Digitalisation of Transmission Substations:

- emphasis on protection and automation

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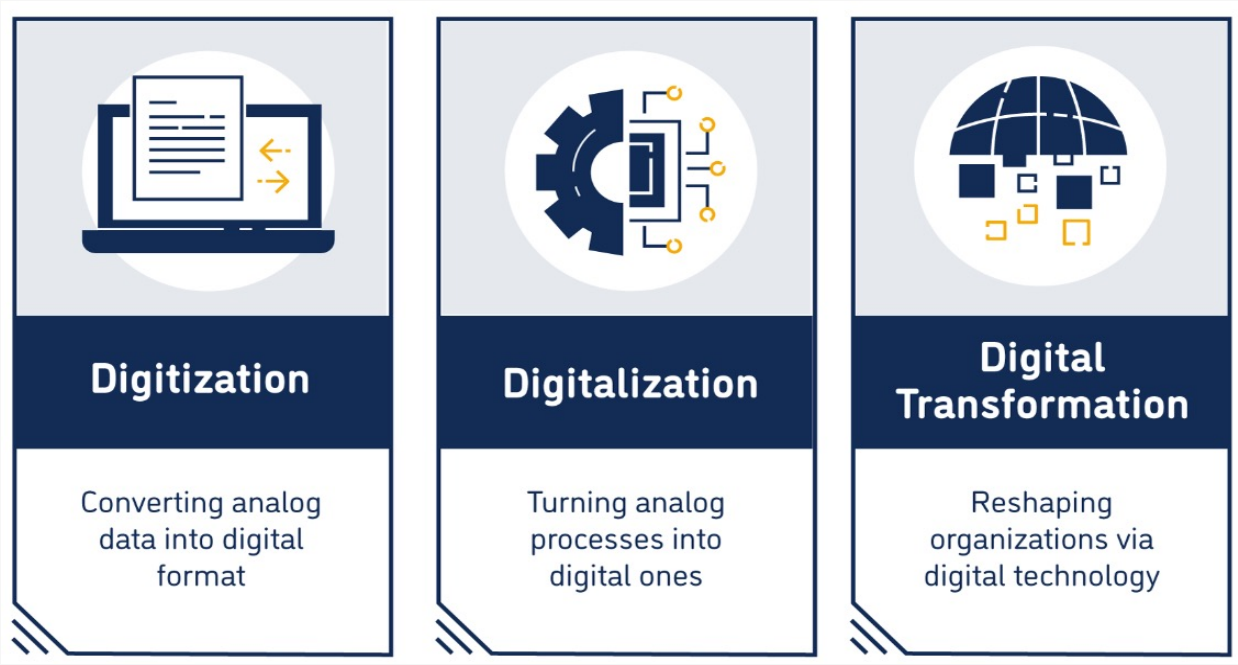
Digital Revolution?

- All aspects of our lives have been reshaped by the Digital Revolution.
- It affects every part of our existence from birth to death:
  - how we manage our lives, communicate, work, acquire knowledge, consume entertainment, travel, relax and has an increasing impact on our mental and physical health.



https://www.channelinsider.com/business-management/digitization-vs-digitalization/

What is Digitisation?

Digitisation is the process of converting analogue data and information into a digital format.

- Involves capturing and representing physical or analogue signals as a series of discrete numerical values that can be easily stored, processed and transmitted using digital technologies.

Digitisation consists of three steps:

- Sampling and quantisation: Analogue signals are captured at regular intervals and converted into a numeric representation that maintains the useful information in the original signal.
- Signal manipulation: Once in digital form, the data can be easily manipulated, edited and enhanced using various software tools and algorithms.
- Storage and transmission: Digital data can be stored on hard drives, solid-state drives, or cloud-based storage platforms, as well as being transmitted over the Internet.

Digitisation revolutionized numerous industries, from entertainment to healthcare and finance.

- Converting analogue data into a digital form, allows organizations to unlock numerous benefits, including improved accessibility, enhanced data management, and increased efficiency.

What about substation voltage, current, power, phase, frequency data?

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What is digitalisation?

Digitalisation involves using digital technologies and data to transform steady-state operations, extreme events, simulator models, processes and human machine interfaces to create new values for employers, managers, employees, customers and users.

Benefits of digitalisation include:

- **Everyday efficiency:** automation of repetitive tasks and streamlining of various business processes, leading to increased productivity and efficiency.
- **Business benefits:** organisations can enhance their operations, reduce costs, and unlock new revenue streams.
- **Information transmission:** Digitalised information is more easily shared, accessed, and analysed. Which leads to improved collaboration, decision-making, and business agility.

Digitalisation is a step towards **digital transformation**, as it helps organizations become more adept at leveraging digital technologies to improve their operations and offerings.

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What is digital transformation?

Digital transformation goes beyond digitisation of data or optimisation of processes.

- It is a fundamental shift in how an organisation operates, leveraging digital technologies to create new or significantly improved business models, customer experiences, and internal capabilities.
- Digital transformation is a strategic, multifaceted initiative that encompasses changes in an organisation's culture, structure, processes, and governance.
- It involves adoption of technologies, such as artificial intelligence, big data, cloud computing and the Internet of Things (IoT), to drive innovation, enhance customer engagement and increase operational efficiency.

What does this mean for the electric power industry ?

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What is digital transformation?

Key components of an organization's ability to digitally transform success include:

- **Comprehensive strategy:** Digital transformation needs a well-defined, organization-wide strategy aligning digital technologies with core objectives and value propositions.
- **Ability to satisfy customer and user expectations:** Employees and wider society expects companies to offer seamless digital solutions that satisfy their expectations.
- **Tech drivers:** Rapid technological advancements, including artificial intelligence, big data analytics, and the Internet of Things, creates new opportunities for companies to transform their operations and better serve the wider community and their customers.
- **By embracing the digital transformation**, organizations stay ahead of the curve, improve competitiveness, and position themselves for long-term success.

How important is "Digital Transformation" in delivering a Net-Zero future?

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Digitisation vs Digitalisation vs Digital Transformation?

Is a digital twin that uses big-data, AI and cloud computing to monitor, protect and control the operational behaviour of a single item of power plant (e.g. transformer) digitalisation or digital transformation?

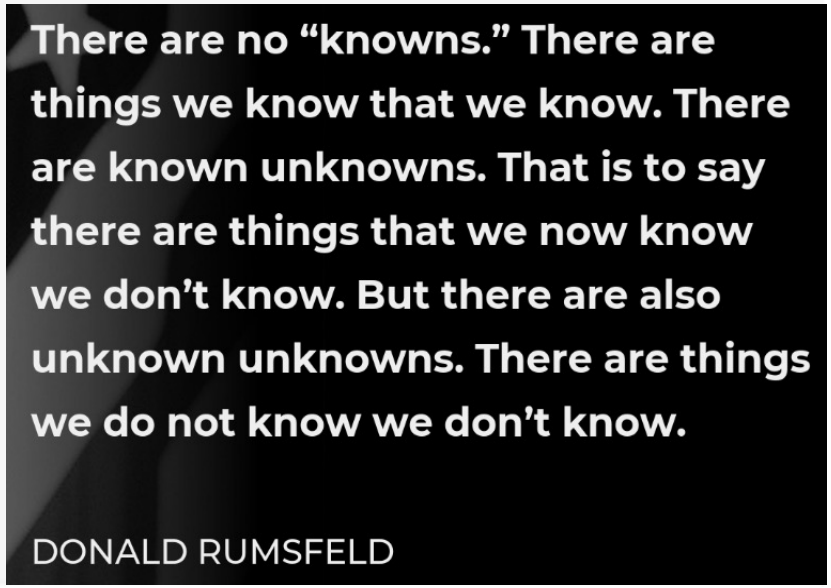
Problem: 99% of “real” big-data used to train a plant-twin is from healthy equipment.

Is the data good enough?

Do we trust models & simulators to generate realistic data from high impact low probability events ?

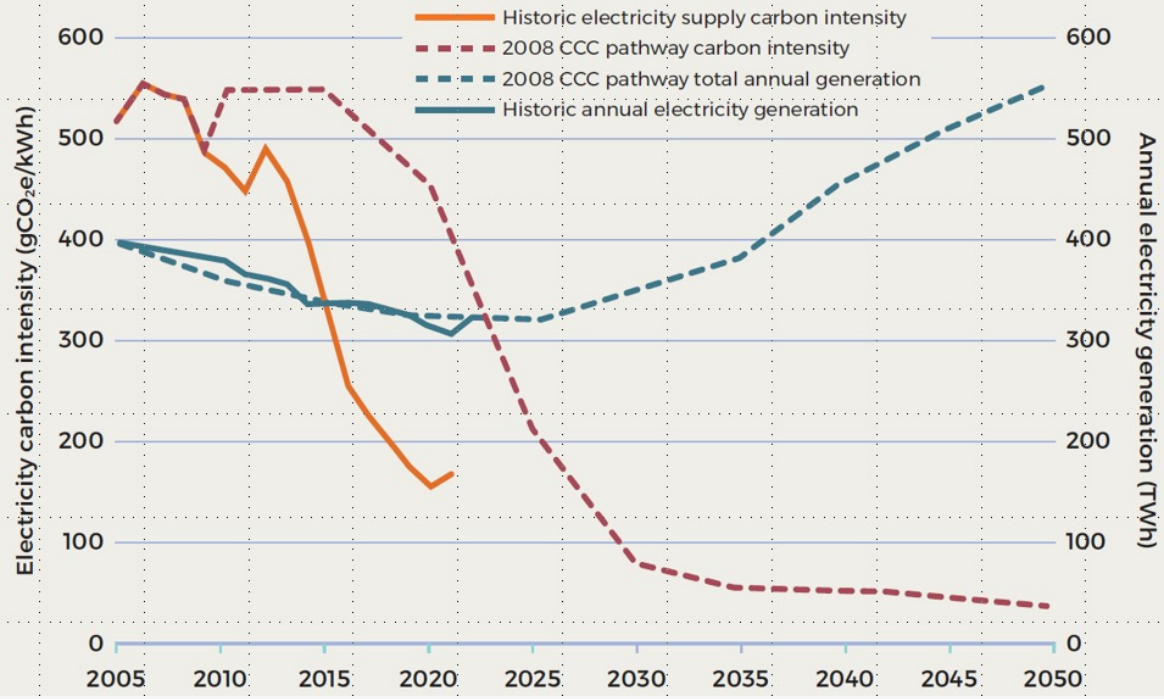
Are our models & simulators good enough?

What happens if we fail to ask the right questions of our simulators?



Extracts from “Rapid decarbonisation of GB electricity system” July 2024

“A more flexible, digitally enabled system” “Transforming the system to be digital-first in a cyber-secure way is essential to supporting and managing a more complex, distributed, renewable-based system, while enabling the public to engage with the system more flexibly, benefiting the grid and saving consumers and government money. Data needs to be shared effectively and developed actively to be a major engine of acceleration.”



Progress in decarbonising the GB electricity system has been faster than the Climate Change Committee’s original 2008 pathway, with reduction in consumption because of efficiency improvements and a faster fall in carbon intensity.

In 2023, 55% of generation was low-carbon and carbon-intensity had fallen by 70% since 2012.

Electricity decarbonisation in the UK | Strategy recommendations (raeng.org.uk)

Extracts from “Rapid decarbonisation of GB electricity system” July 2024

- “Digitalisation is an essential enabler both of the transformation process and of the future energy system itself.”
  - “It can support planning, decision making, and project execution for the transition.”

- “In the resulting, highly diversified electricity system, it is strategic digitalisation which will provide the granular, near real-time understanding of system performance and the automation and system control needed to optimise use of existing capacity, reducing the need for new construction, deliver better resilience, as well as enabling more efficient operations and condition-based maintenance.”

- “Digitalisation will be the basis of new customer offerings, allowing consumers to engage at device level and flex their demand according to price signals, saving themselves money whilst supporting a better-balanced, lower-cost, more resilient electricity system.”

Will home owners invest in digitalisation to make their assets “smart” and automatically capable of reacting to local “energy” price signals?

Future Power Systems and need for Digital Transformation?

- Networks are evolving into complex, low-inertia, bi-directional systems where most of the sources are intermittent renewables and loads are extremely volatile.
  - Complexity further compounded by electrification of heat and transport

- Smart grids, enabled by digital technologies will enhance the efficiency, reliability, resilience and sustainability of our electrical energy systems.
  - What about affordability and ensuring smart grids and digital transformation benefits all

- These intelligent networks will fully integrate intermittent renewable energy resources, manage demand response and provide the resilience to self-heal during disturbances.
  - Building level energy storage will enable demand flexibility & minimise economic costs
  - T&D connected energy storage needed to provide system resilience, but at what cost?

- Growth in HVDC Interconnections between non-synchronised systems, i.e. GB to EU etc.

- What is the future of “continental” energy interconnectors,
  Europe - Africa, Europe - Asia, America – Asia, North – South – East – West Asia?

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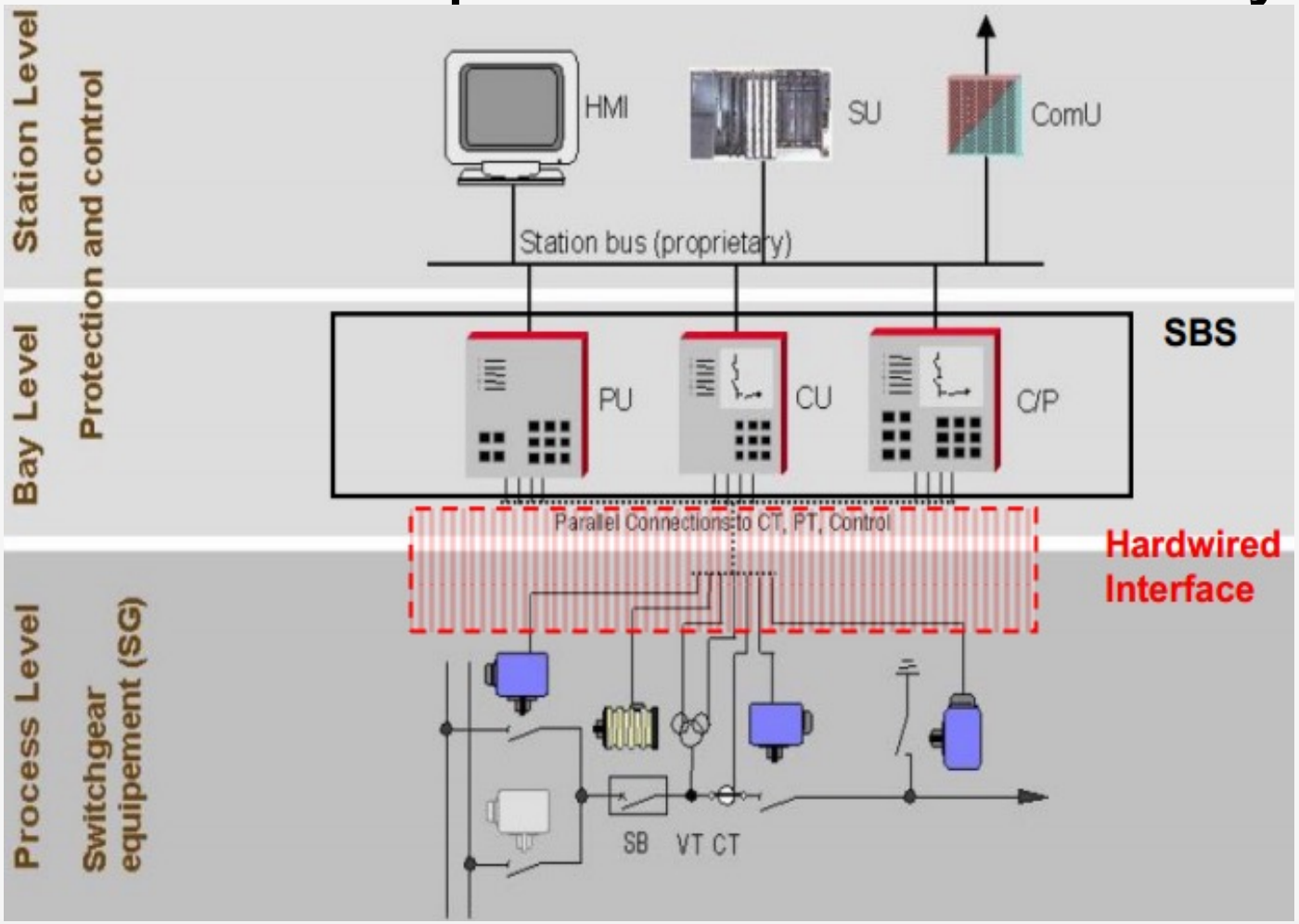
Legacy substation protection & control systems:



IEC 61850 Introduction:

- IEC 61850 standardises the process that enables Intelligent Electronic Devices (IEDs) from different vendors to communicate with each other.
  - standard proposes a LAN using Ethernet to replace the hardwired cabling system.
- IEC 61850 defines three levels in the substation automation system (SAS) architecture, namely process level, bay level, and station level.
  - data exchange between different levels realised using station bus and process bus.
- In an IEC 61850 based substation with process buses:
  - V&I signals are digitised as sampled values (SVs) using Analogue Merging Units (AMU).
  - Binary input signals (circuit breaker open/closed, disconnector open/closed and tap position) are sent from primary equipment to IEC 61850 compliant numerical protection and control devices using Digital Merging Units (DMU).
  - Binary output signals (CB trip or reclose signals, disconnector open/close signals and control signals etc) are sent from IEC 61850 compliant numerical protection and control devices to primary equipment using Digital Merging Units (DMU).
  - Manufacturers often merge AMU & DMU functions into a combined merging unit (CMU).
- Generally one or two process buses are associated with a transmission bay, but an inter-bay process bus may be used for transfer of SVs between bays.

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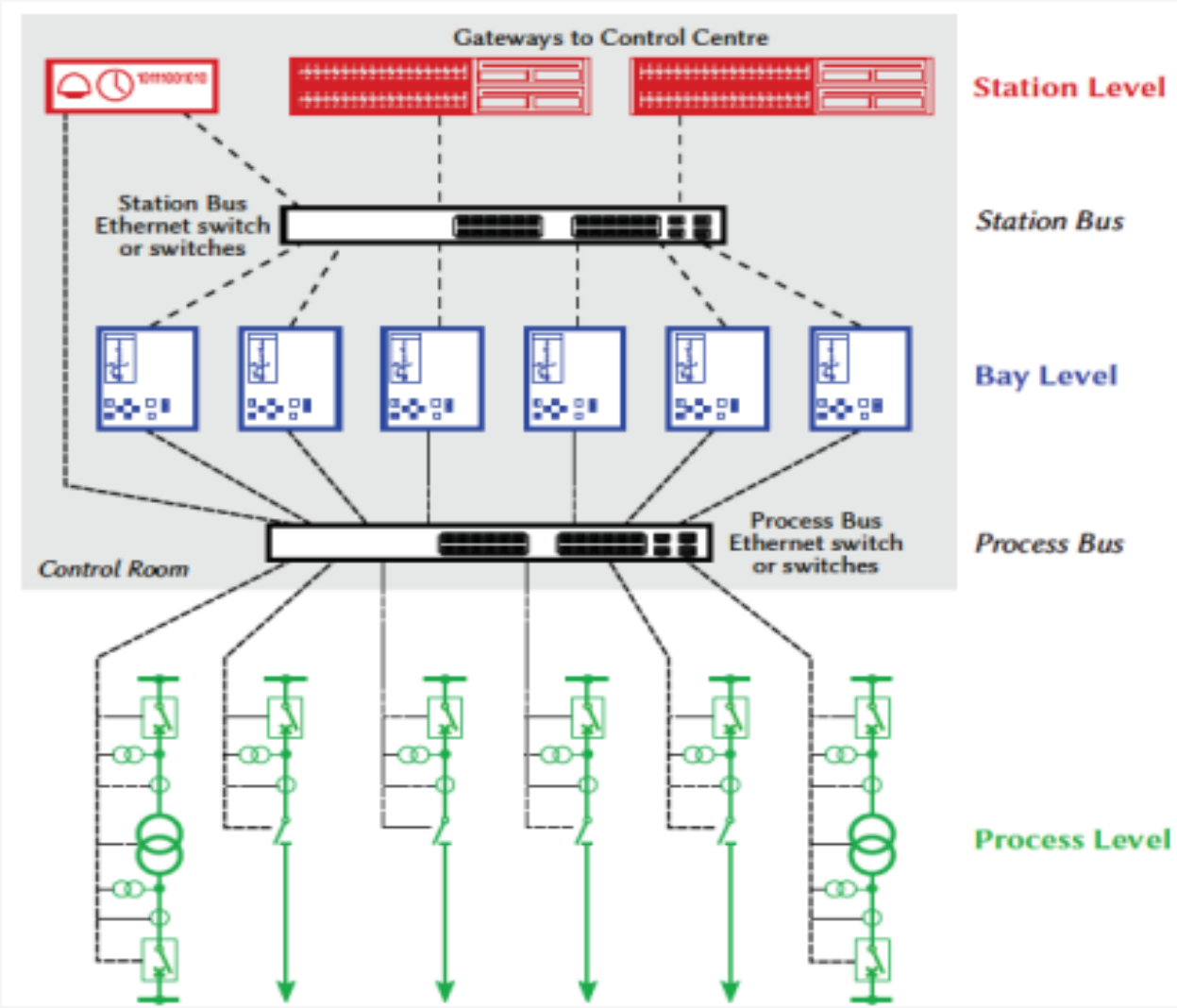
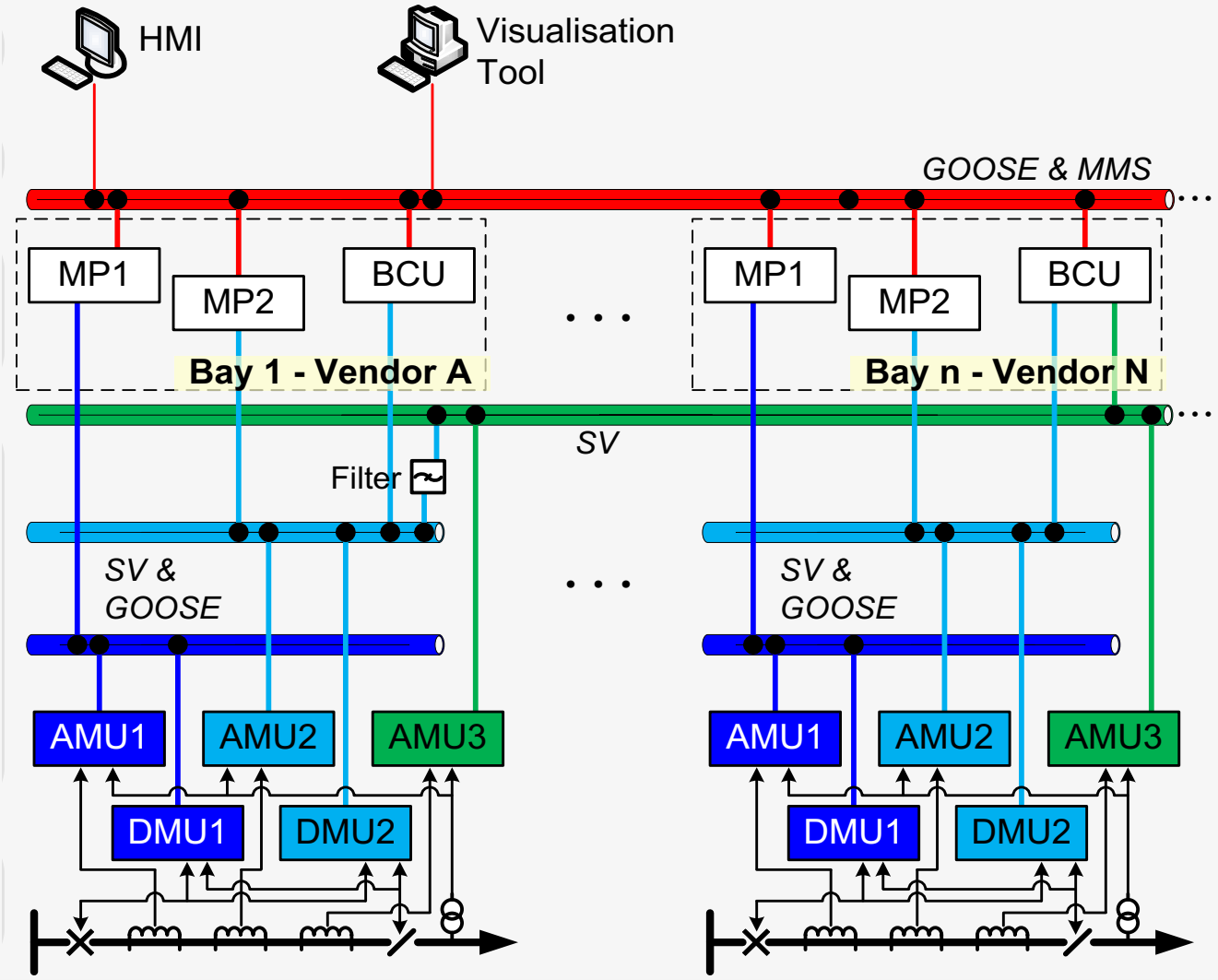
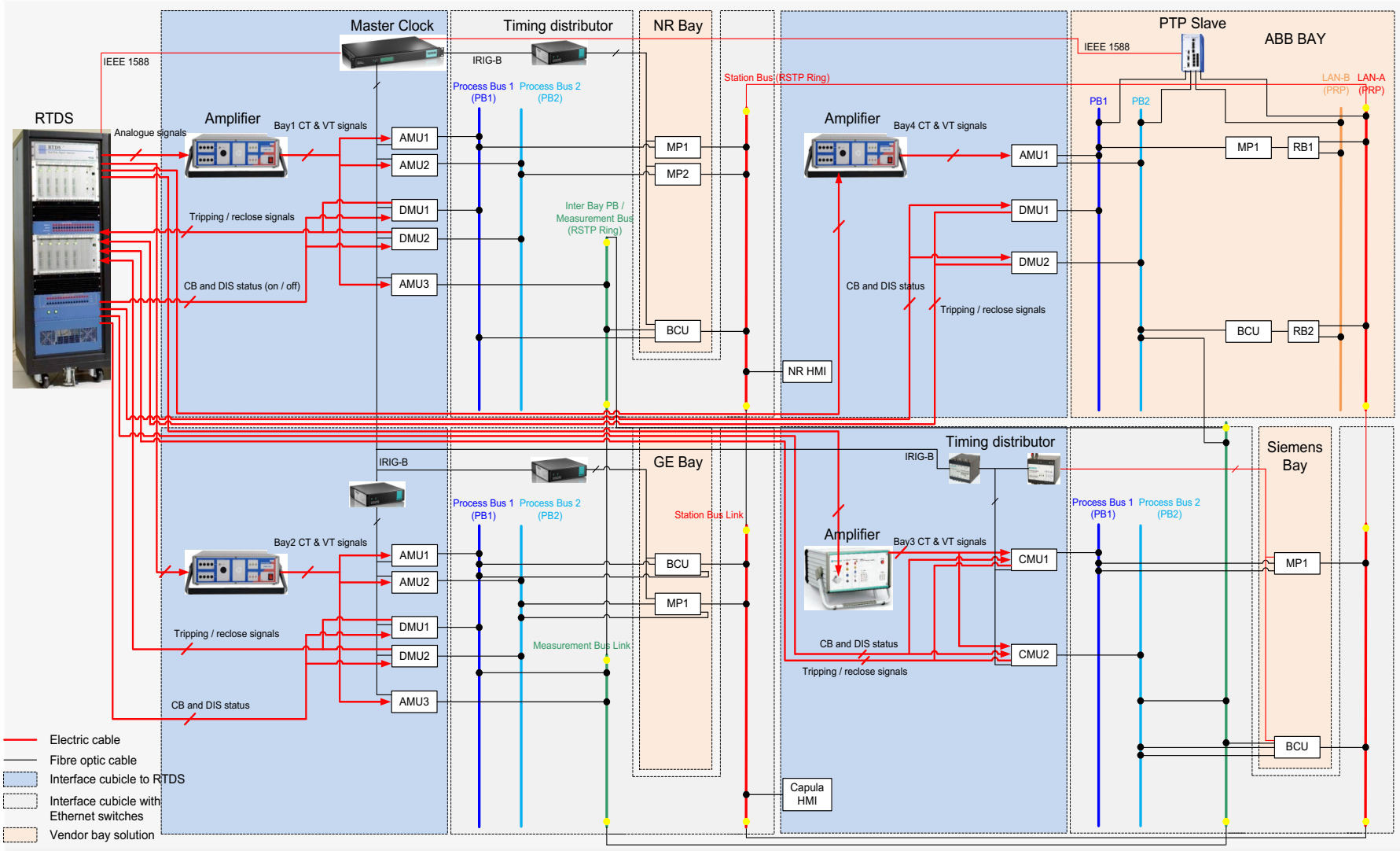
Structure of IEC 61850 substation secondary systems:



Multi-Vendor IEC 61850 Test Platform: Manchester Lab Arrangement





Manchester Multi-Vendor Test Platform – Overview

IEC 61850 substation:

- Digital measurement values are transmitted via optical fibre based Ethernet communication networks to subscribing IEDs, each implementing Protection And Control (PAC) functions.
- Process buses increase the flexibility and functionality of the substation secondary systems and make future expansion and retrofitting easier to implement.
- Ethernet communication offers immediate reduction of cabling cost, and removes the safety hazards associated with having open circuits connected to instrument transformers.
- Standardised system; products from different vendors with “plug and play” features.
- Availability of voltage / current measurements is greatly enhanced by multicasting over Ethernet compared to point-to-point connection in the conventional substations.
- IEC 61850 substations are more suitable for implementing advanced PAC functions.
- Secondary system in an IEC 61850 substation can be more easily upgraded than existing substations that use propriety equipment and communication systems with copper wiring.

IEC 61850: impact on Substation Automation Systems:

- Substation automation systems (SAS) in accordance with IEC 61850 are gaining popularity and will dominate future substation design.
- IEC 61850 offers a ‘future-proof’ solution for the protection, automation and control (PAC) systems with cost reduction in design, operation and maintenance.
- IEEE 1588 Precision Time Protocol (PTP) is being used in IEC 61850 substations due to its sub-microsecond accuracy over Ethernet, which satisfies the accuracy required by sampled value (SV) process bus and other advanced PAC applications.

- However, many utilities still think PTP is not a fully-matured technology ?
  - Propagation delay variations of PTP messages caused by network traffic are sometimes suspected of resulting in unacceptable timing errors.
  - Substation engineers also require understanding of the PTP timing principle and the characteristics of network devices to operate and maintain the system.
  - System operators need confidence that intrinsic data flow interactions in well-designed substation automation system does not degrade time synchronisation.

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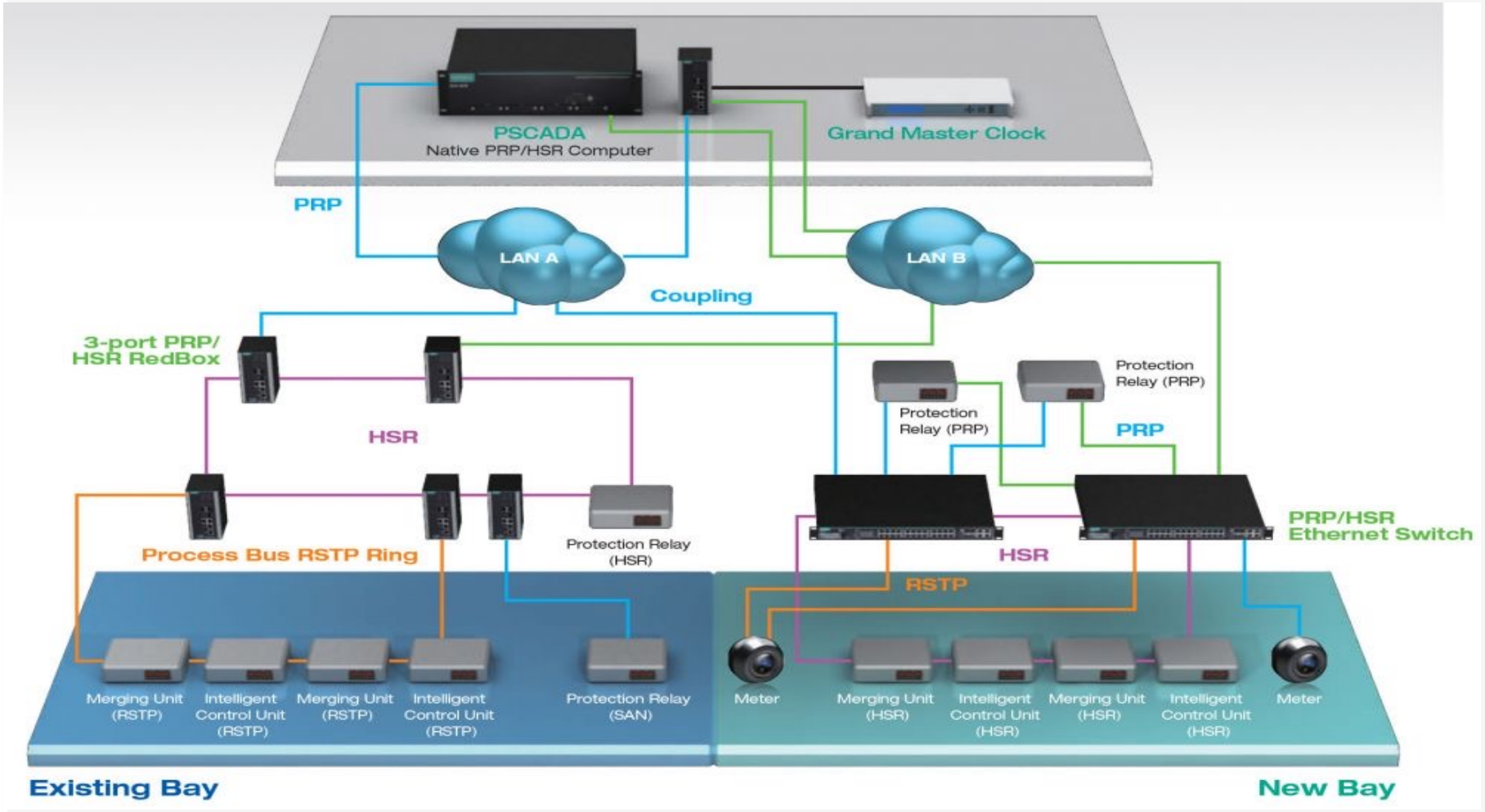
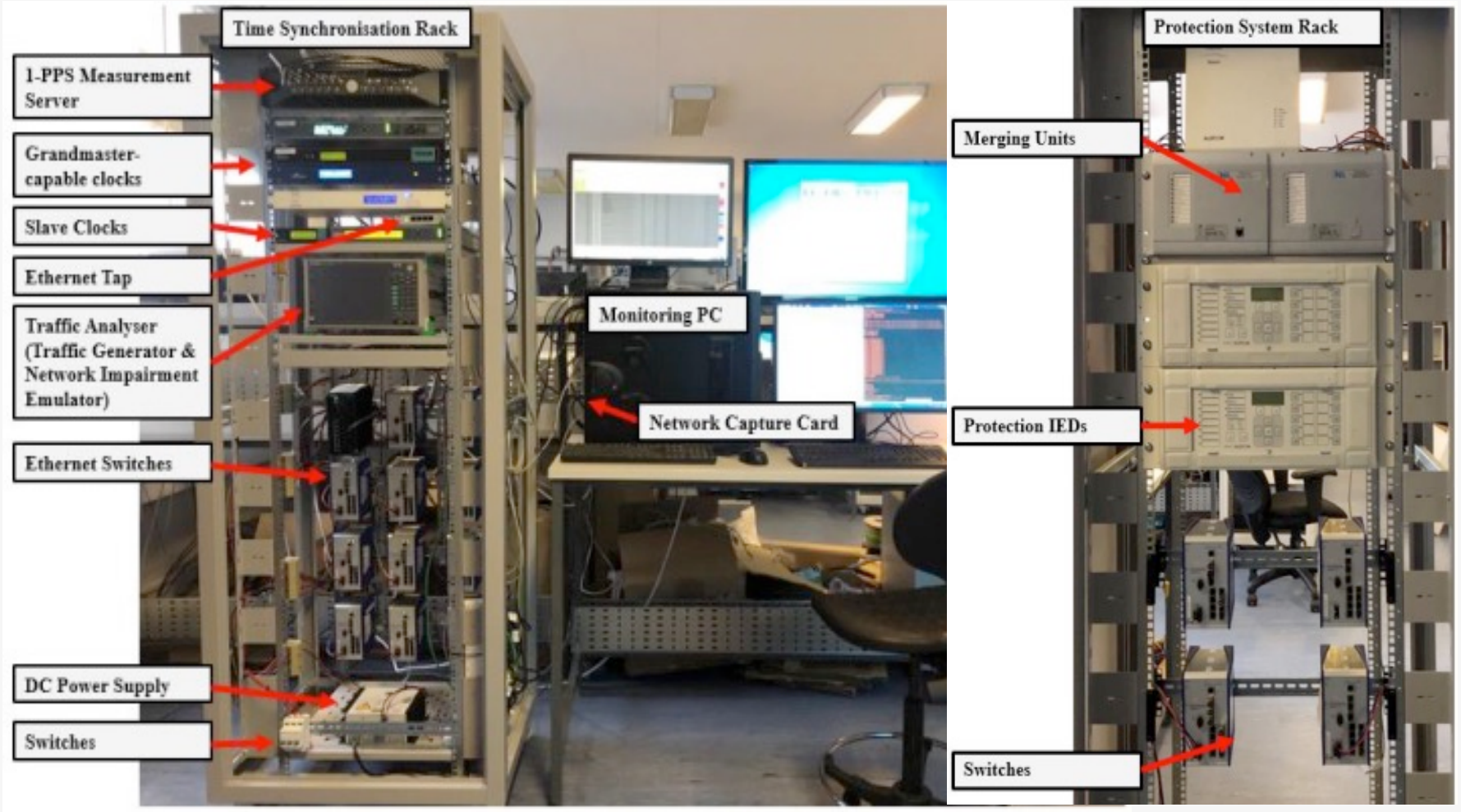
IEC 61850 Substation Communication Networks



Test System: (a) time synchronisation rack & monitoring system, (b) protection system rack:



Thanks.

Hopefully I have inspired you about the opportunities available in Power System Protection and Automation.

Raised many questions and partially answered a few.

Now we move to the Q&A session!