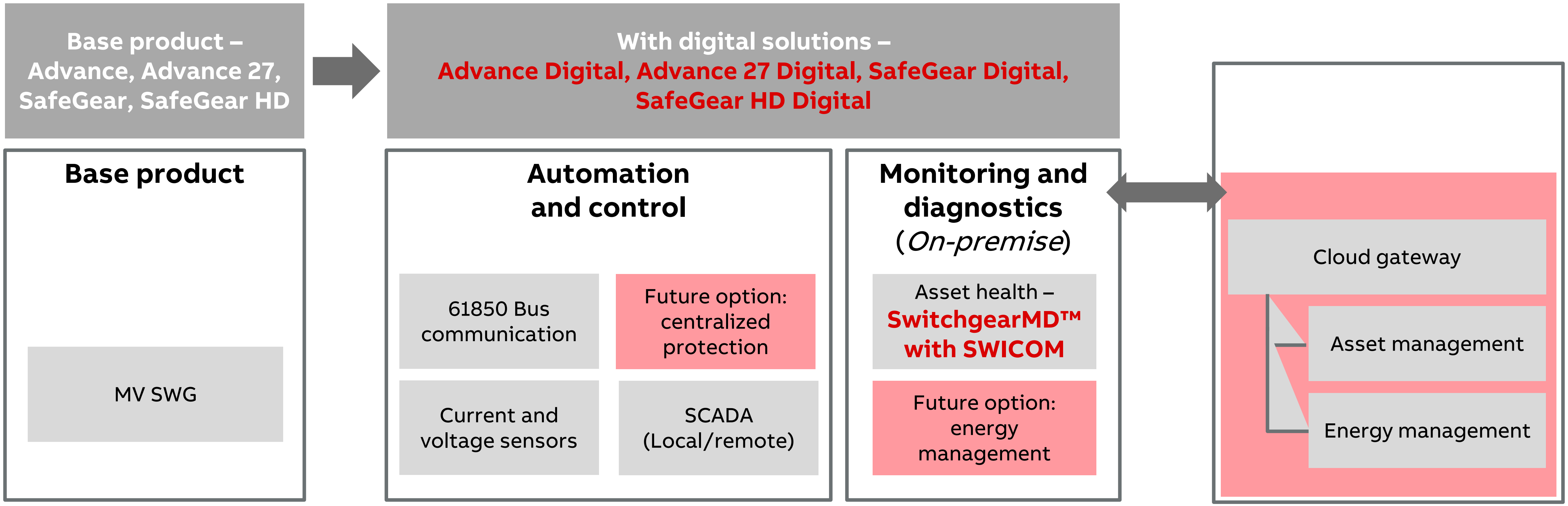
A definition

Switchgear where device status information, current and voltage measurements and commands are reliably transferred on a common communication bus. When equipped, the condition monitoring and diagnostic information of the switchgear and its devices is also digitally available for advanced analysis.

H. Karandikar, T. Neighbours and R. Pate, "**The Next Phase in the Evolution of Safety by Design - Digital Switchgear**," 2019 IEEE Petroleum and Chemical Industry Committee Conference (PCIC), Vancouver, BC, Canada, 2019, pp. 233-240, doi: 10.1109/PCIC30934.2019.9074536.

ANSI MV digital switchgear

Scope



Digital switchgear is the next phase in the evolution of switchgear

SAFETY and SIMPLICITY are the most significant benefits, but there are many more.

Sensor technology and common communication bus are essential to realize the full benefits of digital switchgear.

Digital switchgear is a proven technology embedded with new products and is **UL/cUL certified**.

MV digital switchgear evolution

New concept based on proven technologies

1994-1995
Current and Voltage sensors first introduced by ABB in AIS and GIS

2002-2005
First edition of IEC 61850 introduced

2009
Launched SwitchgearMD™ in the US for new switchgear and retrofit applications

2011
IEC 61850-9-2 was released and introduced the concept of sampled values

Q4 2013
Launch of UniGear Digital in the IEC market

2017
Digital switchgear was introduced into the ANSI market

Q4 2018
First order for ANSI digital switchgear shipped

Q4 2019
Obtained UL certification for use of current and voltage sensors and SwitchgearMD™

Incorporated SWICOM in SwitchgearMD™

Q4 2020
Official launch of UL/cUL listed 5/15 kV ANSI digital switchgear

Governing standards

ANSI/IEEE MV switchgear standards and sensors

- Both the previous version (2015) and latest version (2022) of the metal-clad switchgear standard, IEEE C37.20.2, addresses the use of voltage sensors in Annex D. There are also clauses in the standard that address the use of current sensors.
- Additionally, the use of sensors is also referenced in IEEE C37.20.9-2019 (GIS) and is being added to IEEE C37.20.3-2013 (metal-enclosed switchgear)
- UL347 6th Ed. for MV motor control centers addresses the use of sensors in Annex E

What standards are applicable to sensors?

Background

ITs are primarily covered by IEEE C57.13-2016; this standard does <u>not</u> cover sensors

IEEE standards / guides for current and voltage sensors

- No specific standard exists today
- IEEE PSIM formed new Sensor Subcommittee in January 2020 to organize sensor activities
- IEEE PSIM Working Group formed to work on an IEEE Guide that will be focused on testing of end-to-end sensor systems and Task Force focused on Sensors Accuracy Testing Paper
- IEEE C37.235-2007 - Guide for the Application of Rogowski Coils used for Protective Relaying Purposes
- IEEE C37.92-2005 - Standard for Analog Inputs to Protective Relays From Electronic Voltage and Current Transducers

However, this should not limit your applications

- IEC standards 60044 and 61869 cover sensors
  - IEC 61869-10 (2017): Additional requirements for low-power passive current transformers
  - IEC 61869-11 (2017): Additional requirements for low power passive voltage transformers

Current sensors	• **IEC 60044-8 (2002)** • **IEC 61869-10 (2017) - active**
Voltage sensors	• **IEC 60044-7 (1999)** • **IEC 61869-11 (2017) - active**

Key digital switchgear components

Key digital switchgear components

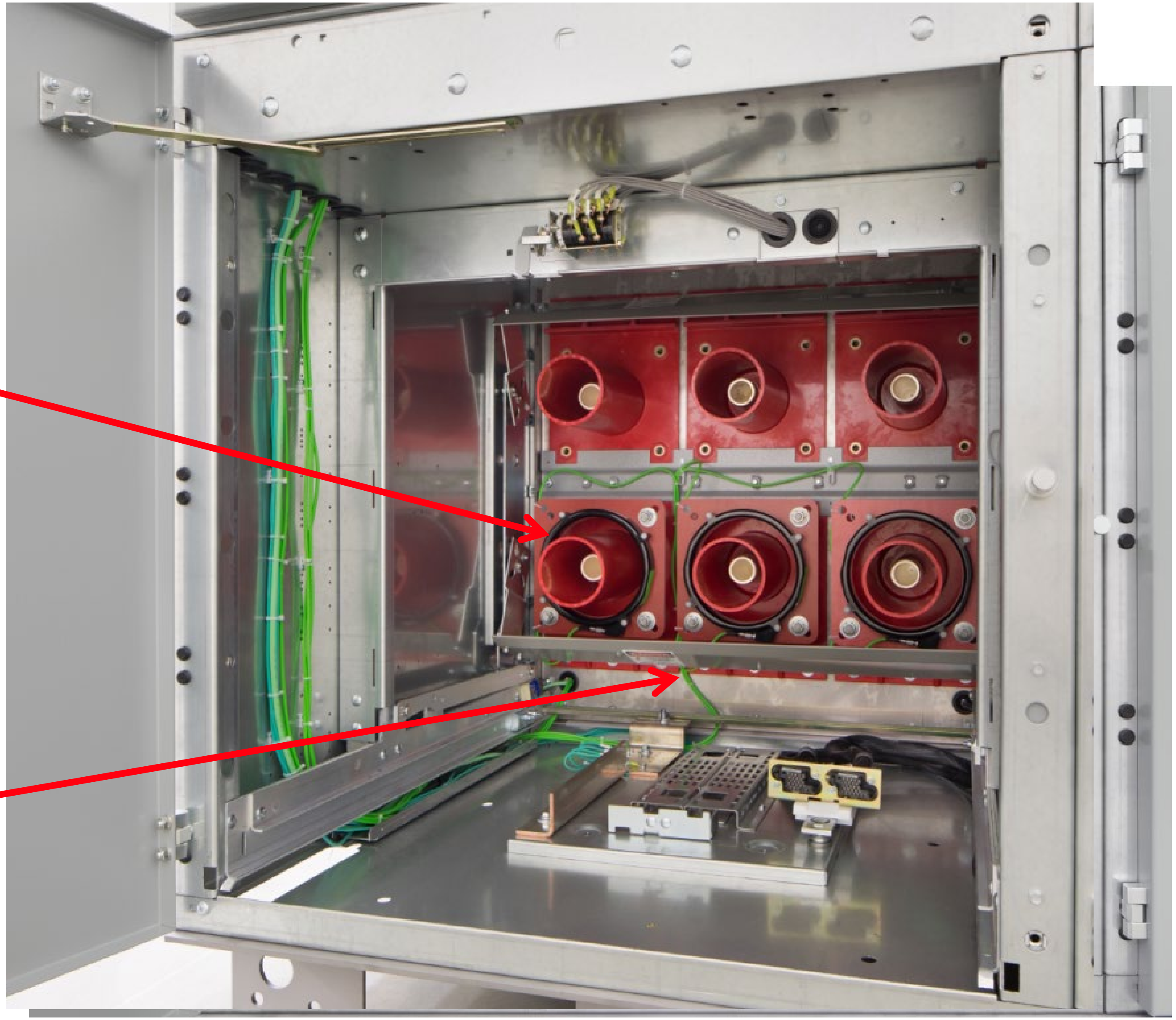
Levels of digitalization

	Description	Main value
Level 0	Simply replace CTs and PTs with current and voltage sensors. Add additional sensor packages (e.g., temperature) as needed.	1. Reduced weight 2. Space saving (primarily due to elimination of PT compartment) 3. Eliminates problems of saturation and ferroresonance 4. Safety – no possibility of unsafe voltages from open CT secondary circuits 5. Equipment condition for switchgear and circuit breakers.
Level 1	Above + IEC61850-8-1 and GOOSE messaging Ethernet cabling between protective relays.	Above + 5. Significant reduction in wiring between frames 6. Late customization
Level 2	Above + Process bus (61850-9-2LE) Requires use of Merging Units (MUs), time synchronization devices and Ethernet switches. Fiber optic connection from bay (switchgear) to substation.	Above + 7. Improved flexibility – changes in protection only require IED level changes.

Digital switchgear

Circuit breaker compartment

Current sensors



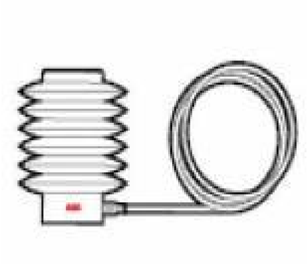
Cat 5E or better Cable

MV sensors	Standards
Current sensors	• **IEEE 802.3ae and 802.3an** • **IEC 60044-8; 61869-10** Electronic current transformers • **UL/UR Certified**

Digital switchgear

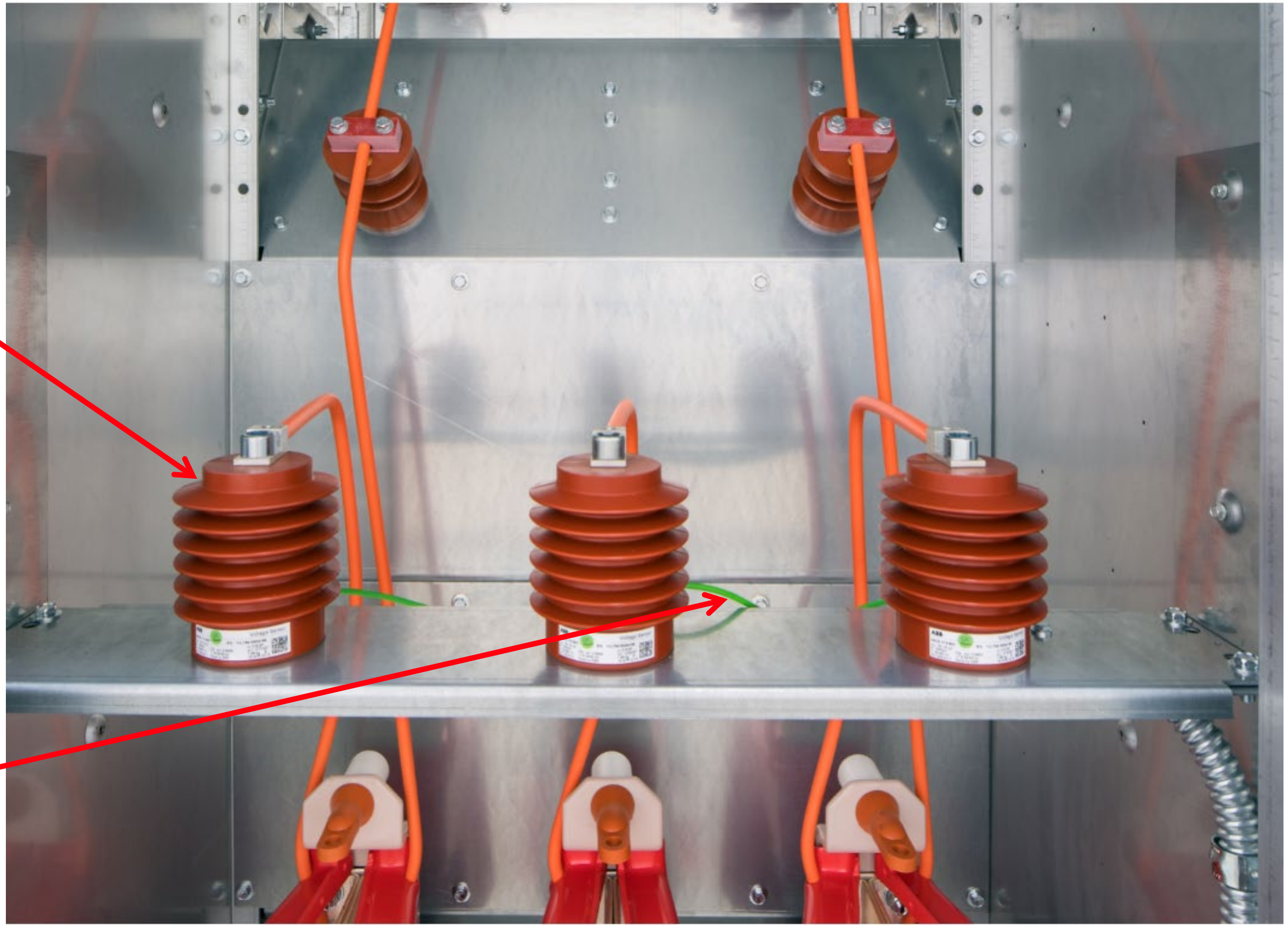
Cable compartment

Voltage sensors



MV sensors	Standards
Voltage sensors	• **IEEE 802.3ae and 802.3an** • **IEC 60044-7** Electronic voltage transformers • **UL/UR Certified**

Cat 5E or Better Cable



Boots cover the sensor terminals in practice.

Sensors – ideal for critical applications

Concerns better addressed by sensors

- 20+ yr old technology in switchgear
- Use solid state components and little or no ferromagnetic material in circuit
- Lack of magnetic core - very low energy output – cannot typically transfer power to secondary
- Current sensors @ 60 Hz have a 0-180 mv output
- Voltage sensors @ 60 Hz have a 0-10 V output
- Increased safety
- Reduced footprint
- More linear response
- Simplified installations – less wiring, smaller footprint, lighter weight
- Reduced energy use, esp. in tight compartments

Current sensors

Current sensors are safer than conventional CTs

Digital switchgear

Rogowski coil sensor

- Us=150 mV for 50 Hz --- 80 A Primary
- Us=180 mV for 60 Hz --- 80 A Primary

Rogowski coil sensor

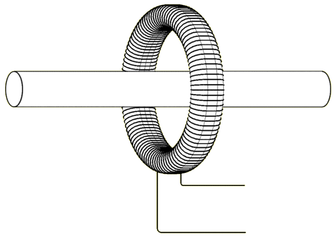
- Output voltage is proportional to the derivative of primary current
- Output voltage is integrated by protective relay

No saturation (air core)

Open CT hazard eliminated

Low Power CT, output is voltage rather than current

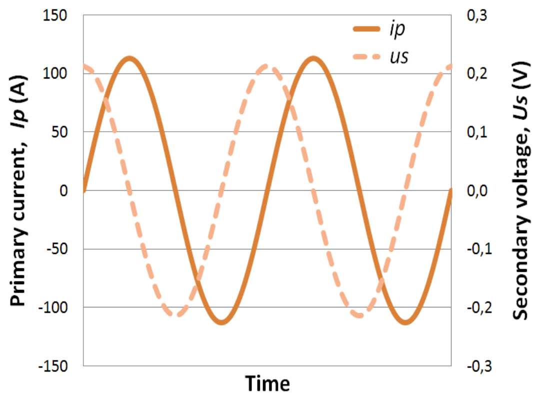
FOCS (Fiber Optic Current Sensor) mainly used in high voltage applications due to higher cost



No saturation (air core)

$$u_s(t) = M\frac{di_p(t)}{dt}$$

Open CT hazard eliminated



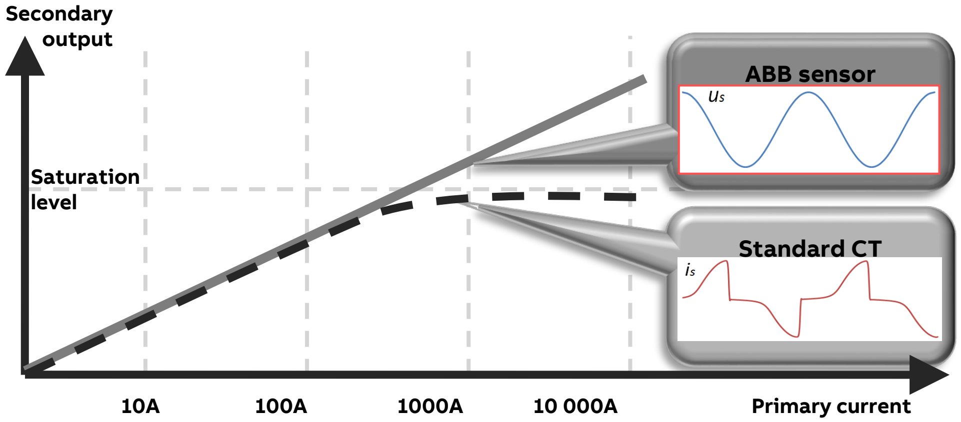
Rated short-time thermal current: up to 85 KA/3s

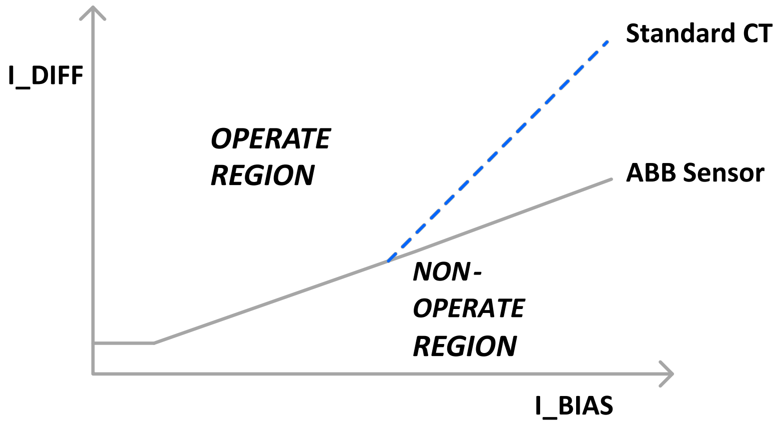
Current sensors

Increased performance in differential protection

Rogowski Coil

- Improved sensitivity for “in zone” faults
- Speed of response – reaches steady state of output faster vs. a Conventional CT
- High security for “out of zone” faults
- Multiple slopes not required (transformer)
- No need for higher accuracy devices for differential protection (87B, 87M, 87L, etc.)
- No need to keep the secondary closed, therefore no need for shorting terminals – connect/disconnect from the relay at any time



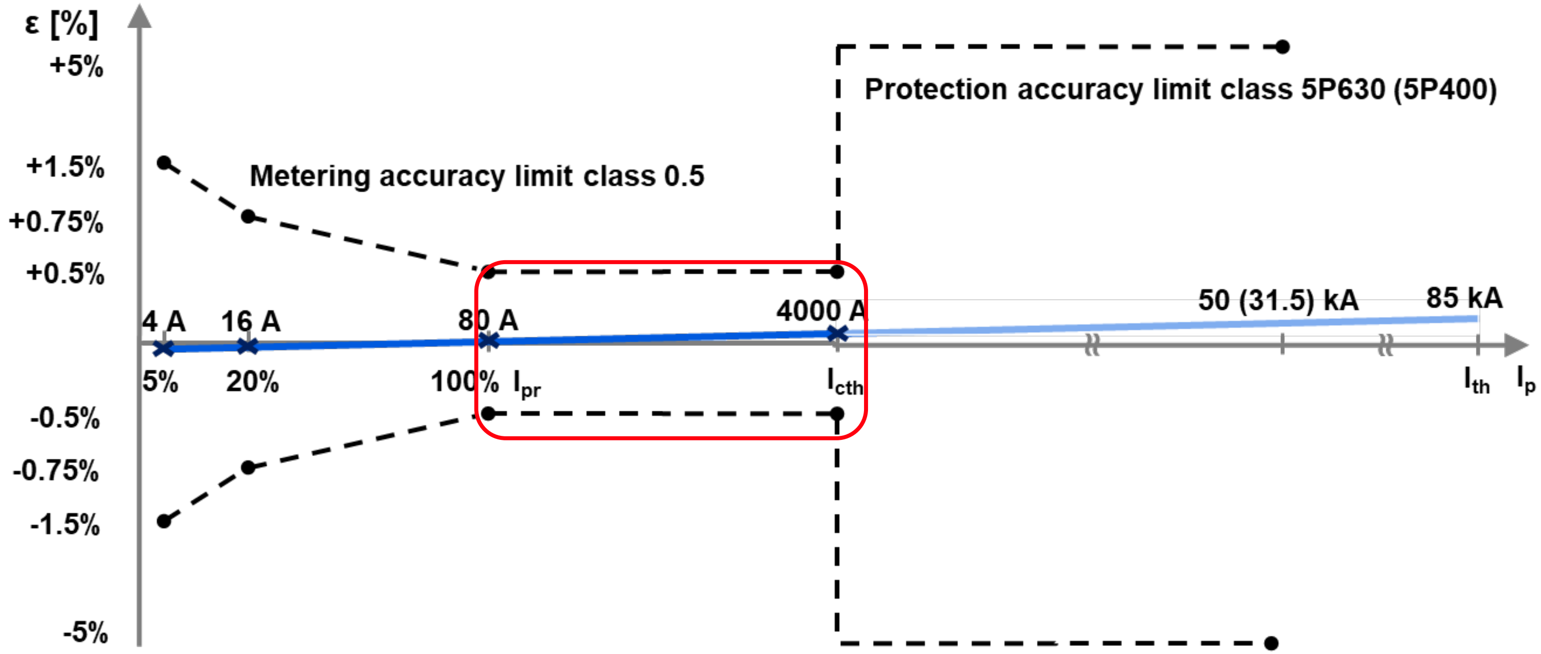


Current sensors

Combined accuracy class 0.5/5P630 (5P400)

- Current sensors, thanks to their linear characteristic, guarantee wide range of primary current
- The sensor standard defines accuracy characteristic as combination of metering and protection class into one
- Thus, current sensors transmit currents from couple of Amps up to short circuit, therefore accuracy class is defined as 5P630, where 630 is not an error but a real number calculated out of maximal current to be transmitted via sensor to secondary side

Accuracy of sensor is improved by utilizing correction factors in the protection relays



Voltage sensors

Voltage sensors are safer than conventional PTs

Voltage sensors

Resistive voltage divider sensor

- Passive element
- No fuses required

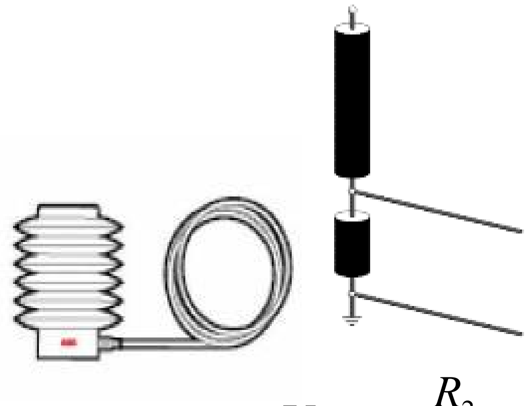
Non-saturable and linear over the whole measuring range

No ferro resonance (non-inductive)

10,000:1 transformation ratio

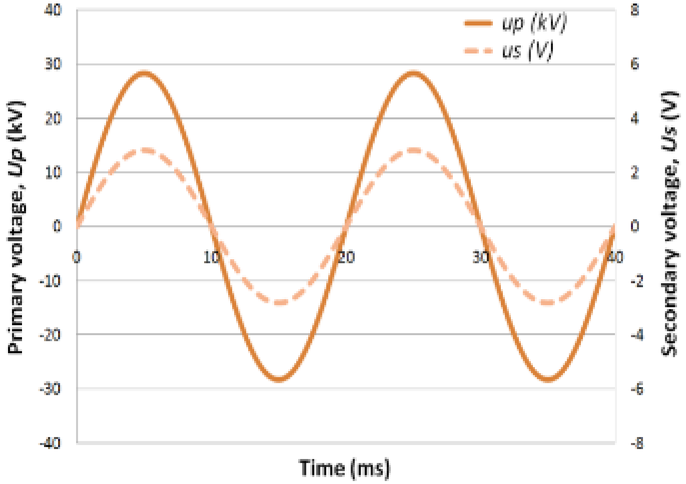
Accuracy up to class 0.5

Gas Insulated Switchgear (GIS) uses Capacitive Voltage Divider (CVD) sensors.



No ferroresonance (non-inductive)

$$U_S = \frac{R_2}{R_1 + R_2} U_P$$

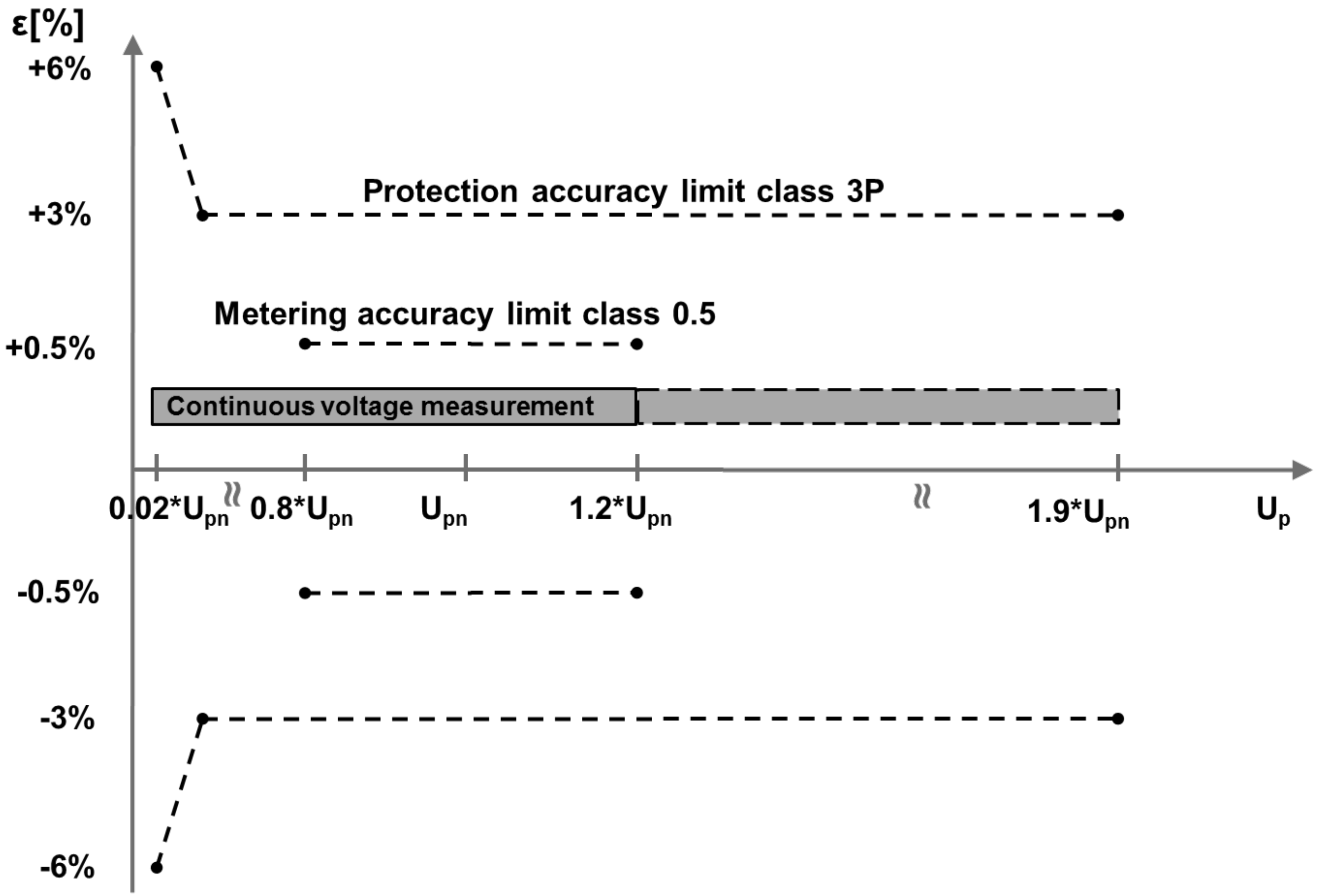


ABB

Voltage sensors

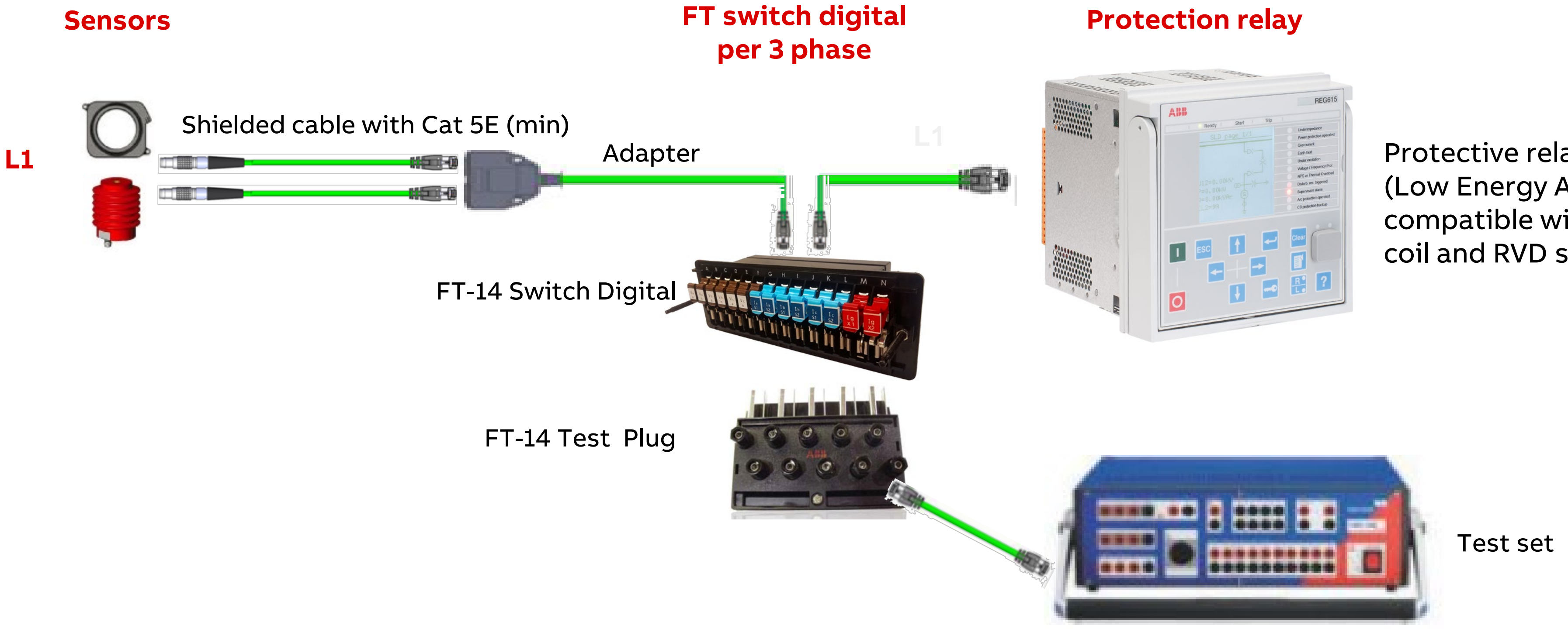
Combined accuracy class 0.5/3P

- For voltage sensors, the sensor standard defines the accuracy class combining metering and protection class into one
- Thus, voltage sensors have accuracy class of 0.5



Current and voltage sensor connections to IED

Point-to-point wiring eliminated and test set-up simplified



Protective relays must have LEA (Low Energy Analog) inputs compatible with the Rogowski coil and RVD sensors.

Almost no analog wiring in the switchgear – increases reliability

Innovation workshop

MV sensors – easy to test and verify

Required tests

1. Primary injection test/Ratio Test
2. ~~Polarity test~~
3. ~~Secondary winding resistance test~~
4. ~~Secondary circuit insulation resistance test~~
5. ~~Magnetization curves test~~

Available primary injection test set

- Omicron CPC 100

Relays for digital switchgear

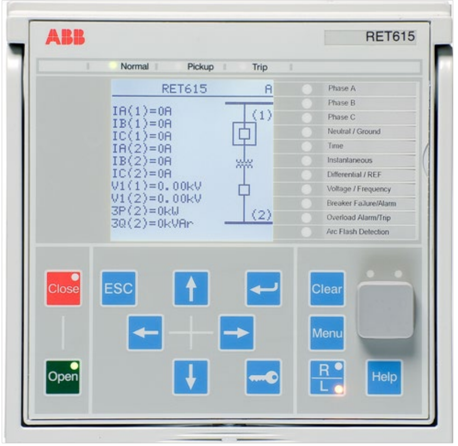
Future proof solution based on IEC 61850 and IEEE 802.3 standards

- Based on worldwide accepted IEC 61850 standard ensuring long-term sustainability
- Ready to be connected to remote control (SCADA) systems
- GOOSE messaging configured with software setting
- Available IEC 61850-9-2LE (Edition 2) features:
  - Vertical communication
  - Horizontal GOOSE communication
  - Process bus
- LEA (Low Energy Analog) inputs with IEEE 802.3 (Cat 5E or better cables)

IEC 61850

Meters for digital switchgear

- Relion relays have powerful metering capabilities and a large display to clearly show all parameters of interest.
- Limited options for standalone meters with Low Energy Analog (LEA) inputs (needed with current and voltage sensors).
  - SATEC Power Quality meters, model PM174/175 are now available for use with ABB current and voltage sensors.



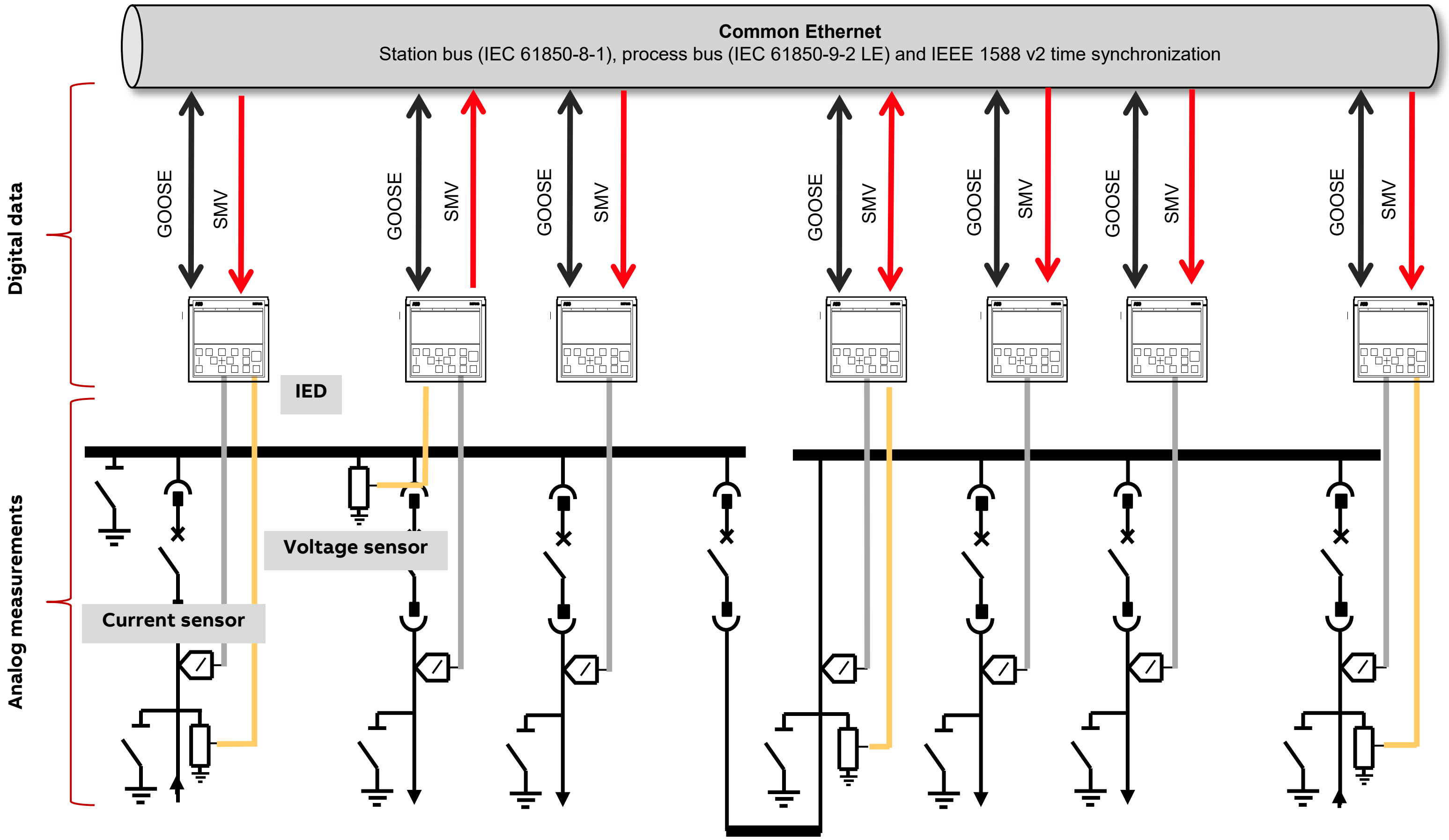
SATEC
Powerful Solutions

PM174

compact, multi-function, three-phase AC power meter and power quality analyzer

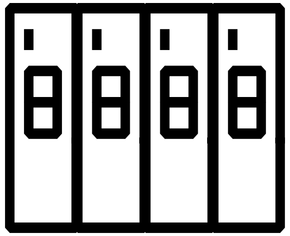
IEC 61850-9-2LE process bus and GOOSE messaging

One line diagram



Benefits of digital switchgear

Value of digital switchgear



Safety

Increased safety due to the use of current and voltage sensors. Condition monitoring technologies reduce personnel exposure due to less unplanned maintenance.

Simplicity

Reduction in hardware and wiring creating a simpler design to install and maintain. Current and voltage sensors provide greater reliability with a wide and linear range

Speed

Flexibility in engineering and design with the ability to compress order to delivery time and to accommodate late changes.

Savings

Lower cost of ownership with increased maintenance intervals, lower inventory costs and energy savings. Digital design offers space and weight savings leading to lower switchgear housing costs and freight costs.

Sustainability

Enables easy future system expansion. Less material usage and reduction in lifetime energy consumption within the switchgear.

Digital switchgear benefits – Safety

Safety by design

Installation and commissioning

- Reduced wiring and simple connectors reduces errors and installation time.
- Reduced weight of components makes handling of the equipment easier.
- Low energy analog (LEA) output of sensors reduce shock hazards during commissioning.

Operation

- Current and voltage sensors have LEA outputs.
- Voltage sensor eliminates danger of ferro resonance.
- Elimination of primary fuse protection for voltage sensors reduces likelihood of personnel interaction with the equipment.
- Sensors have a wide and linear accuracy range.
  - Current sensors do not saturate. Thus, varying loads can be accommodated without the need to change CTs.

Troubleshooting and maintenance

- Current sensor eliminates danger of high voltage across the secondary terminal of an open CT.
- For the same application, fewer sensors vs. transformers to fail.
- Self-supervision and error detection in the relays facilitates troubleshooting.
- Minimal control connections that could fail and require repair.
- With digital test switches the testing process is same as today.

Digital Switchgear benefits – Simplicity

Wiring and variants

Reduced variants

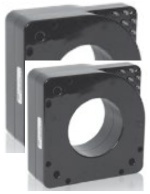
Voltage transformers

10's ➡ 2

Voltage sensors

Full range: up to 4000 A, 63 kA, 27 kV

Current transformers



100's ➡ 1

Current sensors

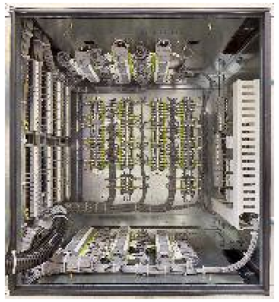
No cable tray

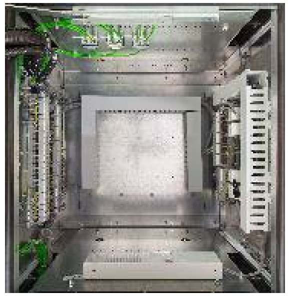
Single conduit to carry fiber

Conventional

Reduced wiring

Digital





Digital switchgear benefits – Speed

Flexibility and efficiency

Flexibility for varying applications

- Changing loads does not require changes in hardware like instrument transformers
  - Saves time and money during planning and execution
- Improved accuracy and range of current and voltage measurement for protection and control

Late changes/late customization

- Optimized set-up for quick and easy switchgear sourcing
- Set-up is flexible towards last-minute changes
  - The determination of wiring philosophy at an early project stage is not required
  - The determination of instrument transformer values at an early project stage is not required

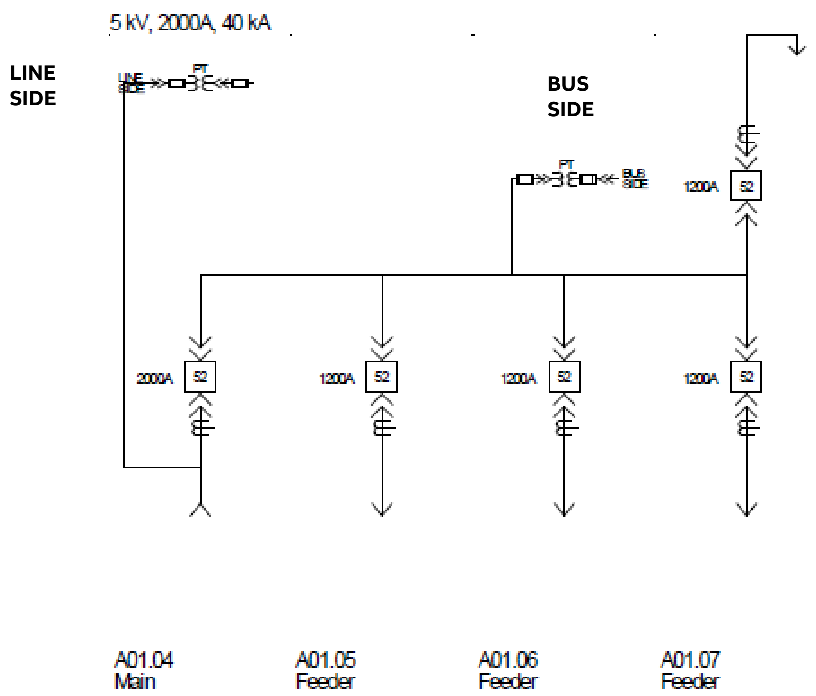
Reduced Overall Project Times

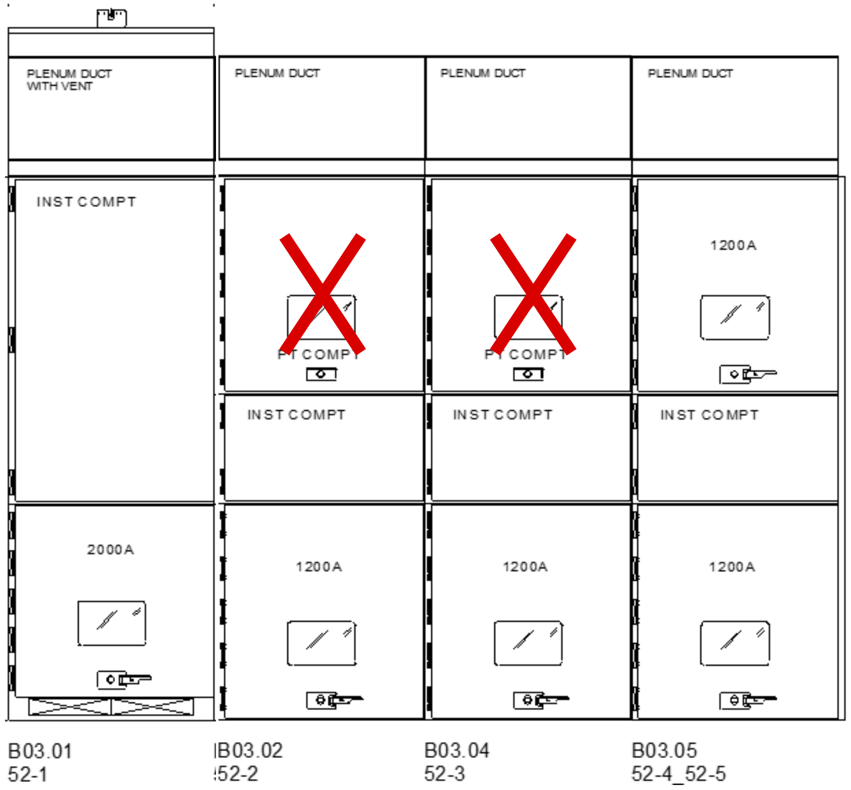
- No need for early definition of details like CT/PT data
  - Reduced engineering and easier configuration selection
  - Reduced project administration and engineering costs
- Minimized time to receive the project documentation
  - CT/PT data not required
  - Flexibility towards last-minute changes
  - Most changes are realizable within the IED's logic, only minor changes in wiring and schematics (if any)

Digital switchgear benefits – Savings

Smaller ffootprint

Reference project: ANSI switchgear at a US industrial user



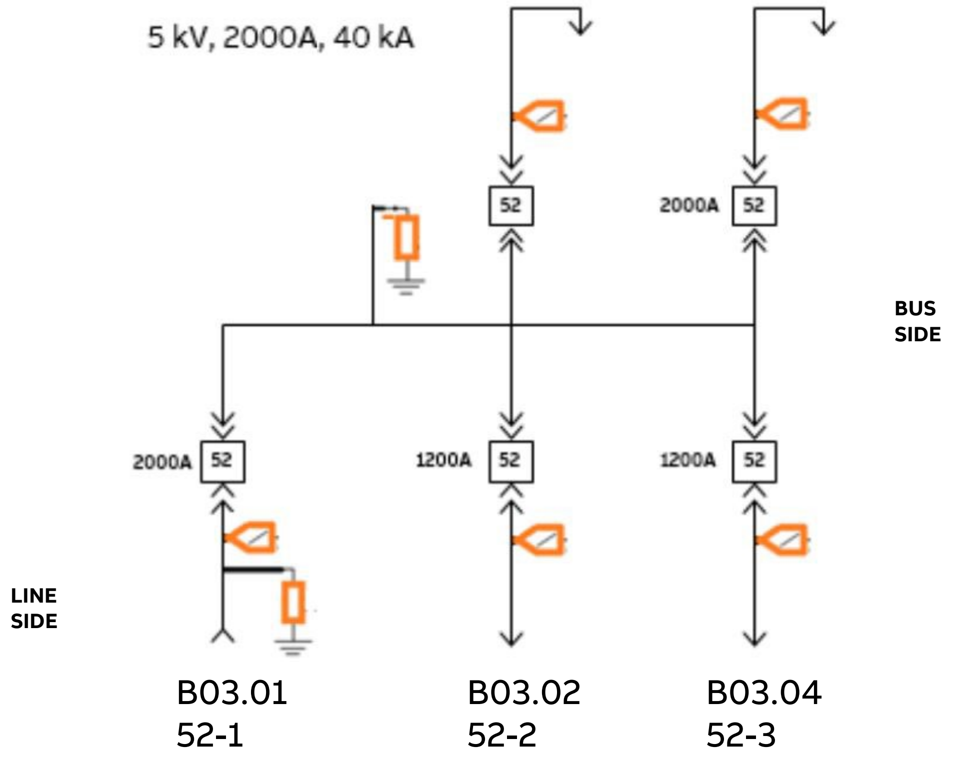


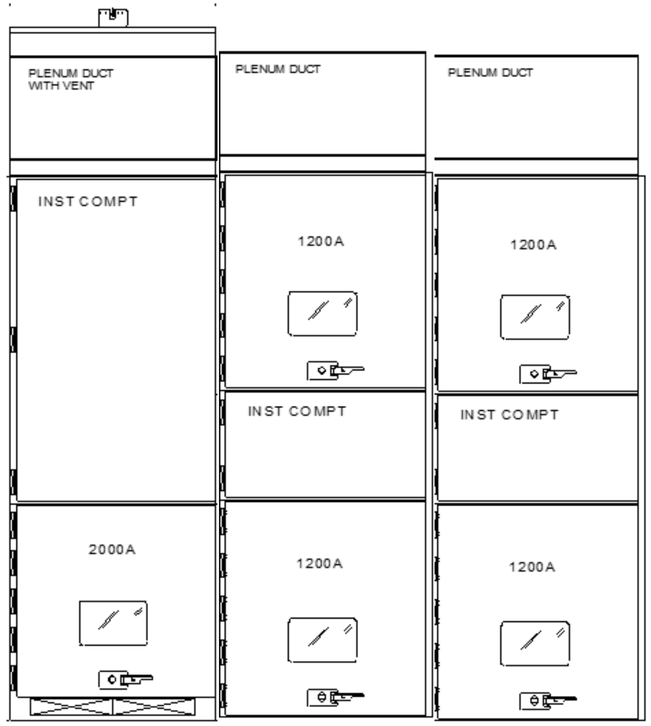
Conventional

Digital switchgear benefits – Savings

Smaller ffootprint

Reference project: ANSI switchgear at a US industrial user





Digital

Footprint: -25%, costs: -8.9%

Digital switchgear benefits – Sustainability

Sustainability via material and energy savings

Reduced material consumption

- Sensors are small and weigh less compared to ITs
- Building support structures can be optimized
- Footprint savings possible (less frames)

Energy loss is minimized with the use of sensors

- Saving potential of up to 250 MWh over 30 years
- Saves up to 150 tons of CO_2

	Feeder	CTs	Number of panels	Number of CTs	Power consumption	Energy consumption in 30 years*
CT w/1A rated secondary current	**Incoming**	1000:1/1A	2	6	140 VA	36 698 kWh
	Outgoing 1	200:1/1A	8	24	448 VA	117 776 kWh
	Outgoing 2	100:1/1A	4	12	102 VA	26 724 kWh
	Total	-	14	42	690 VA	**181 198 kWh**
CT w/5A rated secondary current	**Incoming**	1000:5/5A	2	6	172 VA	45 244 kWh
	Outgoing 1	200:5/5A	8	24	629 VA	165 208 kWh
	Outgoing 2	100:5/5A	4	12	179 VA	47 124 kWh
	Total	-	14	42	980 VA	**257 576 kWh**
Sensor	**Incoming**		2	6	0.0000 VA	0.000 01 kWh
	Outgoing 1		8	24	0.0000 VA	0.000 04 kWh
	Outgoing 2		4	12	0.0000 VA	0.000 02 kWh
	Total	-	14	42	0.0000 VA	**0.000 07 kWh**

* Calculation for switchgear with 14 frames:
- 2 incoming feeders with CTs 1000:x/x A
- 8 outgoing feeders with CTs 200:x/x A
- 4 outgoing feeders with CTs 100:x/x A

All CTs have 2 cores – protection core class 5P20, 20 VA connected to the IED and metering core class 0.5FS5, 5 VA connected to the analog ampere-meter.

ABB

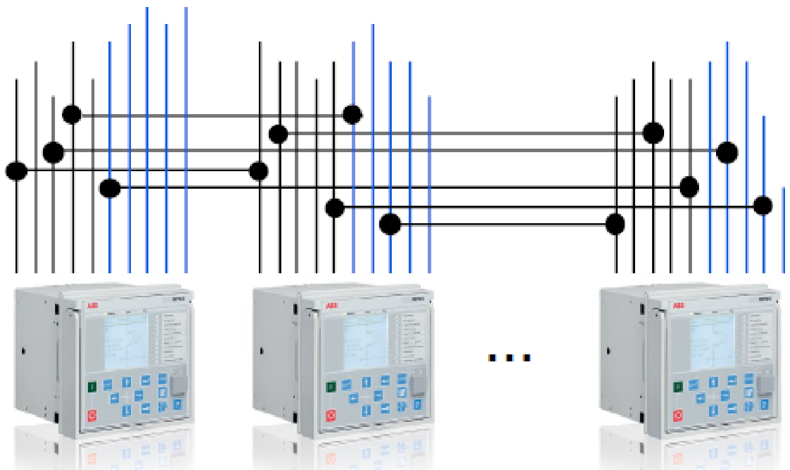
Benefits of digital medium voltage switchgear

Increased system reliability

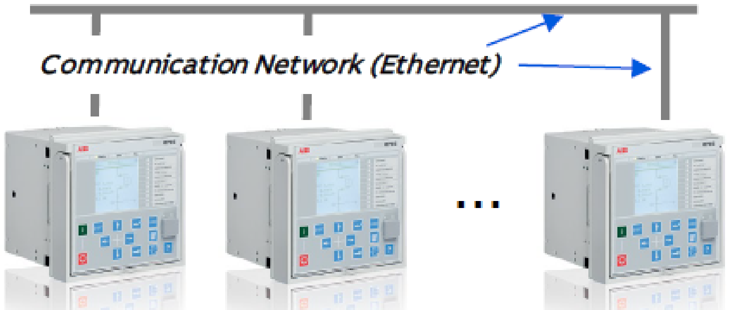
Benefits of IEC 61850 communication

Fast and reliable communication with IEC 61850, the global standard for communications in substations

- Complex control transfer schemes can be configured using the IEC 61850 compliant relays
- Flexibility to adapt and change the switchgear, without costly and time-consuming physical re-wiring
- Using the programmable logic in the protection relays, changes can be done easily and faster
- GOOSE communication between the substation equipment for improved speed and reduced switchgear cabling
- Fewer wires reduces risk of failures



Conventional approach
- Wiring between devices must be done individually per signal



Horizontal GOOSE communication
- Number of interconnections is equal to number of devices

Asset health monitoring

SwitchgearMD™

Asset health monitoring

Temperature monitoring: non-intrusive methods

- **IR cameras**
  - Periodic measurement
  - Require a pre-installed transparent window
  - Requires line of sight through the window thus limiting monitoring locations
  - A good IR camera can be expensive
  - Require a technician to get close to the gear

- **IR sensors**
  - Line of sight required by the sensor thus limiting monitoring locations
  - Real-time monitoring
  - Added installation costs of wiring
  - Accuracy affected by emissivity and reflectivity of adjacent surfaces
  - Sensor susceptible to misalignment due to vibration and shock

- **Fiber optic sensors**
  - Require direct surface contact
  - Real-time monitoring
  - Added installation costs of wiring
  - Limits on mounting locations
  - In dusty and humid environments, the FO cable can create a conductive ground path

- **Wireless Active (battery powered) sensors**
  - Require direct surface contact
  - Real-time monitoring
  - Can monitor any location inside the switchgear
  - Batteries have limited life-spans and this introduces additional maintenance headaches
  - Proper sensor and antenna location is essential

- **Wireless <u>Passive</u> sensors**
  - Require direct surface contact
  - Real-time monitoring
  - Can monitor any location inside the switchgear
  - Proper sensor and antenna location is essential

Asset health monitoring

Partial discharge monitoring

IEC 60270:2000+AMD1:2015 partial discharge measurements

- Direct measurement of current and voltage spikes using high-frequency CTs and HV capacitive couplers
  - Can analyze pulse shapes and plot discharge events relative to the phase of the power line waveform.
  - Expensive and require trained technicians to analyze the data
  - Coupling detectors require a ground reference and this exposes a potential failure mode and safety issue

PD dielectric breakdown causes a small, but sudden, rise in current accompanied by a current pulse, as well as electromagnetic, acoustic and ozone emissions.

IEC 62478:2016 high-voltage test techniques – measurement of partial discharge by electromagnetic and acoustic methods

- Instruments use indirect analytical measurements to obtain a relative signature of PD pulses that can indicate trends
- **TEV (Transient Earth Voltage) measurement**
  - Measure EM emissions conducted to ground (typical values 0.1mV to 1V each)
  - Cannot always monitor faults between phases
- **High Frequency (HF) and VHF measurements**
  - Operate 3-300MHz and use large antennas (not suited for switchgear) and HFCTs or coupled sensors (coupling impairs safety).
- **Acoustic measurements**
  - Use a microphone or acoustic sensor to monitor between 10 Hz and 300 KHz.
  - Wireless method
  - Limited detection range due to sound damping within dielectric materials
- **UHF measurements**
  - Monitor transient EM waves in 300MHz to 3 GHz range.
  - Selective, banded UHF monitoring allows noise rejection.
  - Band-pass UHF PD detection
    - Emission frequencies in 400-800MHz range often found in MV switchgear centered on cavity resonance.

Asset health monitoring

Circuit breaker monitoring

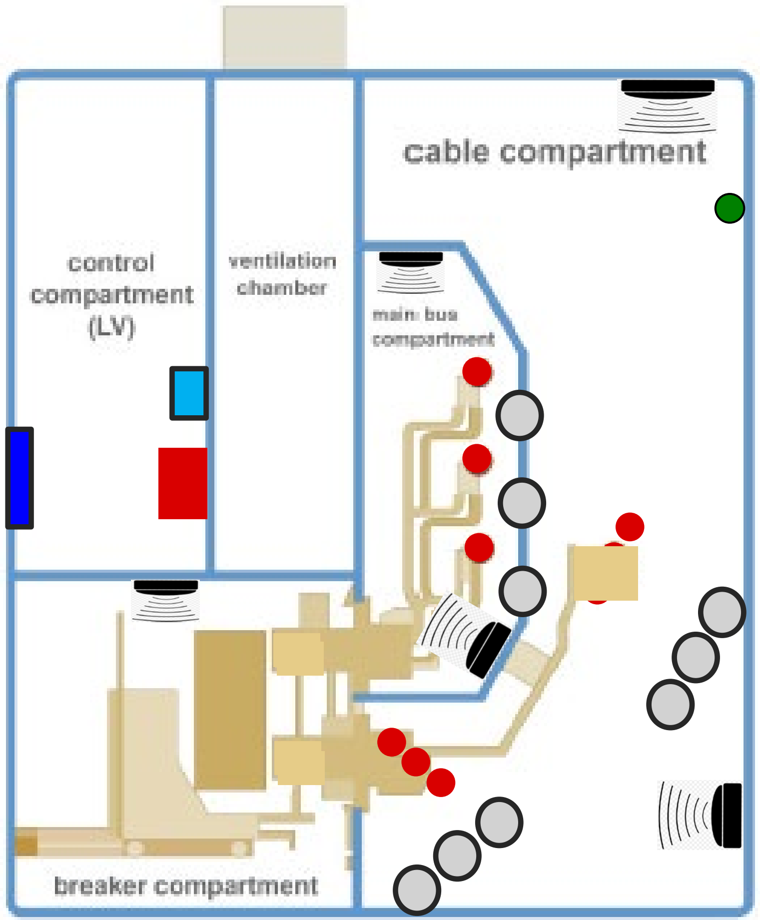
Data retrieved from relays

- Circuit breaker opening time
- Circuit breaker closing time
- Spring charging time (for spring mech breakers)
- I^2t (per phase)
- Number of operations
- Days of inactivity
- Trip coil supervision (Binary)
- Gas pressure (Binary) – for SF_6 breakers

Measurements are retrieved with no additional sensors

ANSI MV metal-clad switchgear monitoring

SwitchgearMD™ component placement



… provides MODBUS connectivity for remote display

Component
SAW sensors (placed under the insulating boot**)**
IR sensors (pointed to bus area just outside the insulating boot covering the bus joint**).**
Humidity Sensor (1 per frame**)**
Antennas for SAW sensors and PD detection (2 antennas per compartment with SAW sensors**)**
Transceiver (can connect to 6 antennas**) / Datacard**
Power Supply Unit
Local HMI (SWICOM)

Asset health monitoring

Application recommendations

- Aging equipment that may be susceptible to primary cable failures
- Remote or isolated equipment that is difficult for personnel to access
- Critical power equipment that serve processes that would be costly to shut down
- Equipment that will take long to replace
- Equipment used in unusual operating or environmental conditions that might decrease life, especially those in caustic environments
- Any new equipment where the end user wants to reduce the lifetime total cost of ownership
- Any new equipment where the end user wants to reduce the risks associated with performing bus inspections or taking bus temperature readings

Installations

Digital switchgear

Global references

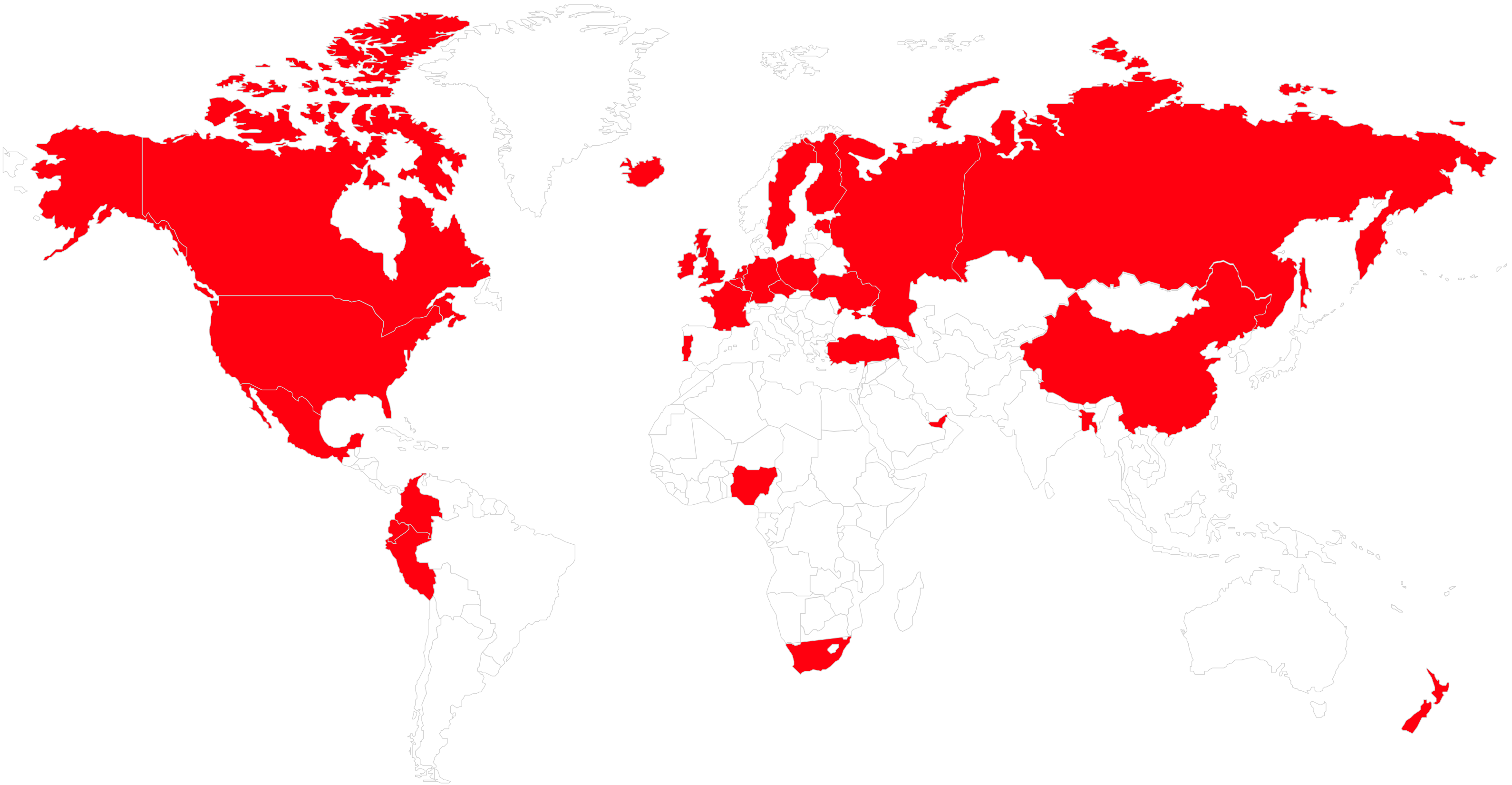
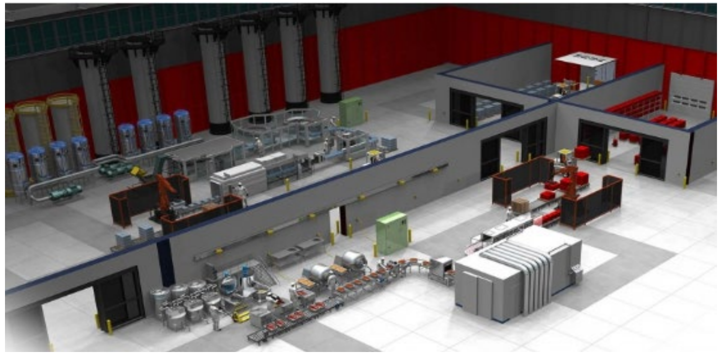


ABB has supplied >1500 Digital Switchgear panels in over 30 countries in Europe, Asia, Africa and the Americas

Digital switchgear

Reference examples in Oil, Gas & Chemical / Food & Beverage

Food & Beverage, USA



- Number of frames: 4
- Voltage level: 4.16 kV
- Commissioned: 03/2019

- Main challenge: Modernize existing and old switchgear

Major downstream company, ZA

- Number of frames: 21
- Voltage level: 3,3/6,6/11 kV
- Commissioned: 08/2015

- Main challenge: Substation usable on various voltage levels and easily movable at site

Chemical company, UK

- Number of frames: 20
- Voltage level: 11 kV
- Commissioned: 04/2016

- Main challenge: Substation usable on various voltage levels and easily movable at site

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Appendix

IEC 61850 Basics for digital switchgear

MV digital switchgear connection and protocol standards

Background of improvements

Institute of Electrical and Electronics Engineers

International Electrotechnical Commission

Ethernet 802.3 Connection Standards

1990: IEEE 802.3i – 10 Mbps

1998: IEEE 802.3z – 1 Gbps

2002: IEEE 802.3ae – 10 Gbps (Cat 6)

2006: IEEE 802.3an – 10 Gbps (Cat 6)

2010: IEEE 802.3ba – 100 Gbps

IEC/IEEE 61850 Protocol Standards

2003: IEC 61850-2 Glossary

2009: IEC 61850-6 Configuration to IEDs

2011: IEC 61850-8-1 Manufacturing Message Specification (GOOSE)

2011: IEC 61850-9-2 Sampled Values

2012: IEC 61850-10 Conformance testing

2016: IEC/IEEE 61850-9-3 - Precision Time Protocol for Power Utility Automation

Introduction to IEC 61850

Station and process bus: physical allocation

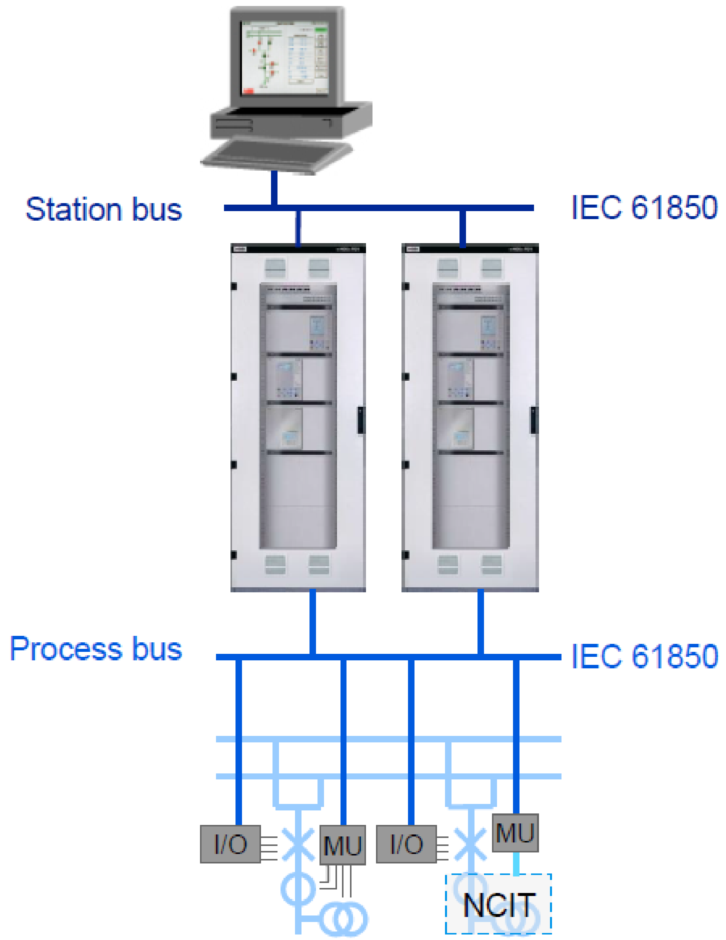
Overview

Station bus

– Serial connection between station level devices
  - E.g., station computer, network gateway, bay level IEDs like protection and control IEDs

Process bus

– Serial connection between bay level IEDs and process interfaces at the primary apparatus
  - E.g., voltage and current sensors
  - Disconnectors, earthing switches, circuit breakers



NCIT: non-conventional instrument transformer

Introduction to IEC 61850

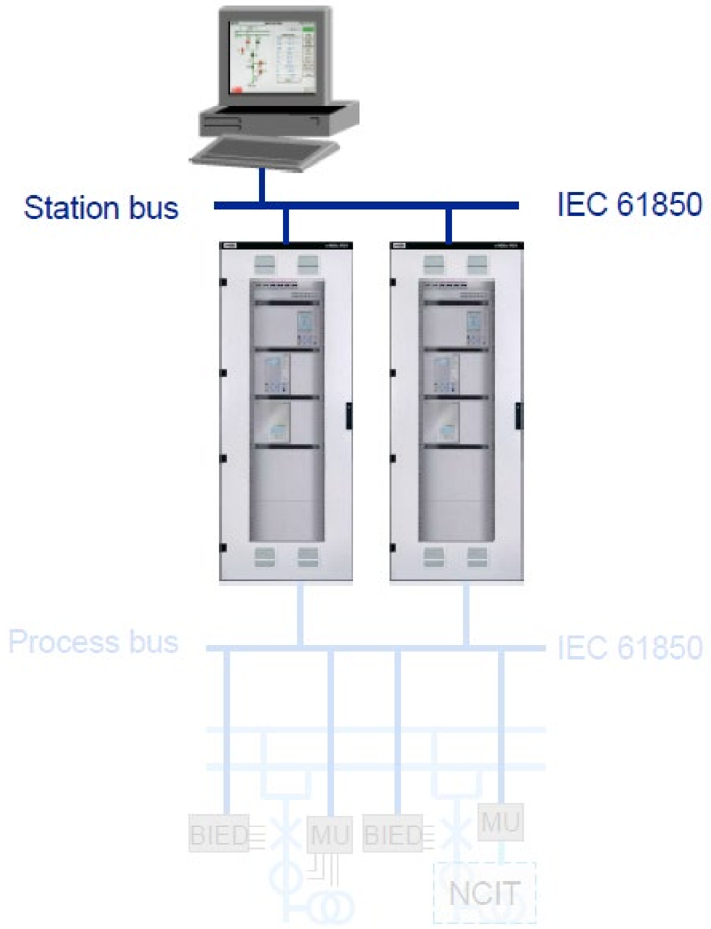
IEC 61850 services on station bus

Overview

Station bus

– Data is transferred according IEC 61850-8-1 for:

- Control service
  - Commands
- Report Service
  - Indications to IEC 61850 clients
- GOOSE service
  - Indication and information exchange between bay level IEDs
- File transfer service
  - Transmission of disturbance records



NCIT: non-conventional instrument transformer

Introduction to IEC 61850

IEC 61850 services on process bus

Overview

Process bus

– Data is transferred according IEC 61850-8-1 for:

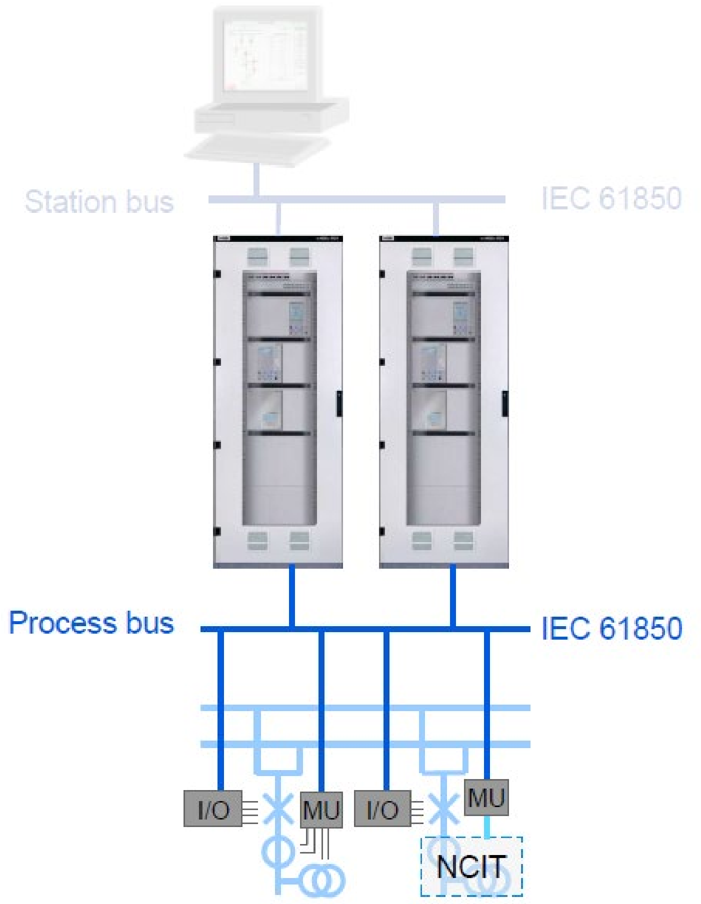
  • GOOSE service

    - Binary states like switch/CB positions
    - Trips
    - Commands

– Data is transferred according IEC 61850-9-2 for:

  • Sampled value service

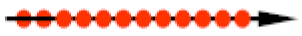
    - Sampled current and voltage measurements



NCIT: non-conventional instrument transformer

Protocol characteristics

GOOSE vs sampled measured values (SMV)

	8-1 GOOSE	9-2 SV
Characteristics	Event driven	Streaming
		
Information transmitted	Binary, Enum	Analog
Update rate	On data change Repetitive	Continous Sampling rate
Update intervals	1ms ... 1s	200-250us

Appendix

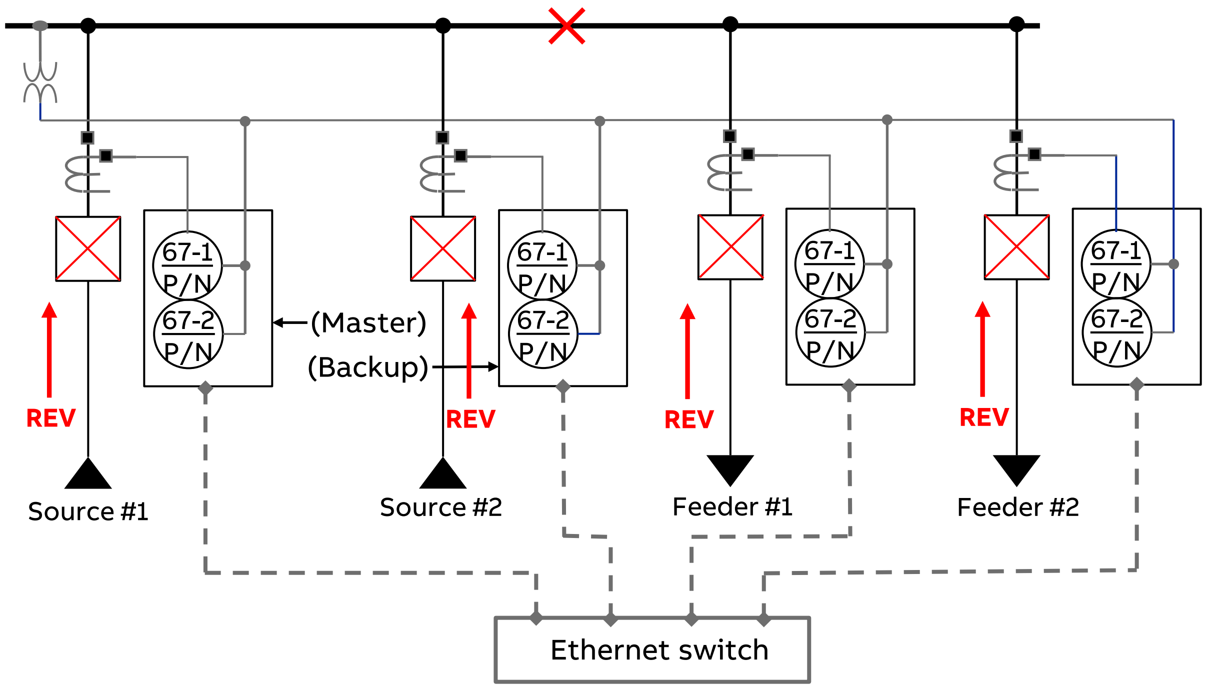
Bus protection applications

Bus protection

Principle of operation (internal bus fault)

Bus protection

- Bus fault occurs
- At least one reverse direction (REV) element is detected
- Not any forward direction (FWD) element is pending
- The “master” relay trips and block-closes all contributing breaker via GOOSE

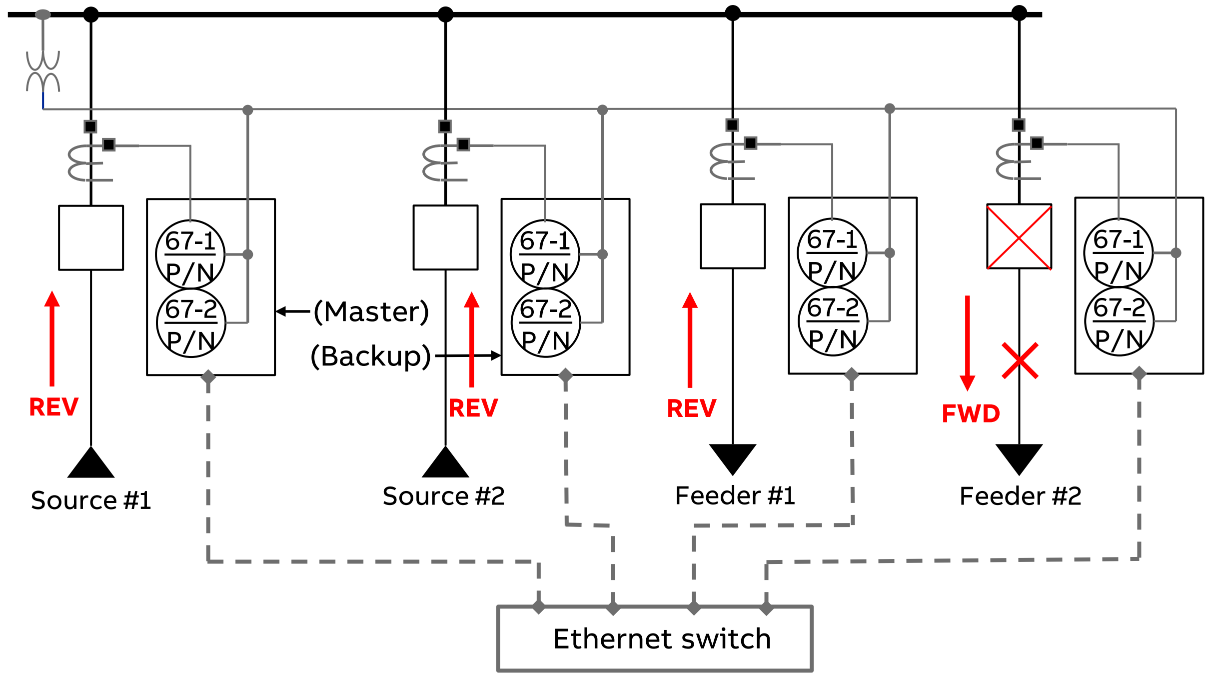


Bus protection

Principle of operation (external through fault)

Bus protection

- An external/through fault occurs, i.e., on Feeder #2
- Feeder #2 relay FWD detected
- The rest of relays either see REV or not FWD
- ONLY Feeder #2 breaker trips



Bus protection

Scheme validation testing results

Operating times for internal bus fault

Trials	Processing Time (ms)	Processing Time (cy)
1	50.50	3.03
2	51.00	3.06
3	49.70	2.98
4	55.30	3.32
5	51.50	3.09
6	51.80	3.11
7	52.10	3.13
8	55.20	3.31
9	56.60	3.40
10	54.20	3.25
Average	**52.79**	**3.17**

Operating times for external through fault

Trials	Processing Time (ms)	Processing Time (cy)
1	50.10	3.01
2	53.20	3.19
3	53.20	3.19
4	50.90	3.05
5	51.20	3.07
6	51.60	3.10
7	56.10	3.37
8	51.20	3.07
9	53.30	3.20
10	55.50	3.33
Average	**52.63**	**3.16**

Bus protection

Novel method using GOOSE messaging

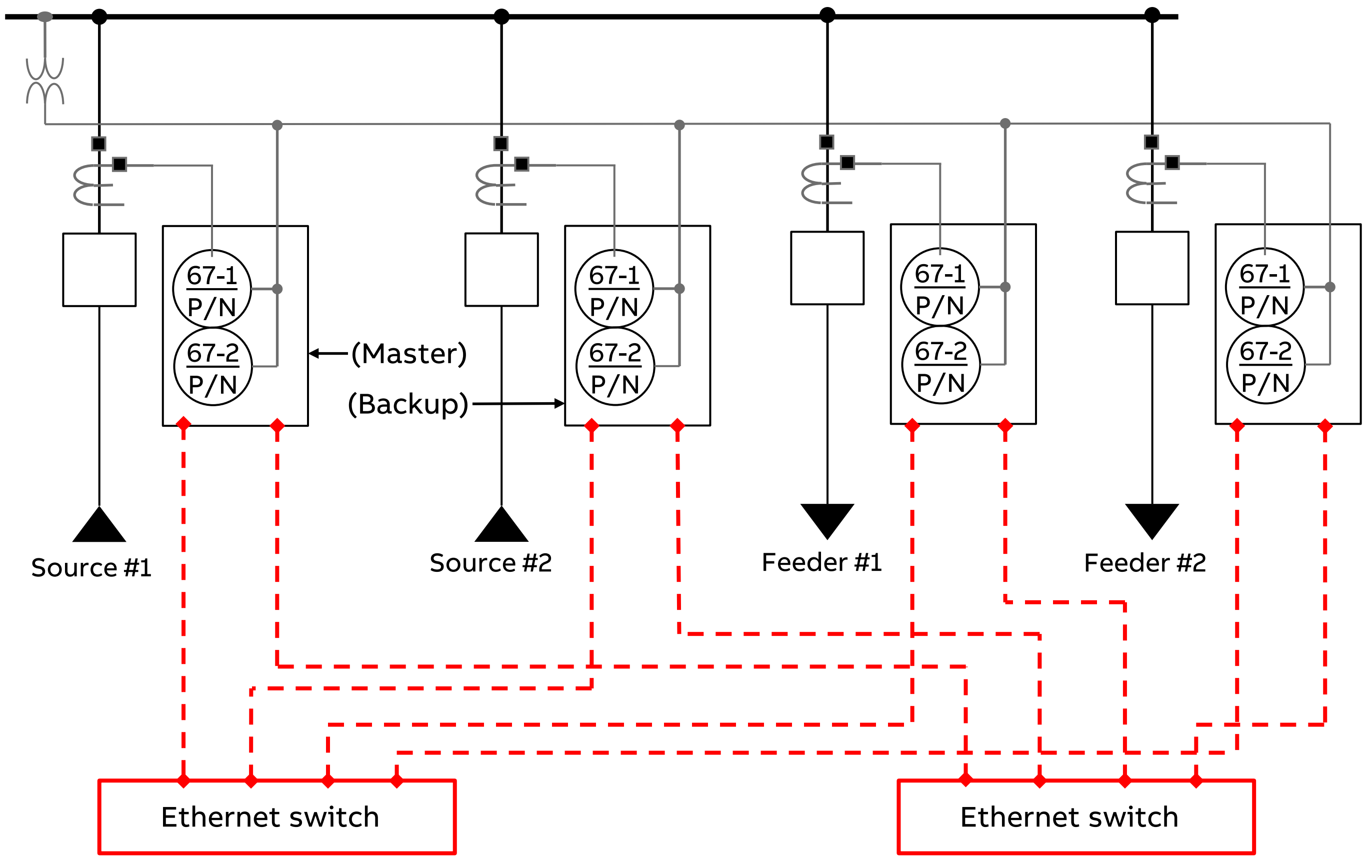
Bus protection

- Utilization of directional overcurrent elements of feeder protection relays
- Dedicated bus protection relay and associated current transformers are **not required** (reduces footprint)
- Reliable: operates only upon a fault on the protected bus
  - All contributing breakers are tripped and block-closed
  - Acceptable operating speed ~3.16 cycles (50.5 ms)
- Secure: able to distinguish between internal and external (through) faults
  - Allows the individual breaker to trip first to maximize system reliability

Bus protection

Communication redundancy

- IEC 61850 Ethernet Redundancy – HSR High-availability Seamless Redundancy (self-healing ring)
- IEC 61850 Ethernet Redundancy – PRP Parallel Redundancy Protocol (double star network).
- Supports IEEE 1588 V2 precision time protocol (PTP) high-accuracy time sync of **1µs**



Appendix

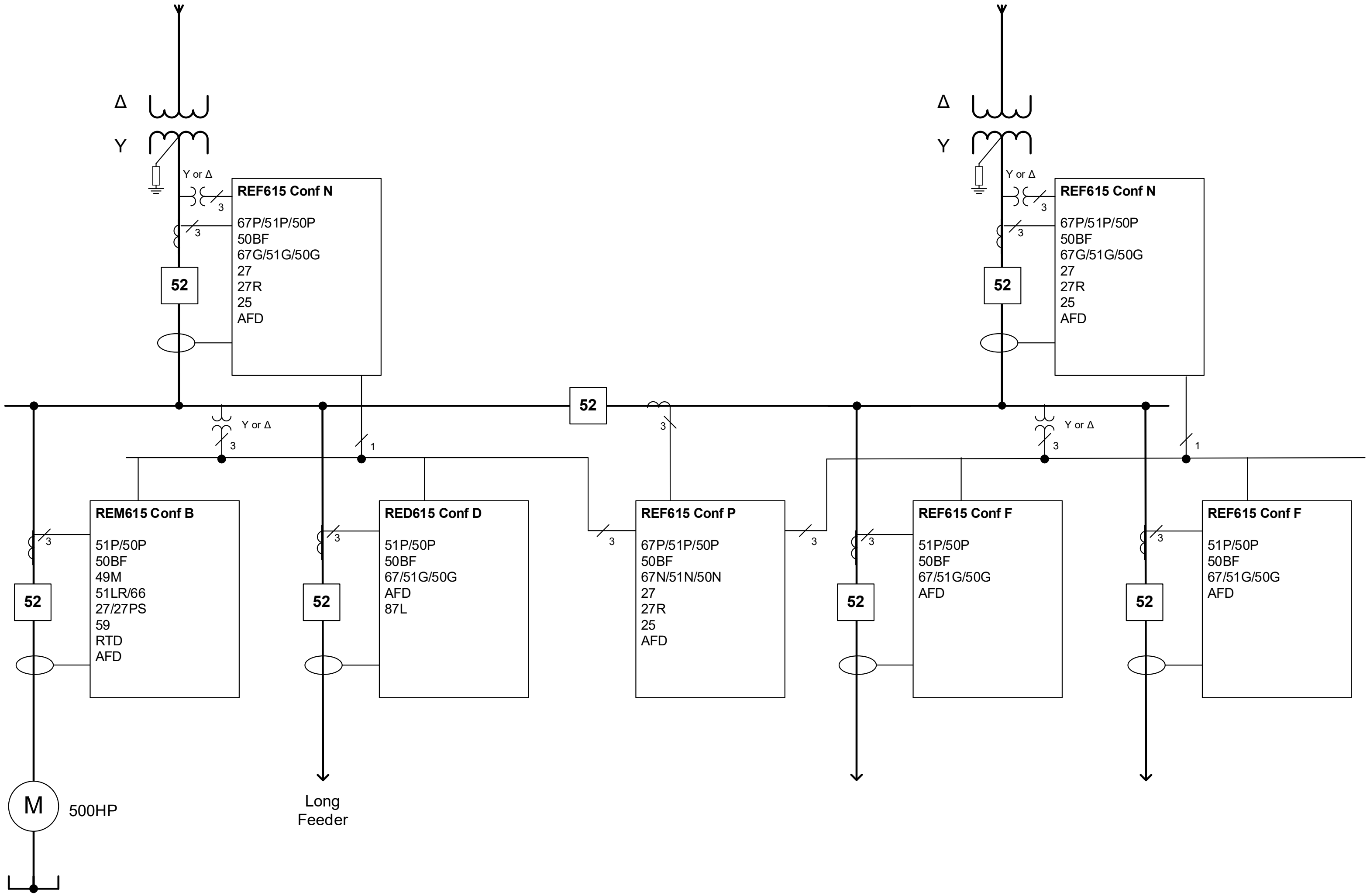
Application areas from components to solutions

Single-line diagram applications

MTM Configuration
Loads – 500HP motor, long feeder, secondary selective substations/ low voltage switchgear

Without digital switchgear - extensive wiring of I/O for controls, PT wiring between cubicles for bus voltage monitoring.

Ferro resonance on PT's, CT saturation studies.

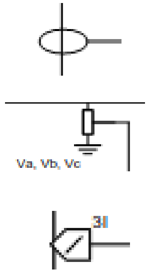


Bus protection application

Relays that support IEC 61850-9-2LE provide real-time sharing of information accurate enough for protection and control.

In this example, voltage samples are shared at rate of 80 samples per cycle for protection. Bus-bar protection can be achieved using Zone Selective Interlocking (ZSI) scheme through GOOSE messaging.

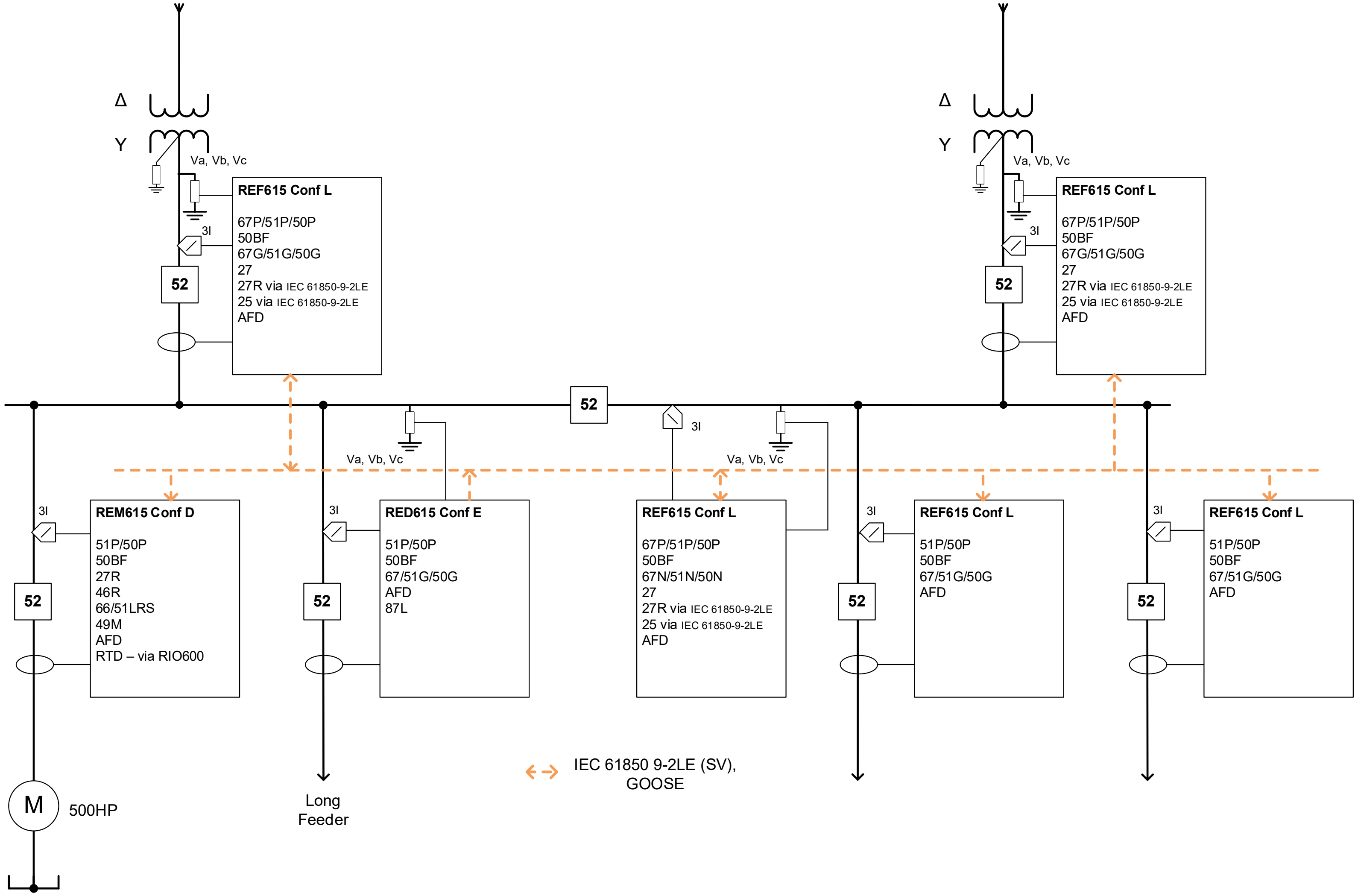
Sensors are immune to CT saturation and ferroresonance.



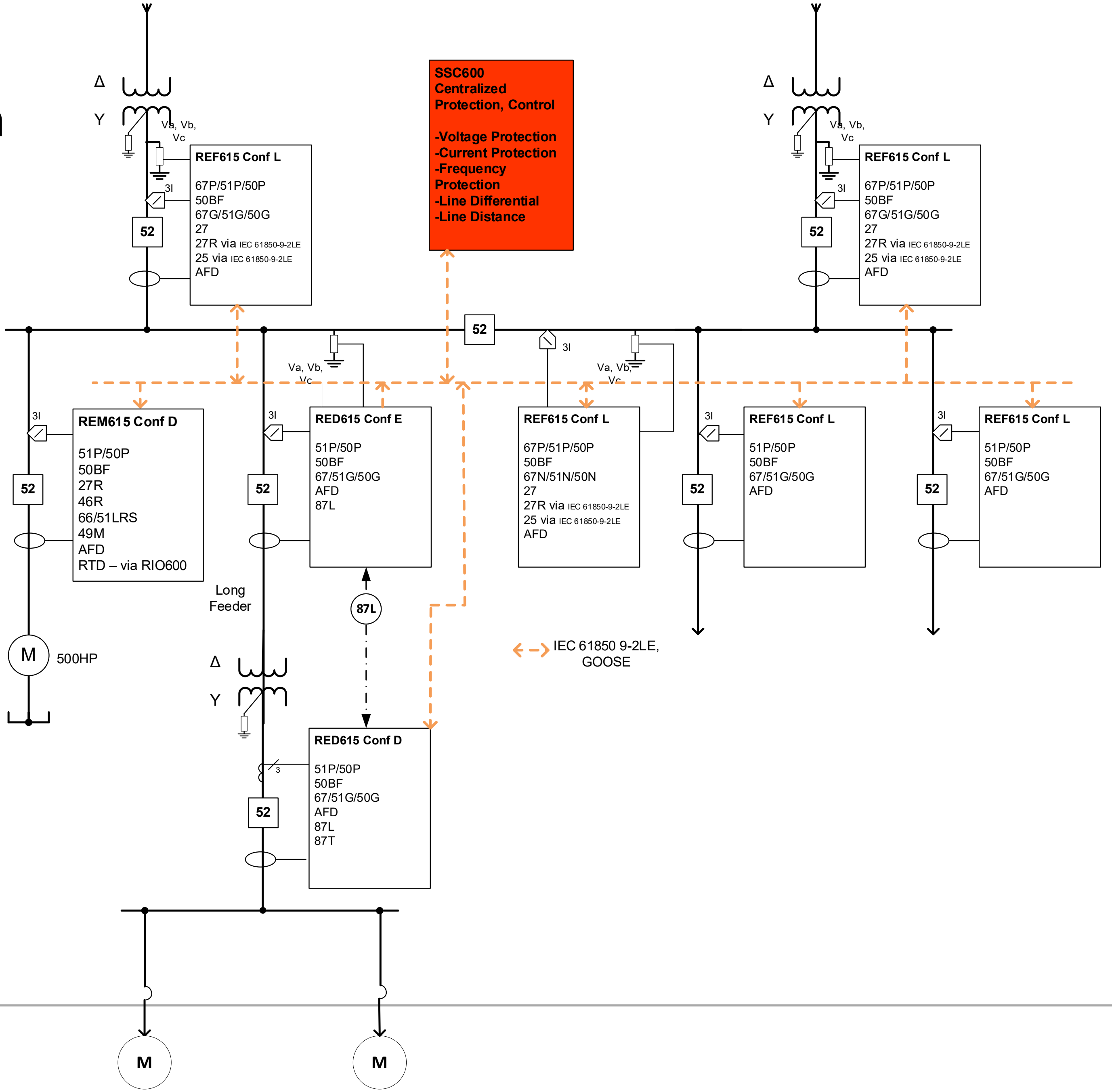
GFCT

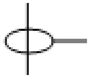
Voltage sensors

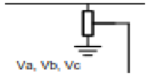
Current sensors



Line protection application




GFCT

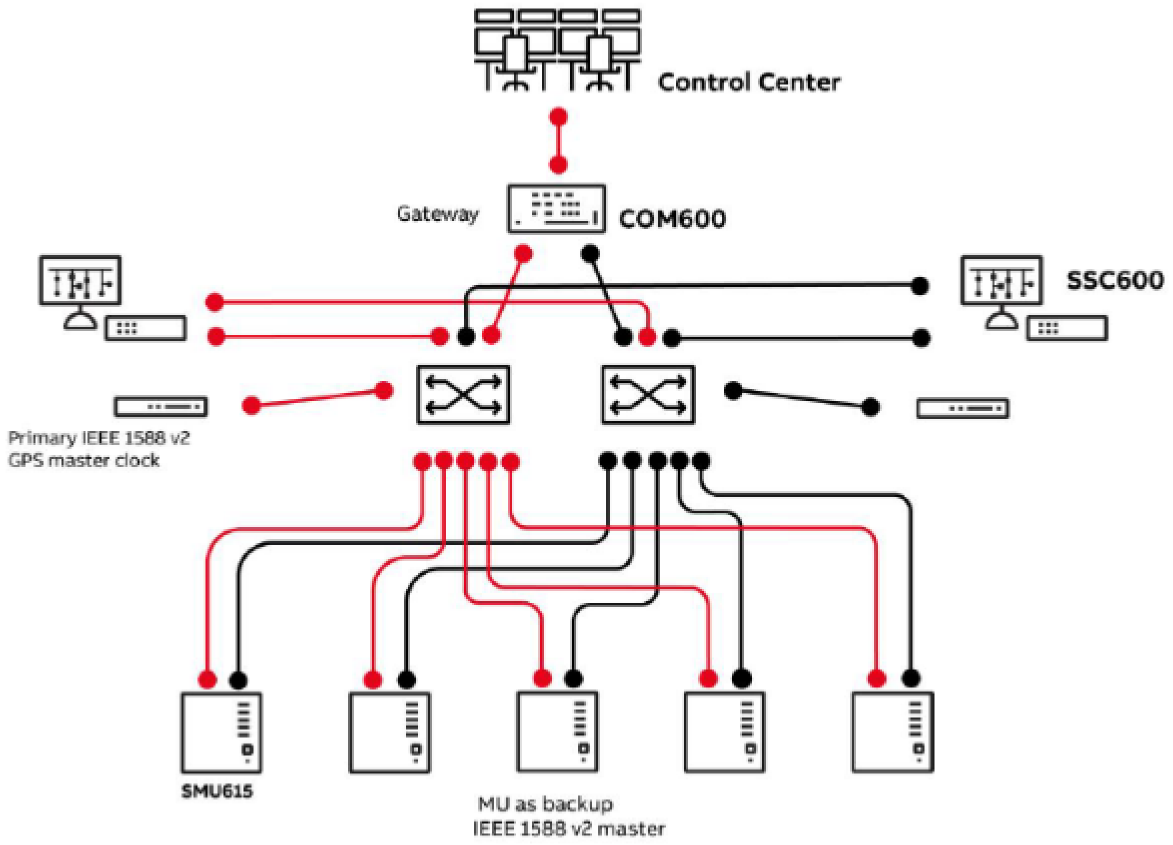


Voltage sensors

Current sensors

Smart substation control and protection

- Centralized, protection and control in one single device at a Substation level for reduced network complexity
- Ease of adding additional functions, changing protection philosophy after commissioning of apparatus
- Back-up protection provided by individual merging unit relay in switchgear
- Lower total cost of ownership of “protection and control system”
- Fully modular software for maximum flexibility during the entire lifetime of the substation
- Parallel Redundancy Protocol (PRP) provides additional redundancy in communication and protection scheme



Smart substation control and protection

Base protection functionality

- Overcurrent
- Earthfault
- Fault recorder
- Switchgear control
- Voltage
- Frequency

Power transformer protection

- Protection for two winding power transformers

Machine protection

- Protection of asynchronous machines

Power quality measurements

- Current and voltage distortions
- Voltage variation
- Voltage unbalance

Feeder/line protection

- Extensive earth-fault protection
- Fault locator
- Distance protection

Interconnection protection

- Protection of interconnection points of distributed generation units

On-load tap changer control

- Position indication
- Voltage regulation
- Line drop compensation

Arc protection option

- Protection against arc flash
- Light sensing in merging units

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