Unified Grid Control Platform for the Carbon-Free Future

White Paper — *Technology Innovation*

Why does the electric utility industry need a new unified grid control infrastructure?

World society faces the imperative of transforming the electric grid to renewable and carbon-free energy sources, driven by stringent regulatory requirements and consumer demands to eliminate carbon dioxide and other greenhouse gases. We have passed the tipping point – the transformation of the grid is underway and will accelerate.

In contrast with the still-operating legacy of large fossil-fueled dispatchable central generating plants, most of the new renewable energy production comprises massive numbers of smaller installations scattered across the transmission and distribution grids, and at utility customer sites. In parallel, the same need for a future free of greenhouse gases for transportation and other industry sectors is also driving electrification and supporting growth of T&D infrastructure.

The number of new distributed energy resources (DER) for production and storage, along with new interfaces and facilities, will expand system operation and protection complexities exponentially. DER are dependent on sunlight or energy sources that operators cannot control as they deal with energy demand at each moment. Inability to dispatch DER production reduces controllability of energy flows and places difficult-to-predict demands on storage. Despite this energy supply and control uncertainty consumers, regulators, and government agencies demand higher service reliability, grid resiliency, and accommodation of constantly changing weather and environmental conditions, and public safety.

This drives massive need for advanced new infrastructure to monitor and control the interaction of granular energy resources with the regional grid and with new categories of loads and consumers. The grid requires evolution of protection, control, and monitoring (PCM) systems to architectures that are functionally adaptable, flexible, resilient, and sustainable. Fixed-function PCM systems designed for the predictable grid with centralized generation will struggle to meet these needs.

In addition, the physical and electrical operating characteristics of DER are profoundly different from legacy generation and demand new protection and control methods. Fossil-fueled turbine-generators have massive rotating inertia, storing energy that stabilizes grid operation and dampens the impact of disturbances. They are also able to provide the necessary short-circuit current during system faults to initiate protective relay tripping. By contrast, DER using power electronic inverters typically have no inertia, and can only deliver close to rated current in the face of a disturbance or fault. Disturbances are not damped and may trigger sudden excursions of voltage or frequency that can lead to loss of stability and blackout. Already, on multiple occasions, recoverable grid disturbances have caused DER inverters across the grid to block or shut down completely, leading to a sudden reduction in energy supply and also risking blackout. Protecting a grid with high penetration of DER calls for a transition from traditional indicators of stability like frequency to direct monitoring and holistic analysis of voltages and currents gathered at high speed from across the impacted region, with rapid control or switching across the region to maintain stability.

The utility industry cannot realistically plan on expanding today's ubiquitous PCM infrastructure with its point-solution products to address these issues: every new need is met with a new solution, increasing PCM infrastructure costs. This will cause loading financial and human resources beyond the breaking point while not bringing essential new integration and operational functions.

The electric utility industry can conceive and build sustainable and affordable new systems for control, protection, monitoring, and management of electric T&D grids by adapting the rapidly advancing IT, computing, and data processing techniques that are transforming other major industries. Many of the latest utility grid functional concepts and solutions can be integrated with broad and fast-moving industrial and business automation and information technologies to reach the sustainable, flexible, adaptable infrastructure *for a unified grid control platform (UGCP)* for monitoring, control, and protection. UGCP enables the utility enterprise to:

- Adapt functional behavior quickly and holistically across the grid for new operating requirements.
- Operate a reliable, redundant, resilient, maintainable, and sustainable architecture of computing and communications.
- Leverage emerging OT and IT networking solutions for scalable high-performance integration of digital substations over wide areas.
- Simplify substation life cycle maintenance with proven IT-based tools for centralized management of communications and computing environments.
- Continuously expand cybersecurity capabilities to counter constantly evolving threats while complying with current and emerging NERC CIP requirements.

This document describes how UGCP concepts already being developed today can fit into a comprehensive architecture of reliable computing and data communications that can continuously adapt to current and future technical, operational, and business needs. It proposes development steps to demonstrate, vet, and deploy the complete architecture, starting at the substation level, and will be comprised of a decentralized, cloud-like array of redundant standardized data processing and storage resources interconnected with high reliability and cybersecure data communications.

Review of existing PCM architecture

Most of today's technical systems for transmission or distribution grid PCM have evolved from practices invented at the outset of the electric age. Panels and racks of dedicated single-function or single-purpose units like protective relays or local apparatus controllers are wired to power system apparatus with thousands of point connections between control building panels and the switchyard.

- ***SCADA and Energy Management Systems (EMS)*** – Monitoring and control of entire grids has been handled by centralized SCADA and EMS with specialized data acquisition by remote terminal units (RTUs) in substations. Information gathering is limited by wide-area communications capacity. The existing energy management systems (EMS) is challenged to adapt to management of thousands of today's highly distributed energy resources that are not dispatchable, or to rapid changes associated with a low-inertia grid. Utility operating organizations and their software suppliers are currently working on distributed energy resource management systems (DERMS); but only as a separate overlay to integrate those resources with legacy grid operations.
- ***Protective relaying systems*** – Electrical short-circuit fault protection and system stability protection have been handled by custom-designed, individually set, redundant, fixed-function relaying systems whose operating methods have been based on predictable power and fault current flows fed from large rotating generation machinery with high inertia and high fault current delivery. Special-purpose protective relays and other intelligent electronic devices (IEDs) in custom packages installed in substations or along distribution circuits approach an evolutionary boundary for handling holistic grid protection challenges. These relays are becoming more complex, difficult to configure and set, and are limited in their ability to add new functions for evolving protection requirements. Updating functions or correcting programming errors requires on-site service and recommissioning. Protection schemes are limited by the unavailability at the substation level of a holistic live set of system measurements and states.
- ***Reliability and maintenance*** – Maintenance of PCM infrastructure comprises repair of failures or problems when observed, plus discovery of some hidden failures by time-based testing and inspection. Many failures are only discovered when a grid disturbance triggers a protection system misoperation and customer outage. Overall configuration, maintenance, and reliability management of PCM systems has required costly dedicated human resources and tools.
- ***Asset management*** – Detailed information on the state of assets or operations has been difficult to gather or share across the enterprise. Some information gathering has required costly single-purpose add-on systems for observation or tracking. There is only slow progress towards gathering of equipment and process data in efficient single streams for sharing among various enterprise and operational users.
- ***Overall operational and business management*** – Enterprise management functions including asset management, event analysis, planning analysis, capital planning, maintenance management, and business management are all handled in unique, costly software and hardware systems isolated from one another and requiring hand-built linkages or human evaluation of the PCM and power system assets. Special-purpose systems independently monitor limited and isolated bodies of asset condition or site surveillance information.

UGCP Substation Architecture

Figure 1 shows the architecture for the physical infrastructure in a substation. The same architecture is scaled to serve large facilities or small nodes and customer sites.

The primary power apparatus features integrated or attached merging units (MUs) – local electronic modules which gather and digitize measurements and point states at each switchyard location and combine them for transmission on a single optical fiber to the processing array attached to a redundant substation Ethernet network. Substation PCM functions can send tripping or control commands back to the apparatus via return optical fibers to the MUs.

The network infrastructure comprises a redundant, resilient, secure Ethernet interconnection of MUs, redundant computer arrays hosting standardized substation PCM functions, and router interfaces to wide-area networking and utility operational and enterprise operating arrays. Networking and processing arrays can be centralized in a control building or distributed around the substation in smaller replaceable structures or modules. Network reliability is based on today's redundancy and security technologies such as PRP dual-link redundancy, looped redundancy, or software-defined networking (SDN); UGCP can absorb high-reliability networking technologies now arising in the larger business and industrial IT worlds going forward. The substation or node network connects through routers to redundant utility operational and enterprise wide-area networks.

Processing units feature operating systems with real-time capability and with functional containerization of power system application programs (apps). The standardized function containers are flexibly deployed across the processing units - operating-system containers or apps can be placed in consideration of reliability, processing workload, failure resilience, or practical maintenance and updating sequences. The ability to commission new or updated apps without disabling any elements leads to a completely sustainable installation. Hardware elements – processors, networking equipment, and MUs – can also be safely upgraded or replaced without outages of primary equipment or grid operating limitations. This also calls for a new sustainable physical installation design that makes these no-outage replacements safe and easy for maintenance crews.

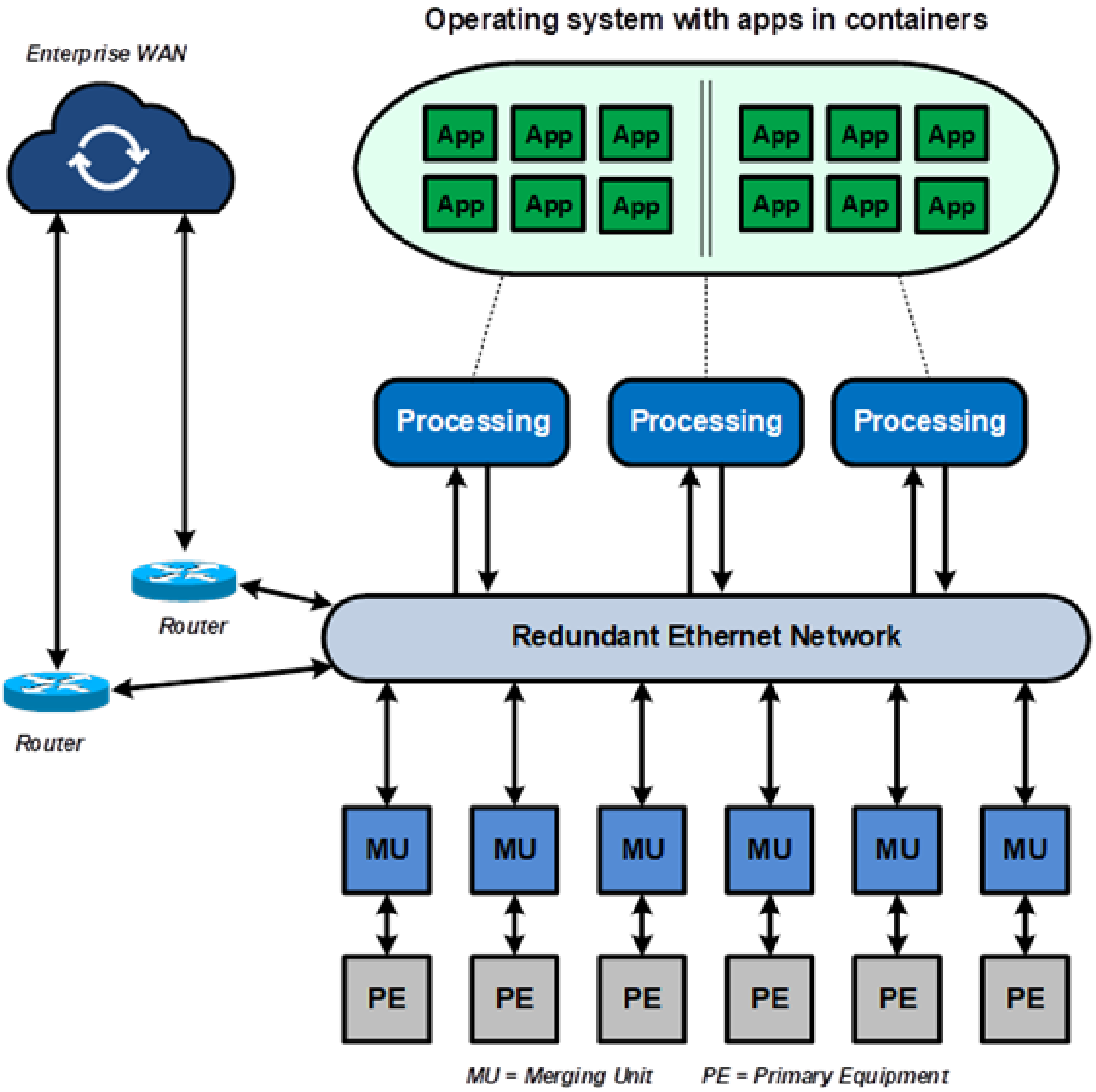

Figure 1. UGCP Substation Architecture

UGCP Wide-Area System Integration Architecture

The array of substations and grid nodes exchange information with a distributed and WAN-based processing infrastructure like that shown in Figure 2 with key samples of enterprise functions.

The enterprise processing functions need not be concentrated at a specific physical location. The distributed processing and networking array yields redundancy, maintainability, sustainability, and flexible deployment of applications with little or no disturbance to operations or to business and management processes. Resiliency is enhanced by configuring a variety of data center and data communications facilities with specific WAN and processing array management functions.

The UGCP platform includes a redundant, high-reliability system for network-based precision time distribution required by emerging synchronized measurement and analysis functions, to eliminate dependence on a single satellite system time reference.

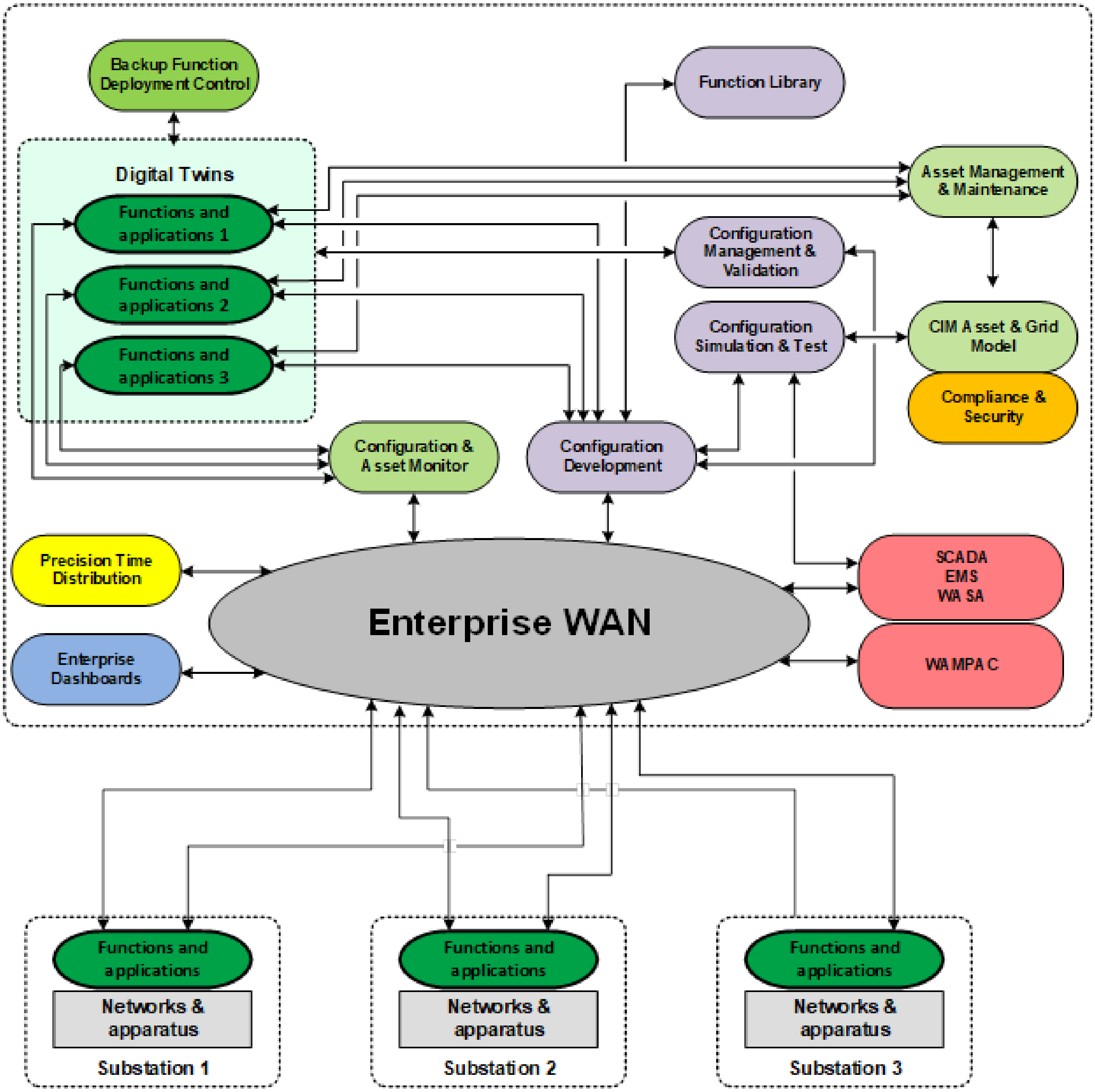

Figure 2. UGCP Overall System Configuration

The key functional elements in the Figure 2 enterprise container are as follows:

- The ***Config & Asset Monitor*** process exchanges live information on status of apps and PCM equipment with the substation – elements in normal operation versus backup and workaround modes.
- The ***Digital Twins*** element maintains mirror images of the equipment topology and app configuration in each substation, whether operating in normal or backup/workaround modes. There are also digital twins for wide-area PCM functions.
- The ***Backup Function Deployment Control*** element interacts with the digital twin status of each grid node or wide-area PCM function and determines what preconfigured alternative or backup operating configurations are to be deployed, based on failures or malfunctions, or on operational decisions and control center requests.
- The ***Configuration Development*** function can assemble new app configurations or insert new or updated apps from a managed library in an operating substation or wide-area configuration offline; and can download and start that configuration in the substation system or wide-area configuration after it has been fully validated. It uses the inherent redundancy of the UGCP to update operating app configurations without outages or disruptions of grid operations.
- The ***Function Library*** supplies to the configuration development function the managed and version-controlled array of all available apps, both familiar and newly introduced for functional updates.
- The Configuration Simulation & Test element is an offline environment for validation of changes to app configuration, including real-time simulations of situations and events based on the grid model, and its current or extreme operating states.
- The ***Configuration Management & Validation*** function ties the operating configurations of substations, grid nodes, and wide-area functions to their digital twin representations, backup adaptations, and any updates under development to track deployed and historical versions.
- The ***Asset Management & Maintenance*** functional grouping tracks all power system and UGCP infrastructure based on history and on live condition or failure inputs processed through the Digital Twins function. It can return dispatches of reconfigurations as well as triggering SME analysis or truck rolls to repair or replace, and feeds current situations to the master grid and asset model.
- The ***CIM Asset & Grid Model*** grouping maintains the database for the condition, history, and plans for all grid and UGCP assets for management, updating sustainment, and replacement. It contains the relationships and ratings of all elements to support the validation of deployed app configurations.
- The ***Compliance & Security*** element monitors the relationships and limitations imposed by regulatory or operational restrictions or modes of grid operations, to interact with the grid model and to support development of app configurations and settings that comply with all requirements and limits. Contingency simulations and tests are needed to support some compliance elements. This module includes application layer traffic monitoring and application-based anomaly detection of security intrusions with dispatching to mitigate disruption events.
- The ***SCADA EMS WASA*** element includes functions normally associated with the grid control center, although UGCP supports redundancy and separation of these functions. Supervisory Control and Data Acquisition (SCADA) comprises the first-tier observation of grid operating state and measurements, with control and mitigation actions in human operator time frames. The Energy Management System (EMS) adds an application layer of analysis, dispatching, optimization, contingency study, operational planning, and support of separate energy market functions. Wide-area situational awareness (WASA) functions overlay SCADA data with high-speed synchronized measurement-based displays and analyses of voltage profile, real and reactive power flow dynamics, grid stability, and parameters that often evolve in faster than human-observation time frames.
- The ***WAMPAC*** element represents wide-area protection, automation, and control. It includes wide-area protective relaying schemes using synchronized measurements and high-speed wide-area control for tripping for backup fault protection [1, 2], grid angular or voltage instability protection, closed loop holistic voltage profile control or energy flow control, and remedial action or system integrity protection schemes.
- The ***Enterprise Dashboards*** component comprises business applications and overall utility enterprise management functions which are able to access all raw or processed information on states, events, and situations to deliver flexible displays aimed at the needs of specific organizational stakeholders or leaders.
- The ***Precision Time Distribution*** component standardizes, delivers, and monitors reference time information flow for the entire UGCP infrastructure with sub-microsecond precision, using Ethernet network precision time protocol (PTP) and its future evolved descendants. Precision time data supports synchronized wide-area measurements and event analysis among other functions. The network-based redundant and resilient distribution system can reference global network satellite systems or calibrated precision time references but is not dependent on them for grid operations.
- The ***Enterprise WAN*** represents redundant and resilient operational and enterprise cloud communications infrastructure including operational monitoring, management, and security functions. Many mission critical UGCP functions include multiple layers of redundancy of paths and equipment. Network components like MPLS or SD-WAN routers support dispatching of many communications paths for multiple layers of failure or outage resilience exceeding any plausible chance of loss of communications for any important function. The network infrastructure can also integrate or segregate operational versus enterprise business communications to meet the needs of a utility OT-IT integration or segregation plan. The management security module detects abnormal traffic patterns and defects or can create traffic baseline definition and whitelisting as with SD-WAN.

Features and Benefits of the new UGCP architecture

UGCP is built largely on IT-world computing, communications, operating system, containerization, and remote updating/management elements whose large-scale usage across industry brings sustainability and cost reductions compared to custom-designed hardware packages with custom programming. This departs from the model of redundant single-zone or single-function IEDs to move towards a similar model to smartphones: platforms with a standard array of sensors, communications paths, and user interfaces. New and interoperable apps tie these platform elements together in new and evolving ways to deliver functions not even conceived when the platform was developed.

The unified grid control platform can deal with the unprecedented PCM challenges the industry now faces as we described in Section 1 while transforming technical performance, reliability, resiliency, operating and capital expenses, and business operations efficiency.

- Hierarchical distributed computing and data management infrastructure overarches the specific physical locations and specific data sources, removing limits on ability to process and share all primary data or processed information for any operational or business use (except for intentionally implemented security boundaries).
- Substations and generating stations remain as major nodes of the electric grid, supplemented by many new and finely grained distributed-resource and user nodes to be integrated in utility operations. Direct process interfaces – measurement and status acquisition and process control – will still be required in substations and nodes.
- The foundational principle is that any data acquisition or processing is performed only once in the overall system for all candidate users. Processing at the substation or grid node level is performed as needed for fast response, limitation of communications path capacity demands, and need to assure operation in the face of foreseen equipment or UGCP system failure contingencies. Power system interface data is processed at the highest practical level in the hierarchy. This single-source principle is augmented by redundant duplicate facilities specifically to handle multiple layers of failure contingencies which go beyond the single-point-of-failure criterion.
- Applications are built around unified electrical and asset hierarchy models of the grid infrastructure to minimize manual configuration of applications. System evolution is mapped into the models so that operating applications can adapt.
- The entire system is capable of continuous performance and functional monitoring, both end-to-end and in overlapping zones, so that maintenance and sustainment comprise remediation of diagnostic failure alarms and dashboard observations of performance bottlenecks. The system can combine its process data gathering and models of grid apparatus to monitor and historize observable power system element performance, malfunctions, and alarmable measurement issues or inconsistencies.
- The electric grid and its nodes, key UGCP elements, and application functions are modeled within UGCP as digital twins, where they are aligned with and continuously compared to real-world counterparts for performance monitoring, configuration management, and alarming of problems.
- The system is structured for in-flight testing and deployment of new applications for, monitoring, control, protection, operations, and management. Outages for updating are eliminated.

Integrating Current Electric Utility Technologies in UGCP

Industry experts and supplier teams are developing components to absorb within UGCP:

- The international standard IEC 61850, *Communication Networks and Systems for Power Utility Automation,* details the specifics for integration of PCM functions by standardized interface models of programmed functional nodes in processing environments, communicating via Ethernet messaging packets. IEC 61850 structure supports flexible location of functions distributed in a computing and data sharing platform like UGCP. It enables creation of digital twins, as well as function-level configuration processes for complete PCM systems. These capabilities are required for practical integration of fine-grained DER and monitored loads like transportation nodes. Manual configuration and maintenance of such large interconnected systems will prove to be massive unproductive work that must be automated.
- The IEC standard Common Information Model (CIM; IEC 61968 and related standard parts) offers a platform for hierarchical and relational recording and management of the properties of all grid assets including PCM.
- Utilities already operate with a range of sophisticated modeling tools for electrical behavior of the grid – operational modeling, three-phase fault analysis, dynamic performance modeling, and wideband transient behavior simulation. Unified modeling initiatives are working to integrate these into a single-source data management toolset, although practical development will continue for years.
- The industry has developed impressive capability for real-time transient modeling for hardware-in-the loop (HIL) testing of PCM hardware devices and their programmed functionality. This can be integrated within UGCP in the near term. Over time, the implementation of functions on standard platforms rather than in special boxes will move all testing into the modeling domain and reduce the need for routine operational HIL testing of equipment.
- Utilities have been increasing their use of Ethernet LAN and WAN technology including the latest transport technologies like MPLS and SD-WAN. Collaboration is improving between IT experts and application domain experts for mission-critical grid monitoring, control, protection, and operations.
- A range of new real-time functions are in constant development to handle requirements of utilities with increasing levels of DER, loss of grid inertia as inverters replace rotating machines, or other new operating stresses. New DERMS are in development and demonstration.
- Utilities have been aggressively deploying phasor measurement units (PMUs) for precise synchronized measurements to support high-rate WASA presentation to operators, with first WAMPAC functions deployed

and others in development. In UGCP, the synchronized measurements are gathered from processing of synchronized MU measurements at low marginal cost rather than from a stand-alone network of PMUs.

- Vendors serving a range of industries are also developing new large-scale data management repositories, analytic and modeling tools, and operational applications. Many of these will be adapted as functional modules in new UGCP deployments.

New UGCP Elements to Integrate

Starting with the base of existing and emerging tools just listed, developers of the overarching UGCP architecture can integrate and adapt the following elements from the general business operations and utility worlds:

- ***Cloud services*** – Today's business operations, including even mission-critical high-speed financial and network operational services and military operations, are developed for distributed computer and communications infrastructure whose specific architecture is in a layer separated from the operational design. The monitored and managed network of data centers and communications systems are dynamically and securely assigned to applications as needed – the application experts can focus only on the functions of the applications themselves and not on the computing or data transmission needs.
- ***Containerization and isolation*** – These cloud services are based on secure and managed partition of users and applications within the computing and communications infrastructure so that there is no cross-impact or cross access among users and functions. Individual apps can be managed and updated while other mission-critical functions continue to operate.
- ***Arrays of standard computers and operating systems*** – real-time operating systems are evolving to support containerized applications in arrays of general-purpose processing hardware – such as flexibly configured racks of blade servers in data centers serving other mission-critical industries.
- ***Redundancy*** – Containerization and communications path isolation do not inherently assure that there is no single point of equipment failure. However, today's networks support configuration of application containers and infrastructure to avoid failures for any plausible set of contingencies. Robust configurations are implemented and managed for mission-critical applications of other industries in the cloud today.
- ***Distributed and remote network management and security tools*** – operation of the redundant robust wide-area networks is managed today with sophisticated monitoring tools that track and report path or component performance, monitor redundant services, redeploy paths and functions to work around failures, and to contain traffic abnormalities or security breaches.
- ***Big-data processing platforms, analytic tools, artificial intelligence (AI) tools, and dashboard tools*** – a host of user-configurable processing tools support the functions of the Technical Operations Center concept described in the next section.

UGCP Enterprise Integration - Technical Operations Center (TOC)

For efficient utility operations, the UGCP architecture of Figure 2 includes databases and integration tools for tracking and management of grid and PCM assets, utility infrastructure sustainment, technical modeling and validation, event and operational analysis, maintenance and dispatching, network and platform management, operational and business management dashboards, regulatory compliance and security management, and enterprise process management.

Most of these conceptual elements are grouped as a Technical Operations Center (TOC), which is not a physical center but an integration of utility operating functions with widespread access to and controlled enterprise-wide sharing of real-time grid information and analysis results for dispatching or planning.

Example TOC functions include:

- Maintenance monitoring, performance and security management, and asset management of primary electric power apparatus, the UGCP platform, and of substation and grid communications networks including the operational WAN and mission critical PCM communications.
- Operational tracking for operation counts, operation timing, system-state validation, measurement and state comparisons, and alarming of data misalignments and failures.
- Event data reporting and situational awareness advice for operators, engineers, and regulators.
- Unified organizational database with electrical and physical modeling of the grid and its components for the full range of operational, configuration/settings and asset management.
- Configuration management and change validation for updating for all UGCP apps and systems. This includes requirements for application checking, secure remote updating, restarting, validation, and error recovery.
- Management and operation of IEC 61850-based PCM system configuration tools and expertise based on IEC 61850 6 Substation Configuration Language (SCL), which automatically arranges functional data exchanges among substation relays and IEDs. SCL eliminates substation control-building point-to-point wiring and most mapping of communicated data points.
- Field crew dispatch for repair and troubleshooting, with preparations driven by effective diagnosis and assessment of the dispatch mission.
- Site access and physical security monitoring with remote access control, monitoring, and historizing.
- Operational support including outage and maintenance clearance management for control centers and field crews.
- Resources to configure real-time management dashboard presentations, combined with tools for training of users for all TOC functions.
- TOC management - key performance indicators (KPIs) & metrics based on service level agreements (SLAs).

Cybersecurity

Cybersecurity, along with physical and operational security, will always be a central focus for UGCP as it employs distributed computing systems and communications. Security management is a function built into the substation and system monitoring, including traffic monitoring and analysis, role-based access security, incident handling, and functional validation of application data integrity. UGCP will utilize ongoing advances in centrally managed security practices, advancing beyond today's role-based access to systems to multi-factor authentication, situational analysis, and resilient rotating key-based authentication and encryption of PCM message packets. Redundant systems can be isolated with combinations of virtual and physical equipment barriers in installations and separated communications paths with hot standby capabilities. UGCP design will evolve constantly to remain resistant to new threats as they arise.

UGCP Business Benefits Summary

1. UGCP achieves lowest long-term cost by leveraging high-bandwidth IT industry equipment and solutions to replace rigid custom-designed substation IEDs. Platforms evolve to achieve sustainability.
2. Containerized applications (apps) are routinely added and integrated or updated in an operating configuration without outages. New or modified apps are fully tested and validated within UGCP before deployment in a live operating system.
3. Functional performance, configuration, integrity, security, and compliance are continuously monitored, modeled in digital twins, assessed, and managed from the distributed Technical Operations Center facility of the enterprise. Most issues are handled remotely as resilient backup keeps the grid operating; there are no hidden failures. Trucks roll for hands-on substation visits only to replace or install hardware or to repair disaster damage.
4. UGCP can deliver complete operating, event, and management information for the enterprise on every level and for every detail for which an application can be created.
5. Complete information tracking and analytic applications result in continuous business improvement. Asset management and supply chain organizations will streamline their operations based on highly standardized equipment.

Utilities will need to evolve the functions of the organization to align with the new business model for UGCP systems and take full advantage of the benefits listed above. They will need to train personnel to operate and sustain these systems.

Roadmap for UGCP Advancement

The existence of platform components and tools today gives utility R&D teams the opportunity to begin construction and demonstration of UGCP in stages, showing the industry the practical implementation of the concepts explained in this article. A practical series of stages is as follows:

1. Develop a specification for specific components, platforms, communications, operating environments, and functions for a UGCP demonstration.
2. Map specifications to a demonstration substation and wide-area network design.
3. Assemble and integrate a digital substation test platform in a laboratory as shown for a Test Area in Figure 4.
4. Develop and test a demonstration set of substation functions on the general-purpose computing platforms, environments, and communications network.
5. Create additional substation or grid node platforms in diverse locations and interconnect with realistic communications.
6. Integrate one or two computing platforms or distributed environments for demonstration of centralized functions.
7. Develop in sequence, a set of demonstration wide area functions including high speed PCM, data archiving, and Technical Operations Center functions from the list in Section 8 above.
8. Create specifications for a practical industry UGCP architecture and environment based on development experience. Level of detail and determination of critical points of specificity versus design choices are critical to success and industry absorption.
9. Plan and support industry adoption and commercial development of a production UGCP based on specifications and demonstrated designs.

Call to Action

Controlling, monitoring, and protecting electric grids with assemblies of functional racks and special-purpose data processing devices will not be a sustainable approach as we face the changes resulting from the emerging carbon-free grid. Utilities will accumulate a massive, unreliable, and ultimately unmanageable array of point solutions whose functions were needed at the time of installation. There is therefore more risk in keeping up the old technology than adapting to UGCP principles given here.

Key elements of UGCP design are already available from other mission-critical industries, as well as from advanced development work on components already taking place in the electric utility industry. The next step, possible today, is to start implementing UGCP designs. Section 11 describes the high-level steps by which trial UGCP substation platforms can be assembled and demonstrated in research projects. These platforms can then be integrated in wide-area UGCP demonstration arrays with sample functions. Readily available IT equipment, computing, application, and communications products can then support the evolution of a fully functional UGCP. Industry forums and standards committees must coordinate a single design and deployment approach to maximize the economic and functional benefits.

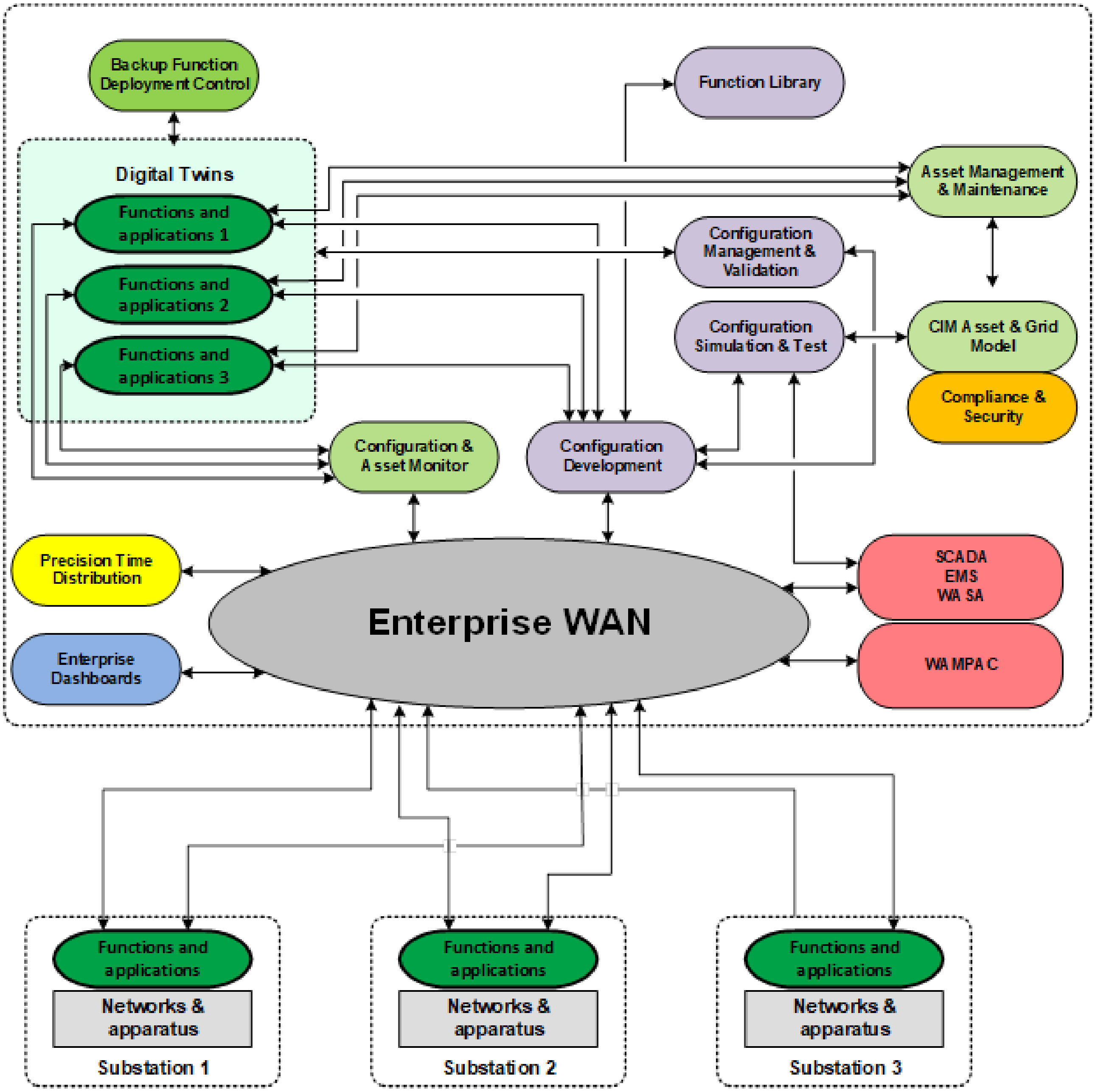

Figure 3. UGCP Demonstration Array

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