WHITE PAPER

Rethinking protection and control for the digital age

Optimized protection and control of your electrical distribution

The power grid will continue to change which means that the solutions enabling the grid must also continue to evolve.

This white paper will help you understand why centralized and virtualized protection and control solutions are gaining traction with the benefits they bring: optimizing management of substation protection and control and enhancing scalability and flexibility.

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The changing grid and growth of energy consumption

Electricity makes modern life possible, and the vast network that is the power grid supports the functioning of all other critical infrastructure, such as, hospitals, water systems, and data centers to name a few.

Grid operators are, however, not only faced with delivering electrical power on demand. They need to make grids more resilient and weatherproof, faced with extreme weather events and wildfires. Further, to achieve ambitious carbon neutrality targets set by governments around the world, grid operators need to increase and manage distributed electricity production, such as solar and wind power. And all at the same time as they need to prepare for the forecasted increase in electricity consumption all over the world, including wide-scale adoption of battery energy storage systems and electrification of transport.

This emerging new energy economy may be critical to our low-carbon future. However, integrating new energy resources is having a fundamental impact on the electrical grid, making power generation and distribution increasingly complex and less predictable.

In other words, grid operators are facing unprecedented challenges protecting the grid at the same time as it must become more flexible and still meet or exceed system reliability requirements. In this quest, medium-voltage (MV) substations that step down high voltage (HV) from transmission systems to deliver a supply of electricity to consumers will be vital – as will protection and control (P&C) technology.

All these ongoing changes need to happen without risking the security of the power supply. It means that the protection and control functionality of our power networks must be enabled to manage continuous changes during the lifetime of devices. This is a tremendous challenge to the automation system, which needs to become more flexible and be able to reconfigure faster.

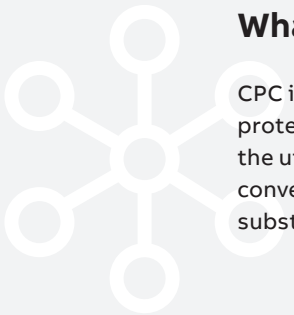
The journey to optimized protection and control of medium-voltage power distribution systems

Protection and control of electricity distribution networks is today most commonly realized with protection and control relays. This model has now been challenged in recent years by a digital and software-oriented solution – centralized protection and control (CPC).

The concept as such is not new, but only the recent developments in digital technologies and standardization have made these solutions technically feasible.

The idea for centralizing protection emerged considering the complexity of conventional approaches. And as the protection relays execute similar tasks, it makes a lot of sense to centralize the functionality in one single location, concentrating P&C into a single device, and having a single central processing unit.

A CPC system is made up of merging units (MU) and/or protection relays with merging unit capabilities for every feeder and a CPC device.



What is centralized protection and control?

CPC is based on the concentration of substation protection and control in a single device and the utilization of communication networks to converse between different components, bays, substations, and the related operators.

In essence, the biggest protection philosophy change with this type of system is the total or partial shift of functions from the bay level, i.e., from the protection relays, to the station level in the substation.

ABB's centralized and virtualized protection and control offering

ABB introduced centralized protection with the Smart Substation Control and Protection SSC600 device in 2018.

The key motivation behind developing this product was to bring a solution to the market that would make maintenance easier. With a centralized protection approach it certainly is, as it is possible to reduce the amount of different hardware variants to only merging units and a centralized protection device, the SSC600.

With SSC600, the flexibility and performance of the whole automation system is substantially increased, allowing for totally new ways to manage substation automation. System upgrades and maintenance also becomes easier and faster with a single device.

Centralizing P&C functionality in the substation reduces complexity and supports optimal, lifelong asset management and up to 15% savings in substation life cycle costs.

SSC600 can be deployed in several different architectures, depending on the other solution components used and overall solution requirements.

SSC600

Voice of the customer

"Smart solutions are vital when developing the infrastructure of tomorrow. We wanted to be a pilot user of ABB's SSC600 to learn about this new technology firsthand. It is an interesting approach, as consolidating multiple relays into one device reduces network complexity and offers effective ways to control protection functions."

Rein Aron, Area Manager, Enefit Connect (in 2021)

In January 2023, ABB launched the first virtualized protection and control solution in the world with Smart Substation Control and Protection SSC600 SW.

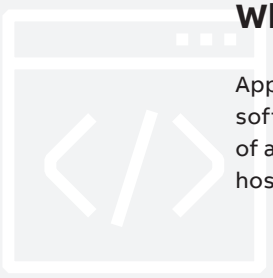
This was a significant step forward in increasing hardware flexibility, as substation intelligence is now also available as standalone software packages. And these can be deployed to the computing hardware of your choice. This further simplifies the management of physical assets, as virtualization enables full separation of the automation from the hardware products.

SSC600 SW is based on virtual machines. These virtual machines are self-contained application containers, which can execute some parts of the substation automation. For example, protection functions for lines, transformers or motors.

Virtualization makes it easy to update, upgrade, modify and maintain the substation intelligence, as the hardware is always the same. And as you are no longer dependent on any device manufacturer, you can decide what kind of computer is the best fit for your needs.

SSC600 SW offers the same proven P&C functionality as ABB's turnkey solution, SSC600.

To create a robust power system protection and control solution that provides the flexibility and enhanced resiliency necessary to face increasingly complex grids, SSC600 SW supports Linux KVM and the VMware Edge Compute Stack platform as virtualization environments and runs on Intel® Xeon® scalable processors to ensure real-time performance.



What is virtualized protection and control?

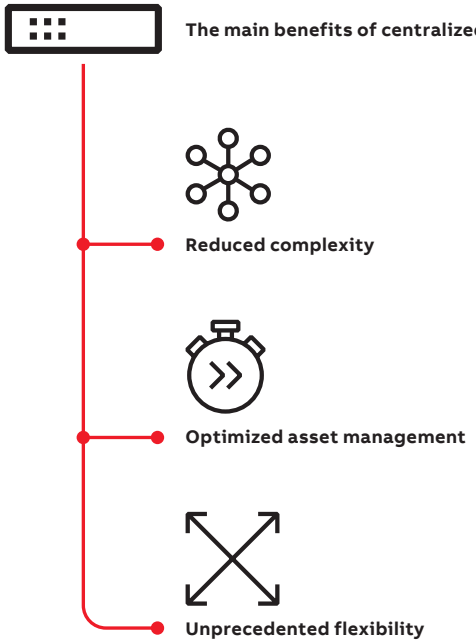
Applied to P&C, virtualization is the use of software for the creation of an abstract image of a traditional P&C solution inside a physical host – ruggedized computing hardware.

Hence, the protection application is no longer tied to a particular centralized device; it is a software image that can be independently deployed to versatile industrial server architectures in different environments.

The benefits of centralized and virtualized protection

Eliminate the complexity of conventional approaches
In asset-intensive businesses, such as utilities and industrial manufacturers, that operate and maintain a myriad of devices, machines, and electrical systems, asset management is a critical strategic undertaking. Managing all these assets efficiently is crucial as it will affect the bottom line.

As the power grid evolves, substation technology also needs to change. In addition to standard primary equipment, such as circuit breakers, busbars and switchgear, most modern substations incorporate intelligent secondary equipment designed for automation and control. This encompasses a wide range of devices for communication through to SCADA (Supervisory Control and Data Acquisition) systems, including both legacy and newer assets, running specific applications.



Managing maintenance of an ever-growing list of different devices in modern substations can become a quite the challenge for grid operators. Complicating matters further are vendor-specific devices, which can mean any upgrades or modifications involve a specialist skillset that needs to be outsourced at a cost.

To simplify and streamline maintenance tasks of electronic devices, ABB introduced centralized protection with SSC600. With a centralized protection approach, it is possible to reduce the amount of different hardware variants to only merging units and a centralized protection device.

With a CPC approach, the flexibility of the whole automation system is substantially increased, allowing for totally new ways to manage substation automation. System upgrades and maintenance also becomes easier and faster with a single substation protection and control device.

One SSC600 device can handle the functionality of 30 protection relays. Centralizing this functionality in the substation reduces network complexity and supports optimal, lifelong asset management and up to 15% savings in substation life cycle costs.

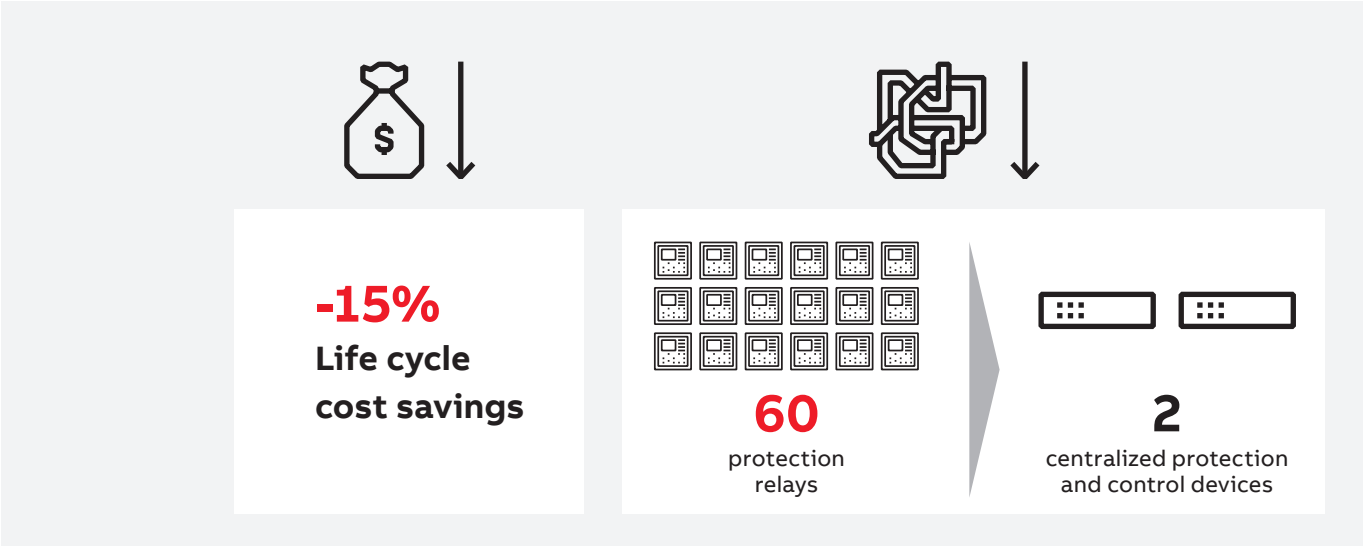


Fig. 1. Centralized protection reduces network complexity and brings up to 15% savings in substation life cycle costs

Simplified life cycle management and unprecedented flexibility

With the introduction of the IEC 61850 communication standard for substation automation systems, many things were considerably simplified, standardizing how devices should report their status and transfer data. This communication is most often physically achieved via an Ethernet cable. The results of digitalization and implementing according to international standards allow substation-wide information to be shared and utilized in a comprehensive way.

ABB's CPC solutions offer extensive application coverage with only one device. This station-wide visibility grants easy and efficient process management. Further, as IEC 61850 standard-compliant solutions, SSC600 and SSC600 SW offer unprecedented flexibility throughout the substation's entire lifetime. As technology continues to advance and new applications develop, so too does the standard.

This means that any future changes to the substation are easy to make with ABB's CPC solutions. As software-based approaches it is easy to update and modify functionality as requirements change. And any future bay expansion need is easily managed via adding merging units.

Also new protection functionality can be easily activated when requirements change. The modular software and the continuous access to new software developments allow easy customization and adaptation to changing protection requirements for the lifetime of the substation.

The advantage of only having to modify one device instead of all bay-level protection and control devices makes upgrading the entire substation system easier than ever.

Voice of the customer

"During my career I have seen all kinds of devices. Nowadays devices age faster than before, which is also the case in substations. We have now chosen to install an entirely new system to be one step ahead. In addition, with SSC600 we no longer need to manage an installed base consisting of protection devices of different types and ages. With the new SSC600 device, we can update all the protection and control functionality in one go."

Olli Mattila, Network Manager, Parikkalan Valo (in 2020)

Further, IEC 61850 allows digitalization of the power system in a way that it allows integration of existing equipment and systems and collaboration with other digital entities, such as a power management system (PMS). Further, standard-compliant devices supplied by different manufacturers can communicate with each other without any engineering-intensive complications in the same power system.

In all, with ABB's CPC solutions, there's minimal engineering from start to finish and fast and easy system-wide upgrades.

Easy backup management
To manage the grid and enable comprehensive automation solutions, there are many different electronic devices installed in modern distribution substations. Each of these devices has their own configuration, which might change throughout the installation's lifecycle.

ABB's CPC solutions efficiently handle configuration backups for all the devices in the switchgear. As the CPC device is connected to all the protection-related equipment, it can read the configurations and store them for future use. Merging unit configurations can be restored with a single click in the web-HMI. The CPC device then ensures that the configuration is written correctly, and the MU is restarted with the restored configuration, making backup management easier than ever.

Virtualization for easier substation management
Since introducing the virtualized product, Smart Substation Control and Protection SSC600 SW, grid operators are no longer tied to specific hardware, which allows you to optimize your IT infrastructure.

Voice of the customer

"The centralization of protection and control as well as the smooth and easy updates are certainly beneficial. In addition, with the help of these new devices we get increasingly more information about the current state and operation of the substation. This data can be used to react, before a bigger problem develops. This is a major benefit."

Kimmo Kärki, Managing Director,
SLT Consultants (in 2020)

With many systems accommodated on one platform, the number and type of devices and hardware in the substations can be reduced. Not only does this greatly simplify performing maintenance activities, it also entails the inherent separation of functionality from hardware (virtualization), which allows integrated, system-wide upgrades and additional functionality, without introducing the need for new hardware. As an example: an SSC600 device can protect 30 bays, whereas with a virtualized approach, customers can install multiple SSC600 SW instances on a single computer for even bigger systems.

Further benefits of using SSC600 SW are the possibility to add new functionality as hardware performance increases over time. With the virtualized product, it's easy to future-proof you substation, as it will be ready for new multi-vendor software functionalities.

There are further benefits as well: a smaller amount of hardware variants leads to fewer spare parts which simplifies maintenance. And with virtual machines backup and recovery processes are well-defined.

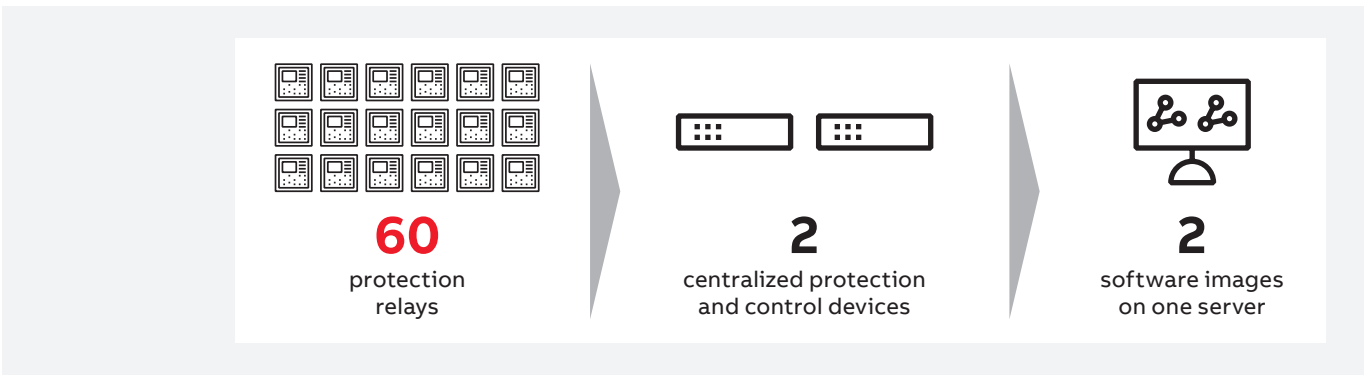


Fig. 2. Reduced complexity with centralized and virtualized protection

Improved grid reliability
Now more than ever, grid operators around the globe are facing an increasing number of challenges related to maintaining the reliability of their grids. Understanding the state of the grid and its components before and after a fault, disturbance, or anomaly, is of utmost importance to power engineers to be able to take corrective actions to minimize such occurrences in the future.

On top of the other benefits with centralization of protection and control, a CPC architecture can also be utilized to achieve a substation-wide disturbance, fault, and event recordings platform, which can replace traditional fault monitoring systems.

For easy and efficient fault analysis, the disturbance recorder application of ABB's SSC600 and SSC600 SW provides us with insights into network events. It continuously records measured values, current and voltage signals from measurement devices, processes the data and stores it. In the event of triggering, it also helps with analysis of the impact on the equipment and the grid. As the CPC device has access to all substation measurements simultaneously, the same data can also be used for substation-wide disturbance, fault, and event recording purposes that can be post-analyzed in the same or in a separate system. Based on this information, reliability improvements can be implemented.

Voice of the customer

"From predictive fault management to power quality issues, all the measurements we need are immediately available on the digital platform. Conventional protection and control systems never gave us that real-time information."

Colin Scoble, Senior Protection Engineer, UK Power Networks (in 2020)

Towards a greener tomorrow
SSC600 and SSC600 SW enable real-time monitoring and control of distributed energy resources (DER), such as wind and solar. And offers optimized lifelong asset management for the entire digital substation with the possibility to flexibly change with the evolving grid.

Voice of the customer

"SSC600 is a modern and cost-efficient solution for detecting, locating and isolating faults. It is also a platform for creating new functionalities for future needs, like electric transportation, distributed generation and energy storages."

Sauli Antila, Head of Network Development, Caruna (in 2018)

Improved safety
Safety is paramount in the design of electrical systems and with ABB's CPC solutions, managing the system remotely is possible. This minimizes the risk of being in proximity of arc flash areas when operating circuit breakers, or in case of an electrical fault, thus helping avoid incidents that can cause injury or loss of production and equipment.

Further, use of non-traditional instrument transformers (current and voltage sensors), and use of arc sensors are also possible. This eliminates concerns with the secondary side of current transformers being left open, and potentially developing high voltages, and ferro-resonance problems that could happen with traditional voltage transformers. A CPC solution where the merging units can be connected to arc sensors, provides additional protection to personnel and equipment in case of an arc fault.

Complete visibility of data
ABB's ADAM offer fleet management for SSC600 and SSC600 SW. Easy-to-use, cybersecure and cloud-based, ADAM provides the full view of your SSC600 devices, so you gain complete visibility of your data and easy device management.

As ADAM is hosted in the cloud, it's always accessible – from anywhere. Any device with internet connectivity and a web browser can be used to get an up-to-date status of all the connected devices and an overall status of substations.

Customer cases and field-proven results

Acciona Energia takes the next step in power system reliability and operational efficiency

A future-proof protection, control and monitoring solution was delivered to Acciona Energia for their substation near the Anabaru wind farm in the state of Karnataka in India – which is now effectively monitored locally and controlled from the control center in Spain. The substation is the home of the first Smart Substation Control and Protection SSC600 device in the wind power segment in the country.
Learn more here.

US utility SRP pilots centralized protection and control

Salt River Project's (SRP) vision to move from a distributed protection and control approach to a centralized approach was born out of the necessity to reduce the number of devices being installed and improve their overall life cycle strategy. Learn more here.

Estonian utility pilots ABB's centralized control and protection solution to safeguard power distribution

Estonian utility Elektrilevi reduces protection system complexity and effectively controls protection functionality of the network with ABB's SSC600 solution.
Learn more here.

Taiwan Power Company selects centralized protection and control solution with SSC600

The advancement of reliable power supply and the introduction of advanced technologies are important to Taiwan Power Company. ABB delivered a system with centralized protection architecture with SSC600 for the Queshan substation on Kinmen island. The result is line with the company's targets: tripping has reduced, the reliability of the power supply improved, and end customer satisfaction increased.
Learn more here.

Finnish utility selects ABB's centralized control and protection solution

As part of refurbishment of its Punkasalmi substation in Finland, Parikkalan Valo sought a solution to ensure safe and reliable power supply. They wanted to be able to manage the electrical network and assets more efficiently; ensuring flexibility to meet future needs as requirements change. They chose SSC600, whereby all P&C functions of the substation are centrally managed, operated, and engineered in the same device. This makes it possible to update the entire P&C functionality in one go.
Learn more here.

ABB – a strategic partner for UK Power Networks' digital future

UK Power Networks recognized the need for a digital platform that can be rapidly deployed and secured to meet the challenges brought forward by changes in power generation and consumer behavior. A pilot with ABB's centralized protection and control was initiated, as consolidating P&C functions into fewer devices simplifies maintenance and the engineering process, and also reduces substation footprint.
Learn more here.

Finnish DSO Caruna is making their network smarter

Caruna, the largest distribution system operator in Finland, wished for a flexible and future-proof solution for their network and chose to pilot ABB's SSC600. To meet new protection requirements and to benefit from the latest developments in relay technology, SSC600 was installed in Caruna's substation in Noormarkku.
Learn more here.

Cloud service pilot with Caruna

Caruna sees cloud services as valuable tools in the future of the electricity distribution business. Together with the company, ABB piloted a concept where a CPC system with SSC600 in the Noormarkku substation was connected to ABB Ability™ cloud services via a secure remote connection to provide complete fleet management. This allowed efficient monitoring and management of the devices. Data from this pilot contributed to R&D activities, and in 2023 ABB introduced fleet management with ADAM to the market.
Learn more here.

What do you need to consider before switching to a CPC approach?

Each substation project has its own specific requirements, but as a first step towards realizing a CPC solution, we'd recommend considering the following lists of key items:

☐ **Identify the existing architecture**
- Where are the protection relays located – in switchgear, or in separate control panels? Are there redundant relays (i.e., two relays per bay)?
- How many feeders and transformers today/future?

☐ **Compare costs associated with a completely new versus retrofit**
In many cases already existing relays can be used for back-up protection. Thus, upgrading existing substations can be cost-efficiently managed with a CPC approach.

☐ **Identify the protection functions** that are likely to be utilized the most.

☐ **Plan for risk mitigation** – consider possibilities for redundancy.
A commonly used redundancy method, especially in new installations, is to duplicate the CPC device. This ensures that if there's a CPC unit failure, there is fully functional protection available as backup. As the CPC devices can have identical configurations, the engineering and maintenance is efficient. Also, during update procedures and testing, the redundant unit can handle protection while the other unit is out of service.

☐ **Plan for CPC system engineering**
The process of engineering a centralized protection scheme includes: (1) Setting up a project, (2) P&C engineering, (3) Merging unit engineering and (4) IEC 61850 engineering.

Setting up a project
The first stage of CPC system engineering is the creation of a project. This can be done using ABB's Protection and Control IED Manager tool PCM600. This free-to-download and use configuration tool is compliant with IEC 61850, which simplifies the IED engineering and enables information exchange with other IEC 61850 -compliant tools.

P&C engineering
The next step is setting up a controls and protection, such as various protection function blocks. With PCM600, you can easily add, delete, and connect the P&C function blocks.

Merging unit engineering
The role of the MU is (1) to collect analog signals and send it to the CPC device via SMV and (2) to host I/O and send the status of the circuit breaker (CB) to the CPC device as well as receive protection trip, CB open and close commands from the CPC device.

IEC 61850 engineering
The IEC 61850 standard is not limited to communication protocols, but has an organized framework for establishing substation engineering, maintenance, and operation. The data is communicated according to the station bus and the process bus sections of the standard. The CPC system utilizes MMS to communicate device status, GOOSE messaging to transfer breaker status, trip and close commands and sampled values (SV) for real time analog value communication.

Precise time synchronization is crucial for communication between MUs and the CPC device. IEEE 1588v2 PTP profile according to C37.238-2011 is typically selected to provide the most accurate and reliable time synchronization. It is important to verify that all devices using 1588-time synchronization are utilizing the same master clock.

Conclusions

The technology needed to improve power supply reliability is already available, tested, and proven. SSC600 and SSC600 SW bring increased awareness of your P&C system, reduce complexity, and improve asset management and provide unprecedented flexibility to change with the evolving grid.

Key for the success of the emerging new power grid will be based on greater digitalization to operate, monitor and deliver electricity sustainably. This power grid will be built on and utilize the same basic infrastructure we know today, but will tap into innovative monitoring, control and communications technologies that communicate and work together to further enhance reliability and efficiency.

Two of the primary drivers for centralized protection approaches were the environmental and regulatory conditions that have propelled the integration of distributed resources as well as the increase in availability requirements on electrical power.

With our CPC solutions, ABB offers beyond that. We and our customers around the world have shown that this technology can make a real, positive difference offering flexible and reliable P&C systems.

For grid operators, the decision to switch to centralized protection should be easy. As ABB's CPC solutions handle the protection functionality of several separate protection devices, cost savings can be achieved. They reduce complexity, for example, not needing to have separate protection relays for over-current, earth fault, and differential protection and a standalone device for disturbance recordings. Further, CPC brings optimized asset management and flexibility with easy updates and modifications, as requirements change.

Although grid operators might be reluctant to change to a CPC approach due to the radical change in protection philosophy, the benefits greatly outnumber any concerns.

Focusing in on reliability and resilience, grid operators can leverage new technologies to meet the challenges of the emerging new power grid. CPC solutions bring increased flexibility and performance, coupled with a reduction in overall lifecycle costs.

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List of abbreviations

CPC	Centralized protection and control
DER	Distributed energy resources
DSO	Distribution system operator
GOOSE	Generic object oriented substation event
HV	High voltage
IED	Intelligent electronic device
IT	Information technology
MMS	Manufacturing message specification
MU	Merging unit
MV	Medium voltage
R&D	Research and development
P&C	Protection and control
PMS	Power management system
SCADA	Supervisory control and data acquisition
SV	Sampled value
SW	Software

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2NGA002231 REV A EN 2024