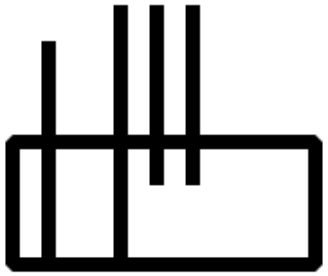
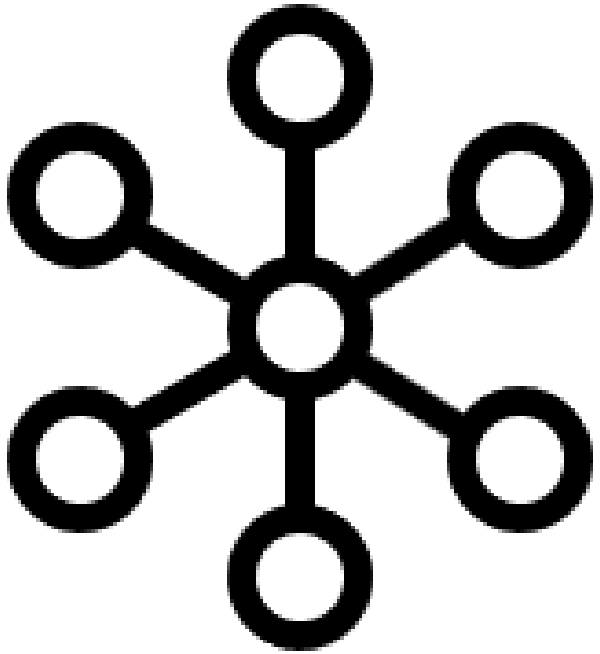
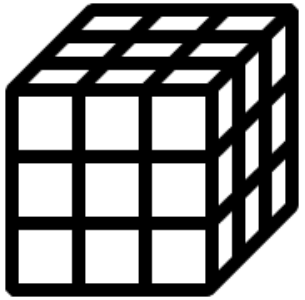






ABB, MARCO NUNES, 7.11.2022

Protection virtualization technology: the utilities revolution

History, technology and applications

CIGRE2022 - Croatia

Protection virtualization technology: the utilities revolution

Introducing Hybrid Protection and Control

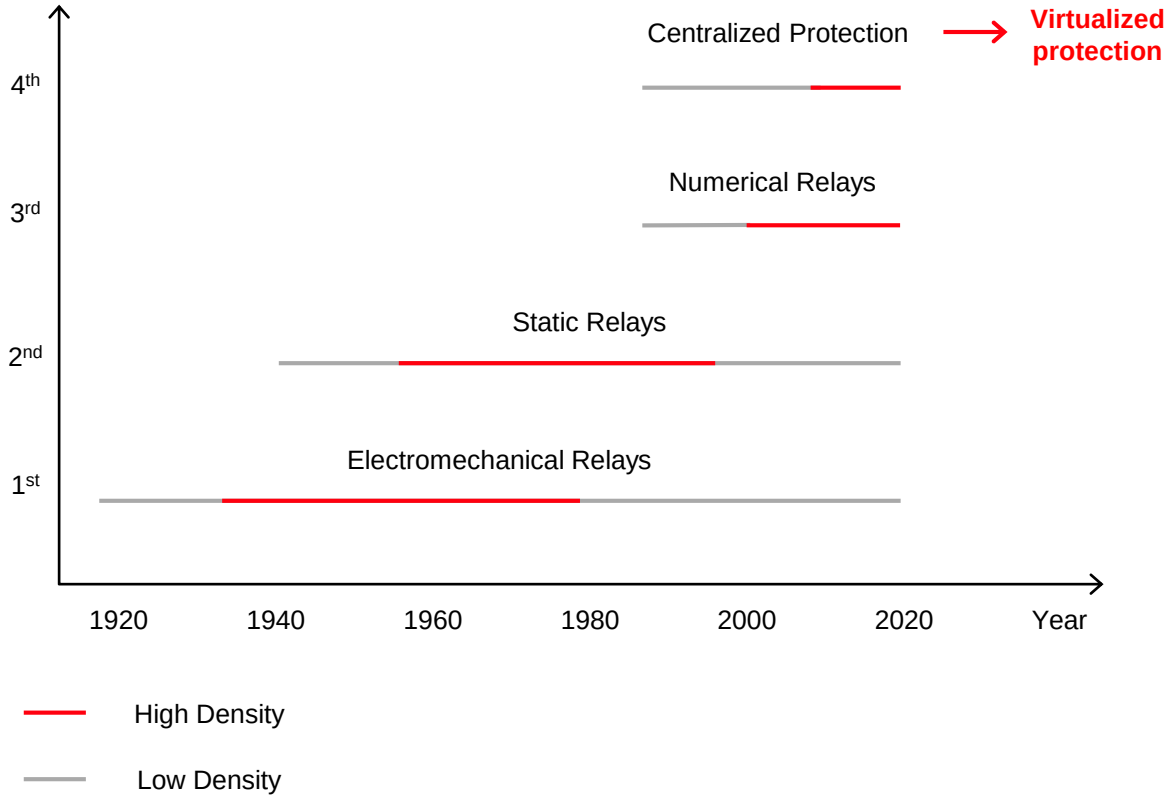
PROTECTION RELAY HISTORY – TECHNOLOGIES

History of Centralized Protection and Control

Protection in power systems has been subject to several technological advancements. From electromechanical mechanisms to the microprocessor intelligent electronic device (IED), relaying has been an essential aspect to the continuing development of a more flexible, interconnected and smart power system.

As mentioned in IEEE PES PSRC WG K15 working group report, the CPC system architecture for the secondary system is not a new concept and dates back almost to the beginning of the widespread adoption of computers for business with the first proposal published in 1969, and the first installation as a field proof concept in 1971.

In the beginning of 1970s, the application of centralized substation protection based on a centralized computer system was proposed. This constitutes an important milestone in the history of power system protection. However, the idea has not been widely applied beside few exceptions in low voltage (LV) systems with an integrated approach, since there were no available computer hardware/ software or communication technologies to support such an idea. In recent years, the dramatic growth in the signal processing capability of relay platforms, and the availability of suitable communication standards for electric substations, have provided a new opportunity to revisit the concept of the centralized protection and control system.



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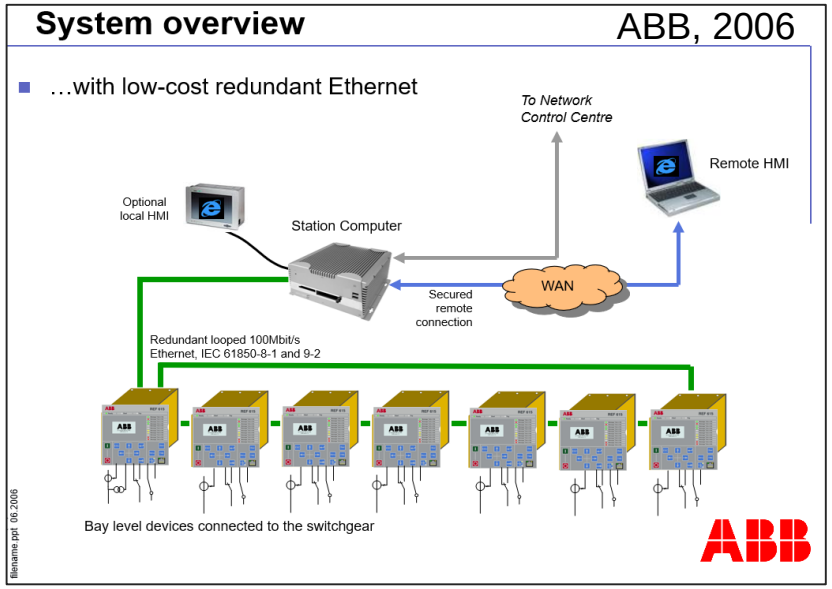
History of 61850-based centralized protection

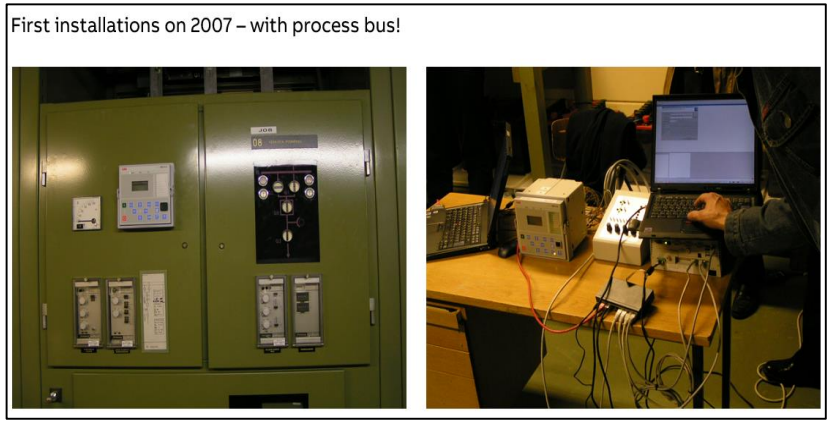
The first centralized protection architectures pilots started 45 years ago, under Westinghouse and GE, with microprocessor-based technology relays, allowing multifunction protection and control in same devices.

Westinghouse in collaboration with EPRI installed a P&C system called WESPAC with fiber-optic based network communication between data acquisition unit in switchyards and protection clusters in control room, **back in 1978-1986**. This **500kV substation owned by PG&E** was one of the very first to have utilized Digital Communications in Substations.

The first investigations on centralized protection based on **61850 standards started back in 2004** in Finland within product management team, and the vision at that time was already to have “digital enabled” relays which could be standalone protection relays, but also Merging Units, be compatible with upcoming “centralized” technologies, based on standard technology, like IEC 61850 and Ethernet.

First pilot installations of IEC 61850-9-2 based centralized protection systems were done back in 2007 after a research project together with universities and distribution utilities.





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Introducing Hybrid Protection and Control

Evolution of protection and control

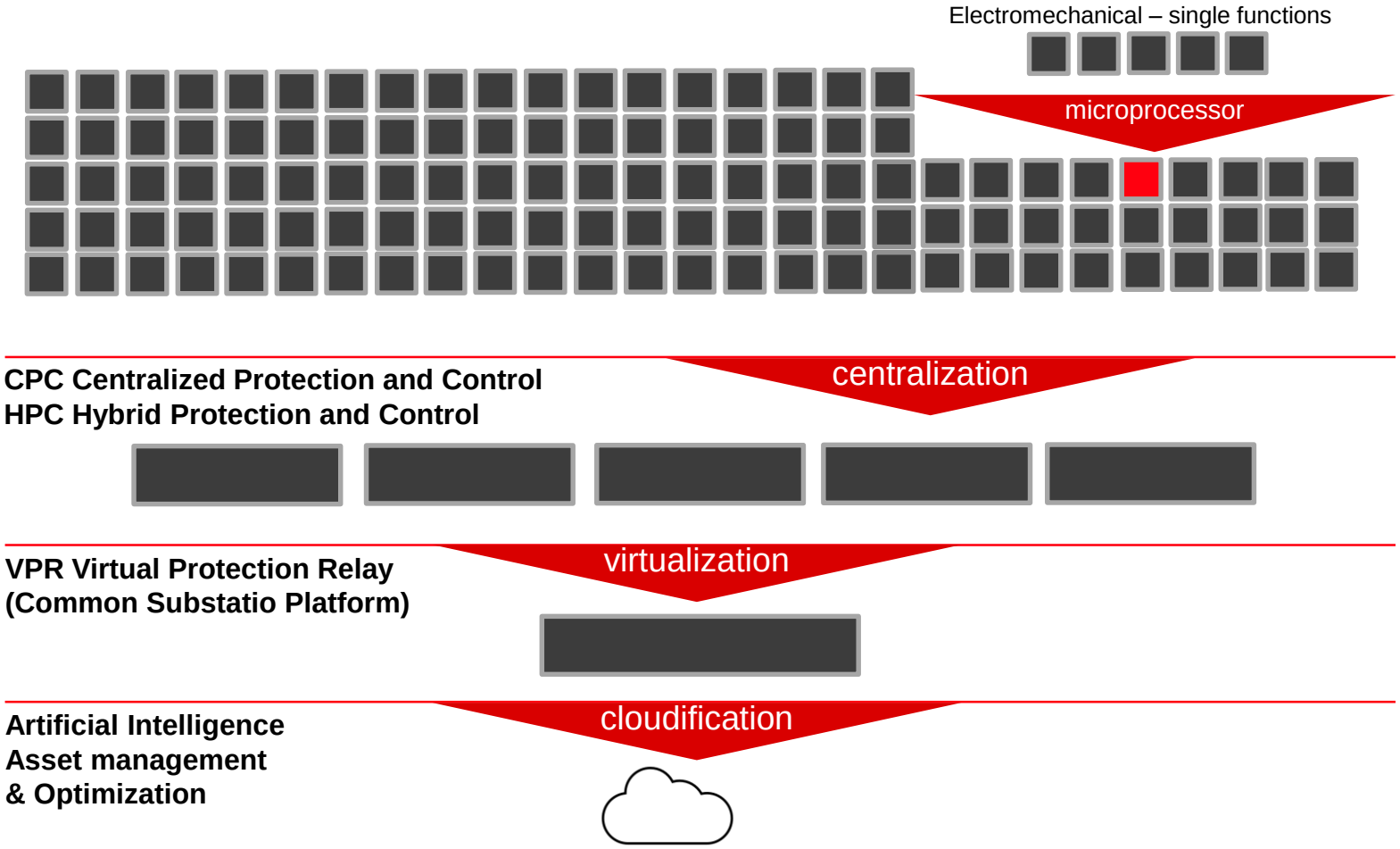
300-500 Electromechanical relays (single functions)

100 Microprocessor-based, multifunction relays

5 centralized protections

1 high-computing server, virtual machines-hypervisors

Cloud, 5G/6G

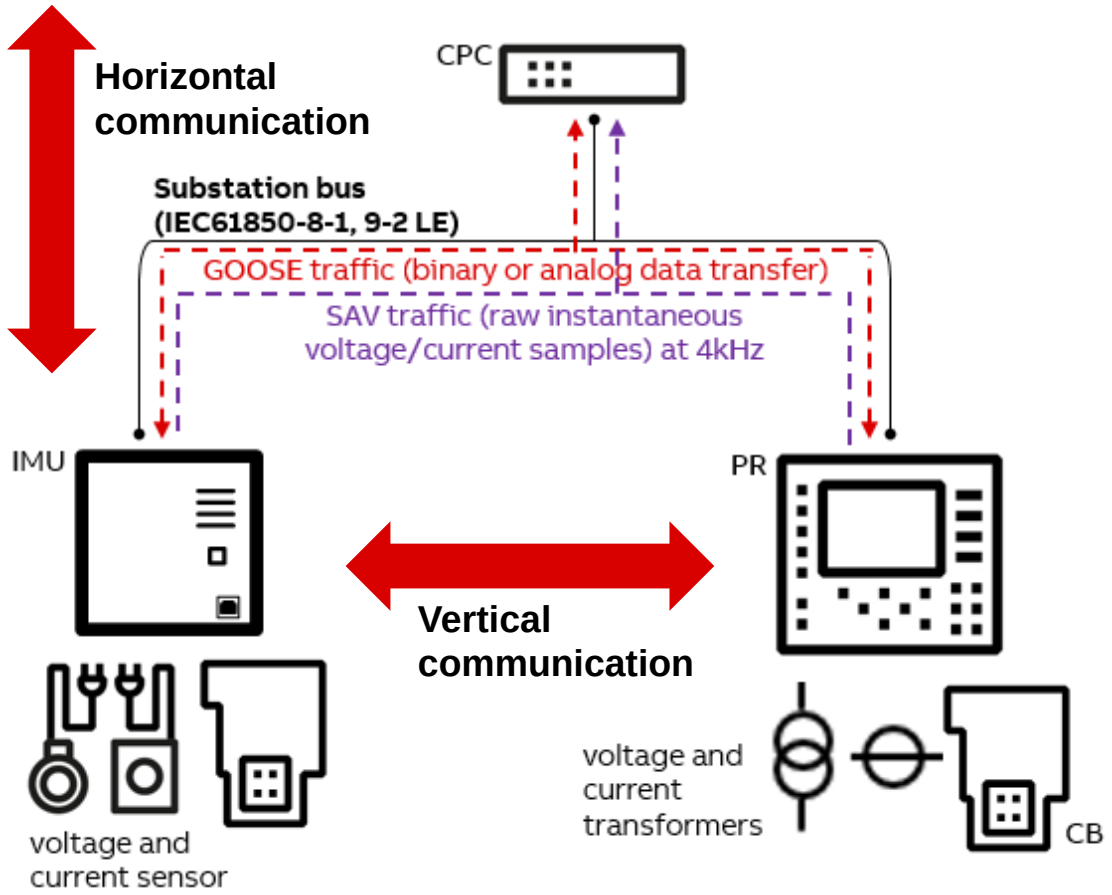


Protection virtualization technology: the utilities revolution

Vertical and Horizontal communication – low latency network !

Hybrid Protection and control

- Blends contemporary & centralized protection approaches
- New Centralized Protection & Control (CPC) device for all feeders in the switchgear line up
- CPC unit works together with PR units; also with Process IO units & Intelligent Merging Units (IMU) incl. CB supervision & command handling; Combined configuration -> 'Hybrid' Protection & Control (HPC)
- CPC unit attributes ->IEC 61850-3 compliant HW; subscribes to IEC 61850-9-2 LE messages; generates & subscribes to IEC 61850-8-1 GOOSE messages; generates IEC 61850-8-1 MMS reports & accepts supervisory control commands
- Provides flexibility for user to select best approach, considering needs/expectations
- Facilitates multiple levels of redundancies -> functional, physical and communication levels
- Opens up possibilities for advanced applications, new ways for remote device & life cycle management
- All CPC functions & applications' data modeled on IEC 61850
- Vinst & Iinst values @ 4kHz sampling rate sent from PR unit with MU capability & IMU to CPC, according to 9-2 LE.
- - GOOSE exchange between IMU/PR & CPC units (CB status, command signal handling, process inputs etc.)



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

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Real time performance?

	Expected behavior	5G OtA?	Conventional Relay architecture	Centralized protection	Virtual protection (VM/Containers)
Protection	<1ms / **deterministic**	×	✓	✓	**VM/OS + HW dependency!**
Trip signal	<5ms / **deterministic**	×	✓	✓	
Load-shedding	< 150 ms	✓	✓ (opt)	✓ (opt)	✓ (opt)
Fault location	< 500 ms	✓	✓ (opt)	✓ (opt)	✓ (opt)
Recording, DR	(Time stamping 1uS)	✓	✓ (opt)	✓ (opt)	✓ (opt)
Measurements	Seconds	✓	✓ (opt)	✓ (opt)	✓ (opt)
Power quality	Seconds	✓	✓ (opt)	✓ (opt)	✓ (opt)
HMI, monitoring	Seconds	✓	NO (extra)	✓ (opt)	✓ (opt)
Gateway	Seconds	✓	NO (extra)	✓ (opt)	✓ (opt)
Thermal overload	Minutes…				

1. Centralized protection = «Vendor controlled environments, including the OS and HW» | 2. Virtualized protection = «Vendor delivers a software package», but VM-HW platform performance to be certified | 3. FAST = high-end CPU | 4. REAL-TIME = high-end CPU + complete Hardware + Operating system/VM + Deterministic applications design

Protection virtualization technology: the utilities revolution

Operating systems

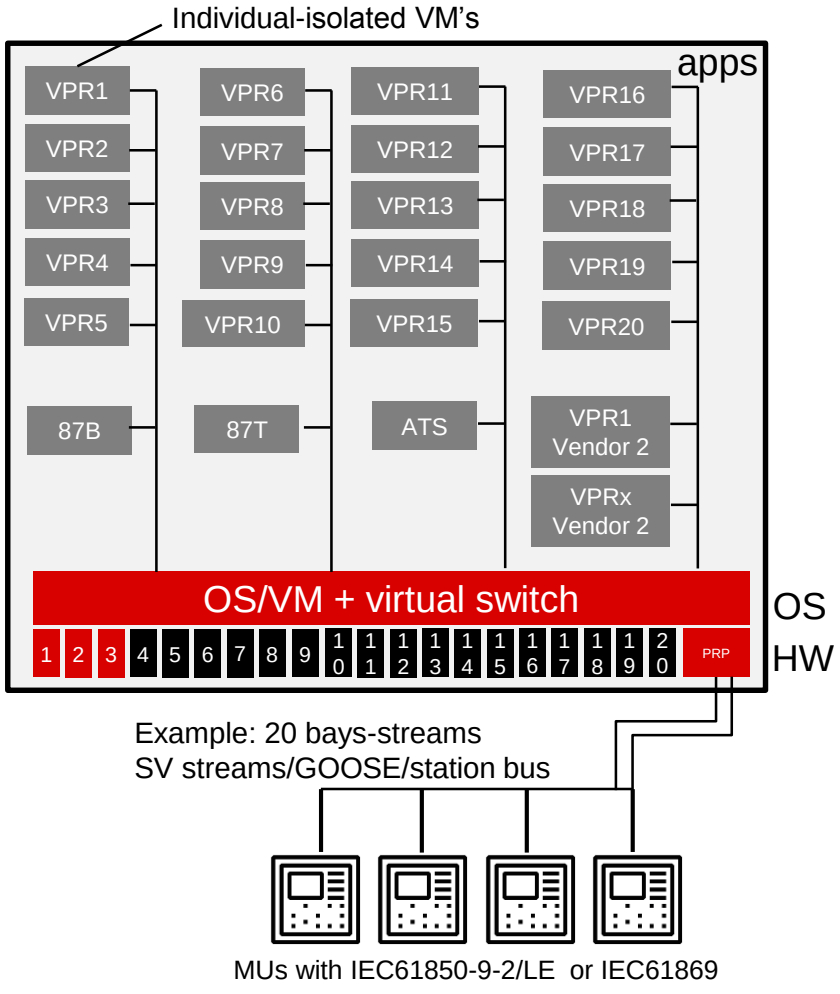
	 Conventional Relay architecture	 Centralized protection	 Virtual protection (with commercial vendor)	 Virtual protection (w/o commercial vendor)
Type of OS	Vendor	Vendor	Vendor/open source	Open source
Performance responsibility	Vendor	Vendor	Multiple vendors (certification)	??
Costs – CAPEX	+++	+++	++	+++
Costs – OPEX	+++	+++	+	- - -
Internal skills needed	+++	++	+	- - -
Licensing risks	+++	+++	++	-
Cybersecurity	++	++	+++	- -
Asset management	+	++	+++	- -
Flexibility	-	++	+++	+++
3rd party apps integr.	- - -	- - -	+++	+++

Protection virtualization technology: the utilities revolution

Virtual Protection: isolated virtual relays containers or substation management container ?

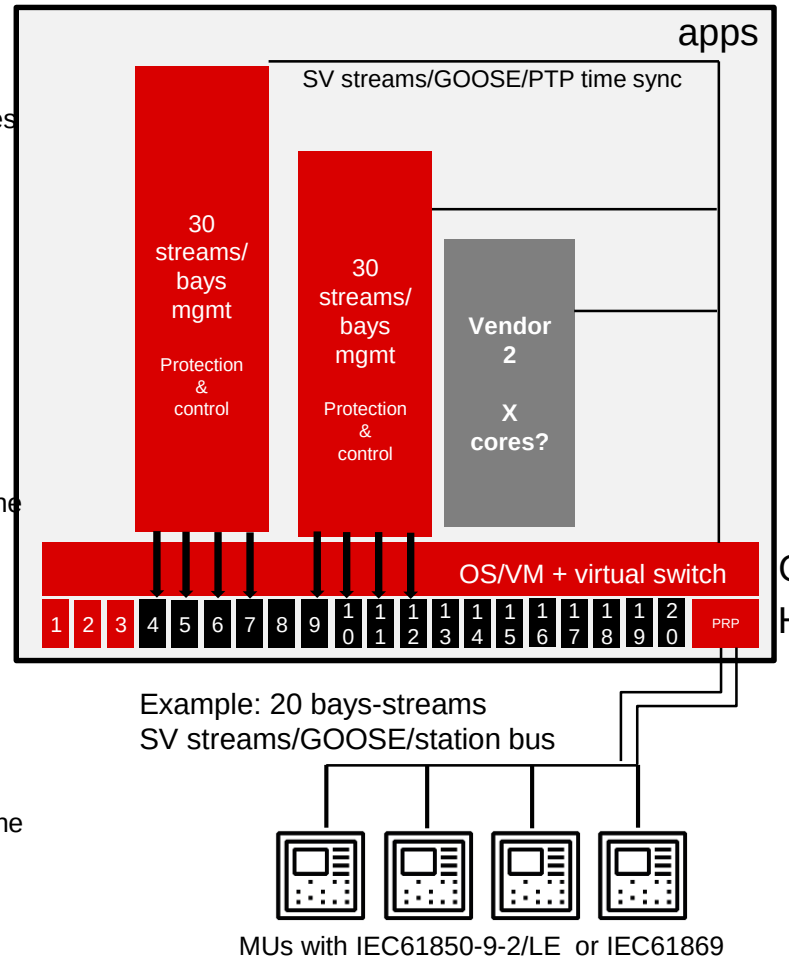
Approach 1
Individual virtual IED's

- Each physical relay converted into a virtual relay (VPR)
- Each virtual relay would be an isolated VM
- Each virtual relays would have its own configuration
- Each virtual relays would need its own subscribers, and tools
- Multibays logics would require dedicated VM's
- Individual VM's performance could not be granted if the IED's exceed the number of cores
- This solution is not optimized



Approach 2
Substation VM's

- Each Virtual Machine, includes 30 bays management, protection functions and substation tools.
- Each Virtual Machine (VM) is optimized to run on 4 cores only, real time, up to 30 bays
- VM's redundancy is possible inside the same server.
- One single configuration for the complete substation up to 30 bays.
- For substations more than 30 bays, additional VM's can be added.
- The hardware can be standardized with same CPU and cores, independently of the IED's or bays protected



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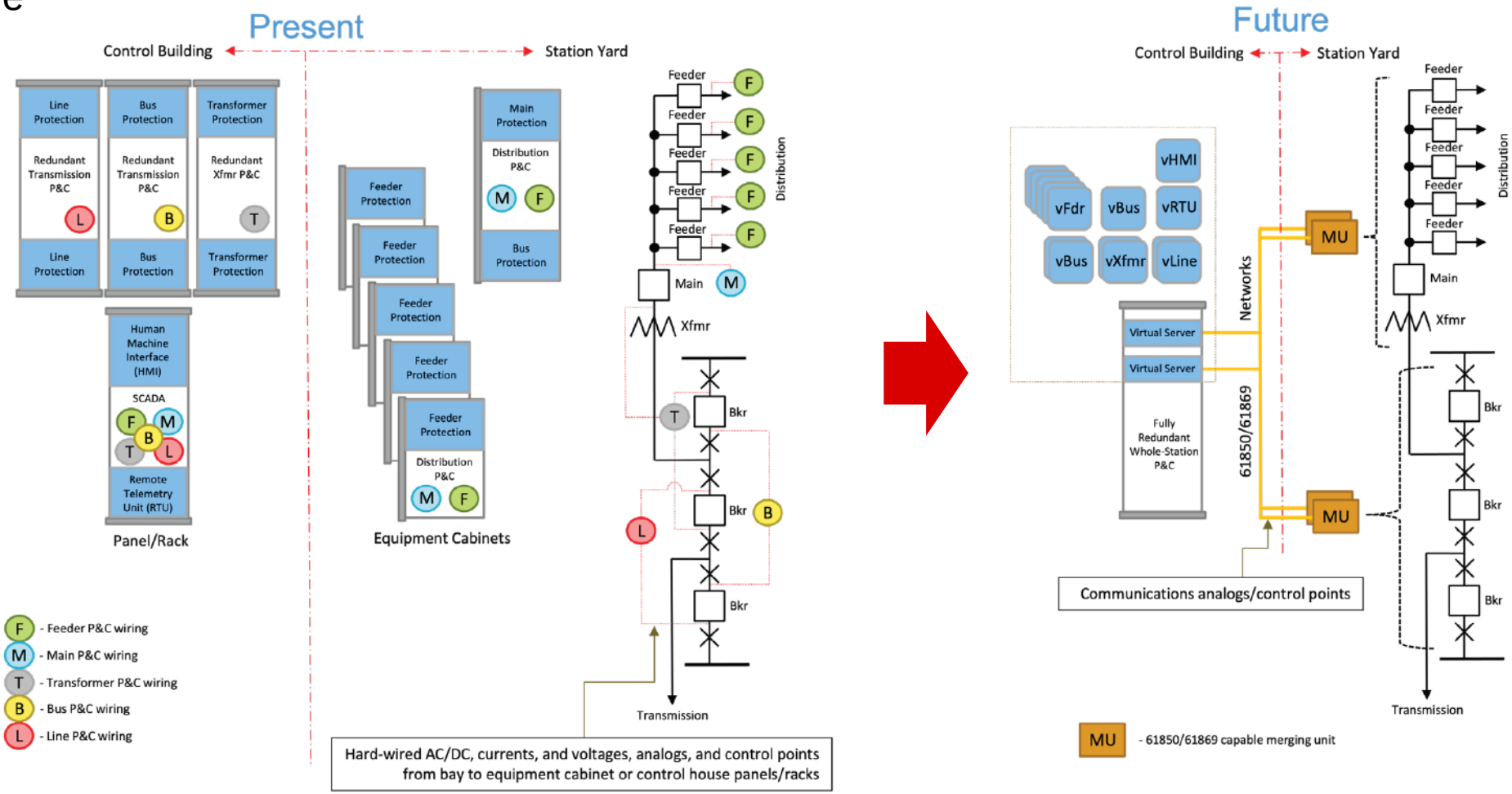
Architecture



Source: DELL (2022)

Protection virtualization technology: the utilities revolution

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

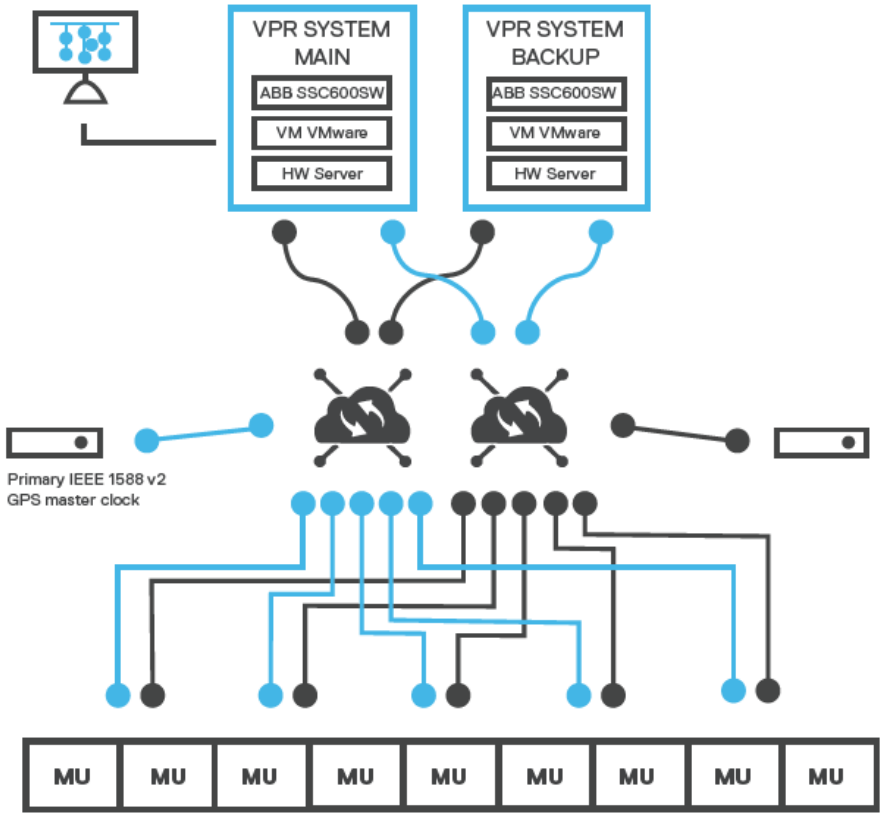


ABB SSC600 as Virtual Machine

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)

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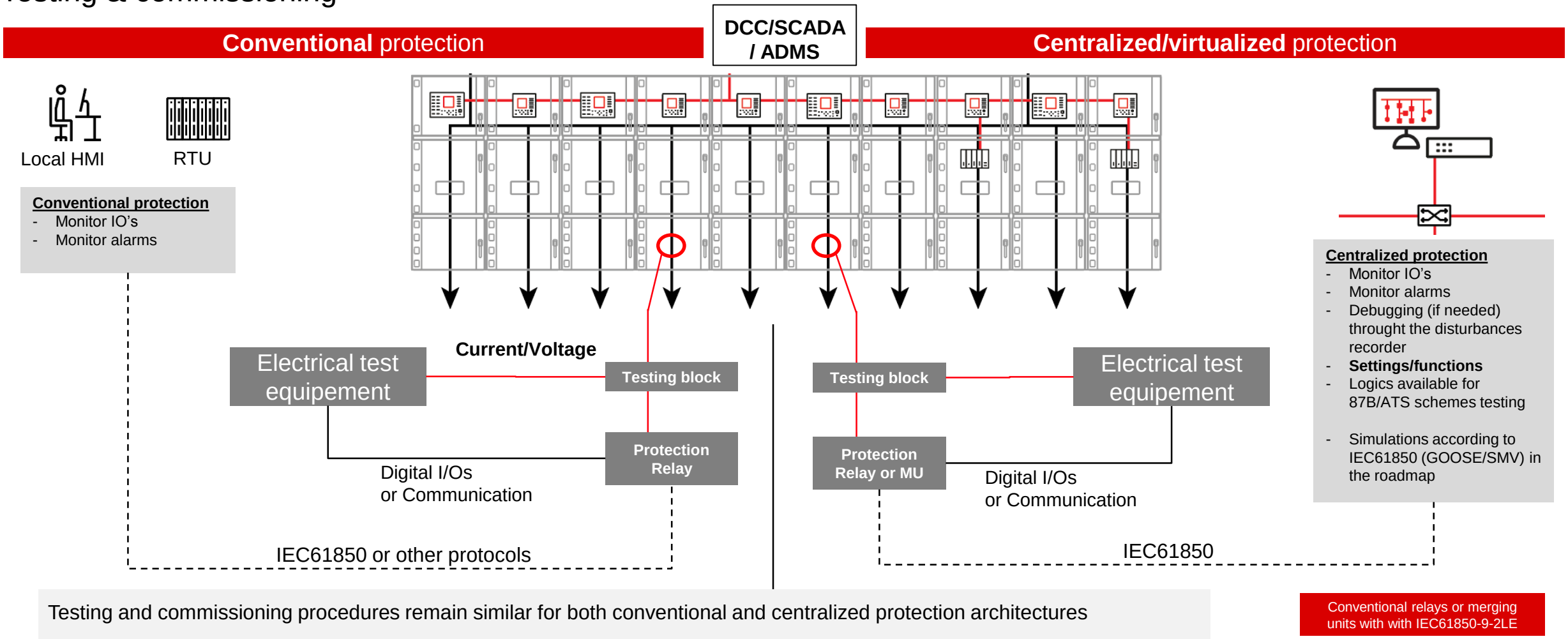
Testing & commissioning



Both Conventional and Centralized/virtualized protection architectures are compatible with conventional IT's and sensors

Protection virtualization technology: the utilities revolution

Conclusion

Turnkey & flexiblity	- **ALL-IN-ONE substation automation system, including Protection, Control and Monitoring functions**
Reliability	- Off-the-shelf appliance, ruggedized hardware, - 25% to 90% reduction of hardwiring - Communication supervised, redundant
Reduction of assets	- Ppgradable protection functions - Simplification of assets
Interoperability	- Simplification of configurations - Interoperability of assets
Security Remote patching	- Increased speed and performance - Patching and cybersecurity management enhanced and simplified
System savings OPEX/CAPEX	- Faster and more accurate fault analysis - Centralized settings and backup management - 25% up to 50% costs reduction OPEX/CAPEX
Backups & asset management	- Virtualized environments make the OS and HW type irrelevant from lifecycle stand point
Lifecycle management	

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Links/press and articles on “Substation Protection Virtualization”

- ABB to support the increasing digitalization of substations (ABB press release on Intel collaboration, Feb2019)
- Virtualization of Substation Applications – IEEE Power and Energy Society (ieee-pes.org) – IEEE
- Modernized Grids Require Substation Virtualization – Advantech – Advantech
- PODCAST - Evolution of Protection & Control: Pathways to Substation Digitalization using Virtualization Technology | T&D World (tdworld.com) – ABB – Intel – VMWare
- Virtualization in digital substations – Welotec – Welotec
- SEAPATH: Virtualization for Real – time Power Grid Substation Automation - Eloi Bail & Robin Massink – YouTube – RTE/EDF
- (2) Virtualization in the next generation Digital Substation | LinkedIn - Advantech
- The virtualized substation. No, really – POWERGRID International (power – grid.com) – Intel
- Future of the Utility Market (intel.com) – Intel
- Power-of-Infrastructure-Modernization-Ebook.pdf (gridwise.org) – Intel
- Eight Tips for Successful Substation Virtualization Implementation | Automation World – Advantech
- Introducing the Virtual Protection Relay Coalition (USA-2022) – Intel / Entergy / AEP
- Powering a More Sustainable Grid with Innovative Substation Modernization Technologies – Intel/DELL/ABB (2022)

Thanks for your attention !

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