WHITE PAPER

SCADA for renewable energy and water applications

Supervisory control and data acquisition (SCADA) is the most widely used automation system for renewable energy and water applications worldwide. Its flexibility and scalability make it ideal for the entire spectrum of clean power and water installations, be they locally or remotely operated plants, fleets or networks.

But what sort of SCADA platform should a company or utility choose for a solar power plant, wind park, water distribution or transmission network, pumping station or fleet of unmanned hydropower or renewable energy plants?

We try to answer that question in this white paper by explaining in brief what a typical SCADA system is and does and which capabilities and functionalities the SCADA platform should offer the customer and different types of user.

What is a SCADA system?

A supervisory control and data acquisition (SCADA) system comprises hardware and software that monitor and control plant, network and process equipment in local or remote operations. It gathers and processes real-time data from those operations, interacts directly with process equipment through a human-machine interface (HMI), stores process values and events locally, and forwards that data via concentrators for consolidation and use centrally.

SCADA systems are used for a broad range of applications, including power and water, oil and gas pipelines, food and beverage plants, building automation and data centers, and manufacturing facilities.

Thanks to its flexibility and scalability, SCADA is the automation system of choice for renewable energy and water applications - from simple configurations like small solar photovoltaic plants to large, complex installations of multiple plants or networks across a geographically dispersed area.

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01 SCADA is the system of choice for renewable energy and water applications

Water and infrastructure
Water distribution
Water transmission
Wastewater treatment
Water treatment
Remote pumping stations
Flood protection
Tunnel automation

Renewable energy
Hydropower plants
Solar PV plants
Solar CSP plants
Wind power automation

The components of a SCADA system

1. Remote terminal units and programmable logic controllers
Remote terminal units (RTUs) and programmable logic controllers (PLCs) are microcomputers that are deployed across the site or sites that the SCADA system controls. They communicate with site equipment and objects such as pumps and valves, solar panels and inverters, motors and variable speed drives, sensors and HMIs, and then route the data from those objects to computers or servers with SCADA software. They also receive control commands from the SCADA server and pass those commands to the relevant field objects. Many RTUs store the data in their database and wait for a request from the SCADA server to transmit the data.

2. SCADA servers
SCADA servers are either a dedicated computer or a network server that communicates with the RTUs and PLCs. They initiate all communication, collect and store the data, provide interfaces for userrs and send the information to other systems.

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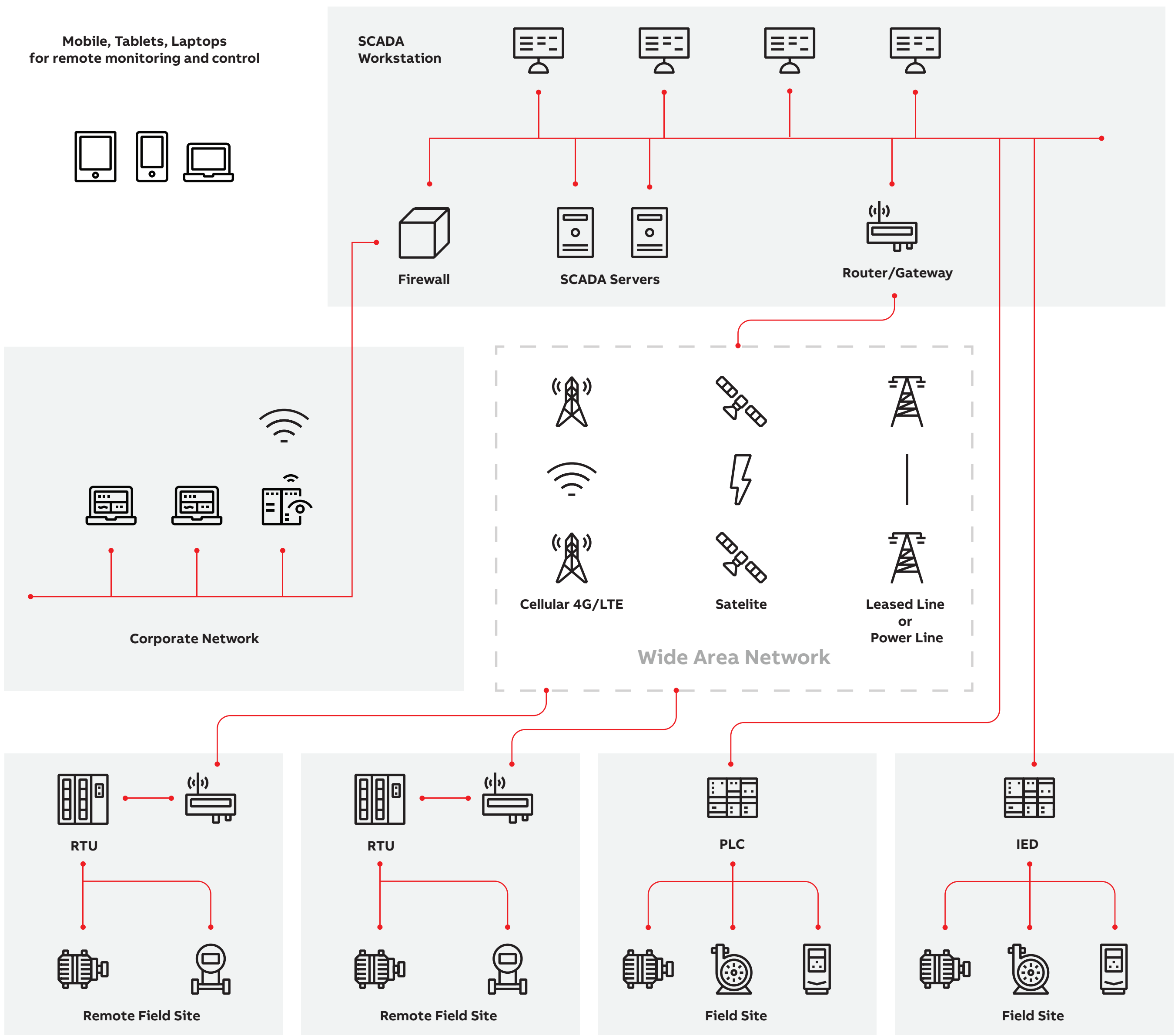
02 A typical small-scale SCADA system



SCADA servers allow users to perform control functions on field objects. They continuously communicate with other objects within the server - such as the graphical interface and security system - to facilitate data logging, alarm processing, trending and reporting.

3. Communication equipment and networks
The communication network provides the link between the RTUs and PLCs in the field and the SCADA server in the control center. It provides bidirectional communication between RTUs, PLCs and the SCADA servers.

SCADA systems can be connected using various communication media such as twisted pair cables, coaxial metal cables, fiber-optic cables, satellites, high frequency radio, telephone lines or microwave radio.

4. SCADA workstations
SCADA workstations present the data to the user and allow them to intervene in process control.

The SCADA workstation hosts the HMI for operations. The HMI provides the operator with graphical representation of field parameters and alarm generators that visualize normal and abnormal process conditions and produce a permanent record of analog and discrete variables.

SCADA systems are evolving with new technologies

New hardware and software technologies are changing the way automation systems are designed and companies operate. Some of the key technologies that leading vendors like ABB are incorporating into SCADA systems include the cloud, virtualization, mobility, big data analytics, and other enablers of the Industrial Internet of Things.

The convergence of information technology (IT) and SCADA operations technology (OT) has made SCADA a more integrated part of overall operations. Technology drivers such as industrial Ethernet networks, wireless mobile applications and wireless networks for plants are tying SCADA to other business systems, such as performance software, electronic work instructions, geographical information systems, asset management, computerized maintenance management systems, standard operating procedures, and hydraulic modeling software.

SCADA systems are also aligning with standard networking technologies, with Ethernet and TCP/IP-based protocols replacing older proprietary standards. Increasingly, a de facto-standard OPC server (OPC UA in particular) is being packaged with SCADA platform software.

What should you look for in a SCADA platform?

In addition to its two traditional functions of supervisory control and data acquisition, a SCADA platform should have the flexibility and scalability to meet all user and application requirements, from the simplest to the most complex.

This includes all the new technologies associated with the Industrial Internet of Things, third-party information system integration and cyber security.

Not all users require the full spectrum of features and functionalities, but a platform that offers that scope allows users to integrate easily new features as their needs evolve and budget allows, without having to change platform.

ABB advises customers to choose a highly scalable and field-proven platform that offers the following key features for greater user awareness, faster response and better decisions:

- **Flexible and scalable system architecture** to support a broad range of applications and requirements
- **Remote monitoring and control** from the central control room to geographically distributed sites
- **Data acquisition and control** using integrated standard communication protocols to connect to multiple different systems
- **High-performance HMI** with centralized, consolidated view of entire network operations
- **Abnormal situation awareness with advanced alarm management** based on EEMUA 191 and ISA 18.2 requirements
- **Integrated information management** that transforms data into meaningful information for real-time business decisions
- **Mobile operations** to access data anytime and from anywhere
- **Integrated GIS** for interactive exploration of spatial and process information
- **Edge computing and big data analytics** platform for predictive analysis and cloud computing
- **Engineering** that offers all the functionality necessary to efficiently engineer, configure, administer, secure, commission and maintain any SCADA system component
- **Easy integration with third-party systems** to enable data sharing with enterprise level systems such as manufacturing execution (MES) and distributed control
- **Built-in security** to ensure a secure and reliable operations environment

1. Flexible and scalable system architecture

Because SCADA applications are usually geographically distributed and grow in size over time, a SCADA system's architecture should be distributed, flexible and scalable.

Distributed architecture
For geographically distributed applications, SCADA systems are designed with a multi-nodal and hierarchal architecture.

In water distribution networks, for instance, a single SCADA system manages the entire network from a central location, using data from field equipment deployed throughout the city or region.

In fleet applications such as hydropower, on the other hand, each plant has a resident SCADA system, which is connected to a central control center for overall fleet management. The hierarchal server architecture allows each resident SCADA system to send signals to the central SCADA, which monitors and controls each plant through the SCADA server (Figure 03).

Flexible architecture
SCADA system architecture must be highly flexible so that It can adapt to different application requirements. For a small water treatment plant, a SCADA server can be deployed on a single node, on which all system functionalities run. The server's processing power and data storage capacity are, however, limited. Many small and non-critical

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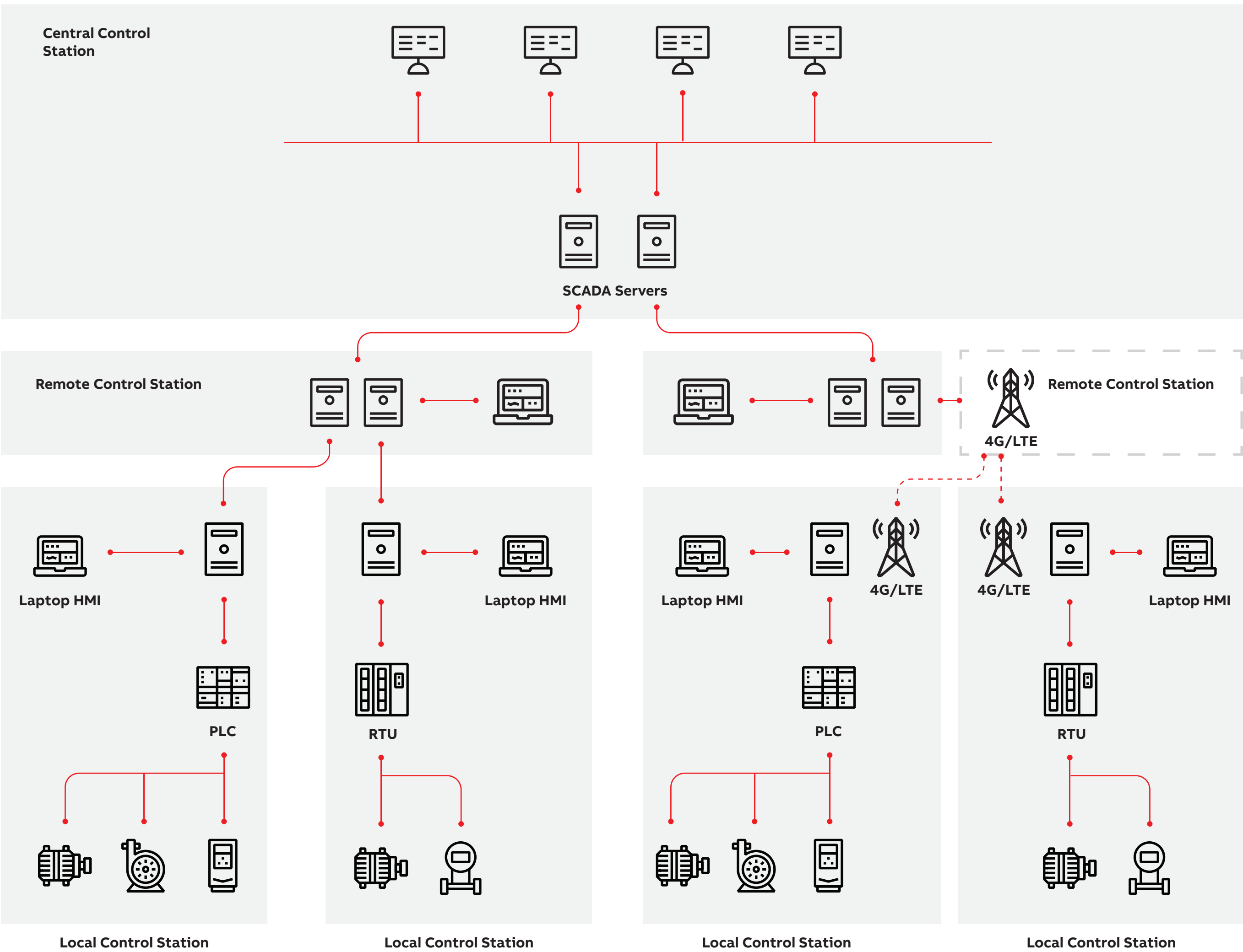
03 Distributed hierarchal SCADA architecture



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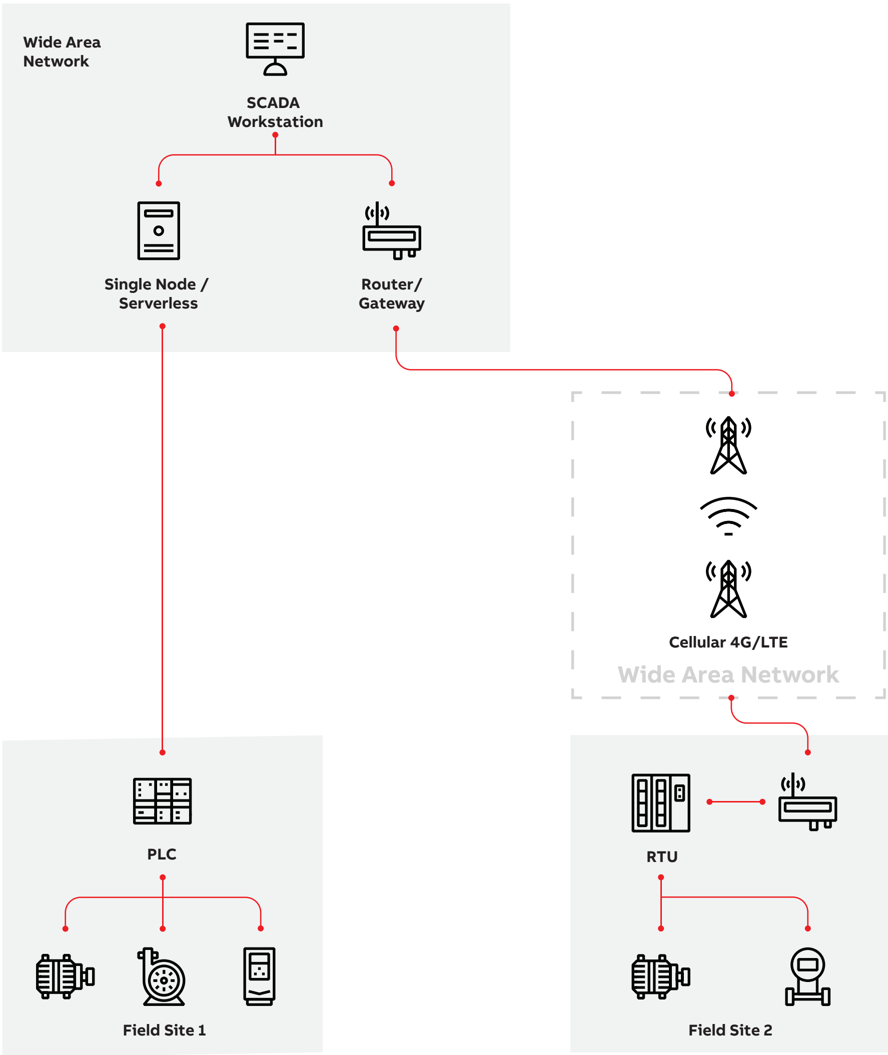
04 Single node or serverless architecture



applications, like small solar photovoltaic plants, where plant monitoring is the main requirement use such an architecture (Figure 04).

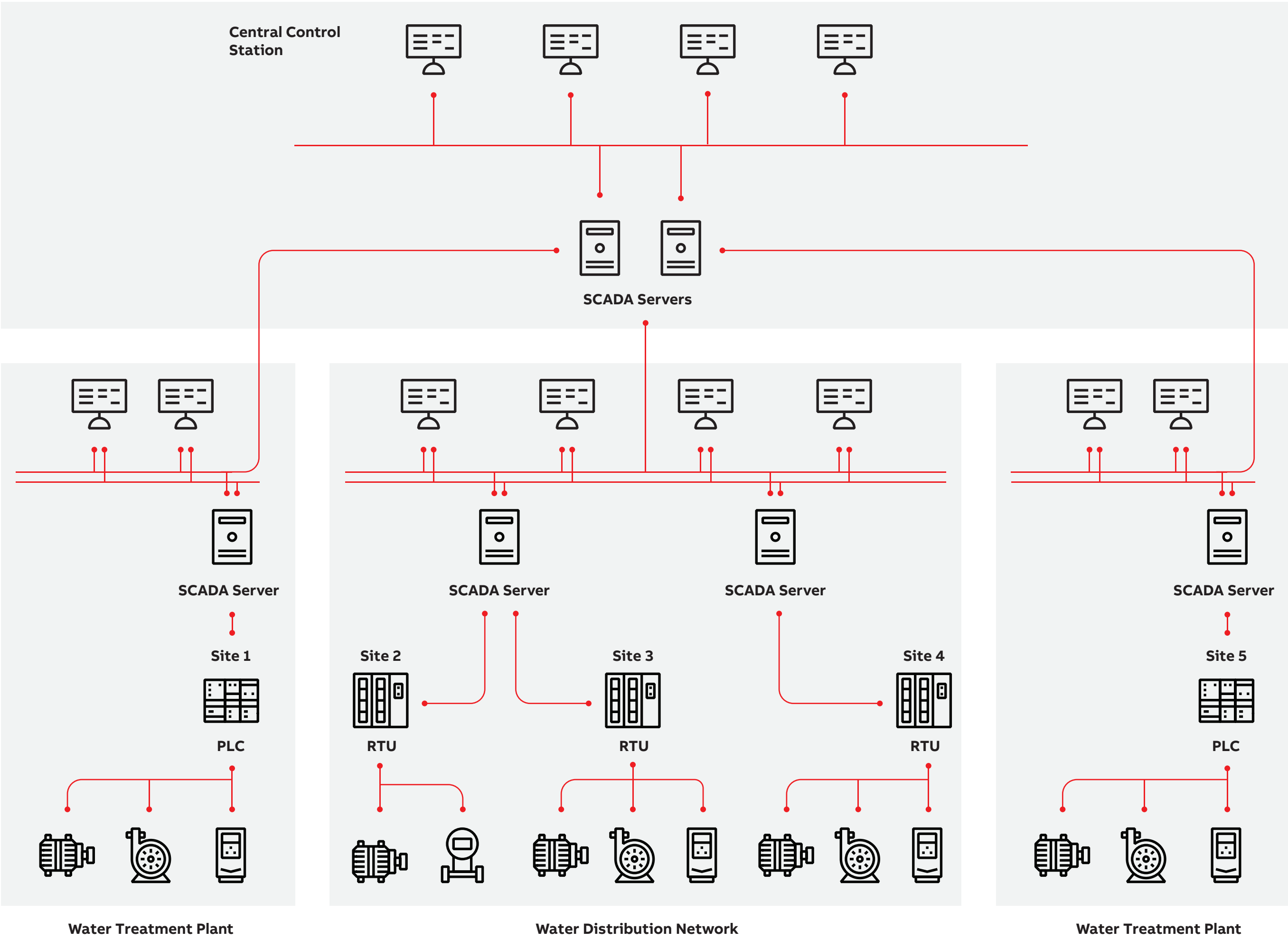
SCADA system architectures should include a redundancy scheme to ensure reliable operations. Redundancy can be deployed at all levels depending on the criticality of the process, including data acquisition, SCADA servers and SCADA workstations (it should be possible for SCADA servers to be redundant for other SCADA servers). Redundancy can also act as a disaster recovery system - if a fire or flood disables one control center, the redundant control center can seamlessly take over its operation.

Some applications require architectures like multi-master, where multiple SCADA servers can act as the master server for geographically distributed plants like remote pumping stations. In such architectures data are acquired from each pumping station and stored in all the SCADA servers. Other applications require multiple SCADA servers connected in a hierarchal architecture to transmit data up to the central control room and control commands down to the field instruments.

Scalable architecture
A SCADA system should offer unlimited scalability. It should be easy to grow the system as needs evolve over time, expanding it into previously unforeseen areas and integrating it with other systems that may or may not already exist.
For instance, it should be possible to evolve the system from small to large by increasing the number of SCADA servers, clients and field equipment and by expanding from a single application to a network of multiple facilities.

It should also be possible to scale the system vertically and horizontally: vertically by integrating enterprise level systems such as enterprise resource planning, supply chain automation and enterprise asset management; horizontally by integrating peer level systems such as historian, manufacturing execution, distributed control, workflow and mobility solutions.

A SCADA system that evolves from a single site to multiple sites or regions must allow for diversity of languages and regulations, without impacting usability and performance. For example, a small SCADA system for water treatment should be able to grow over time into a system that handles multiple water and wastewater treatment plants and water distribution networks across a wide geographic area (Figure 05).



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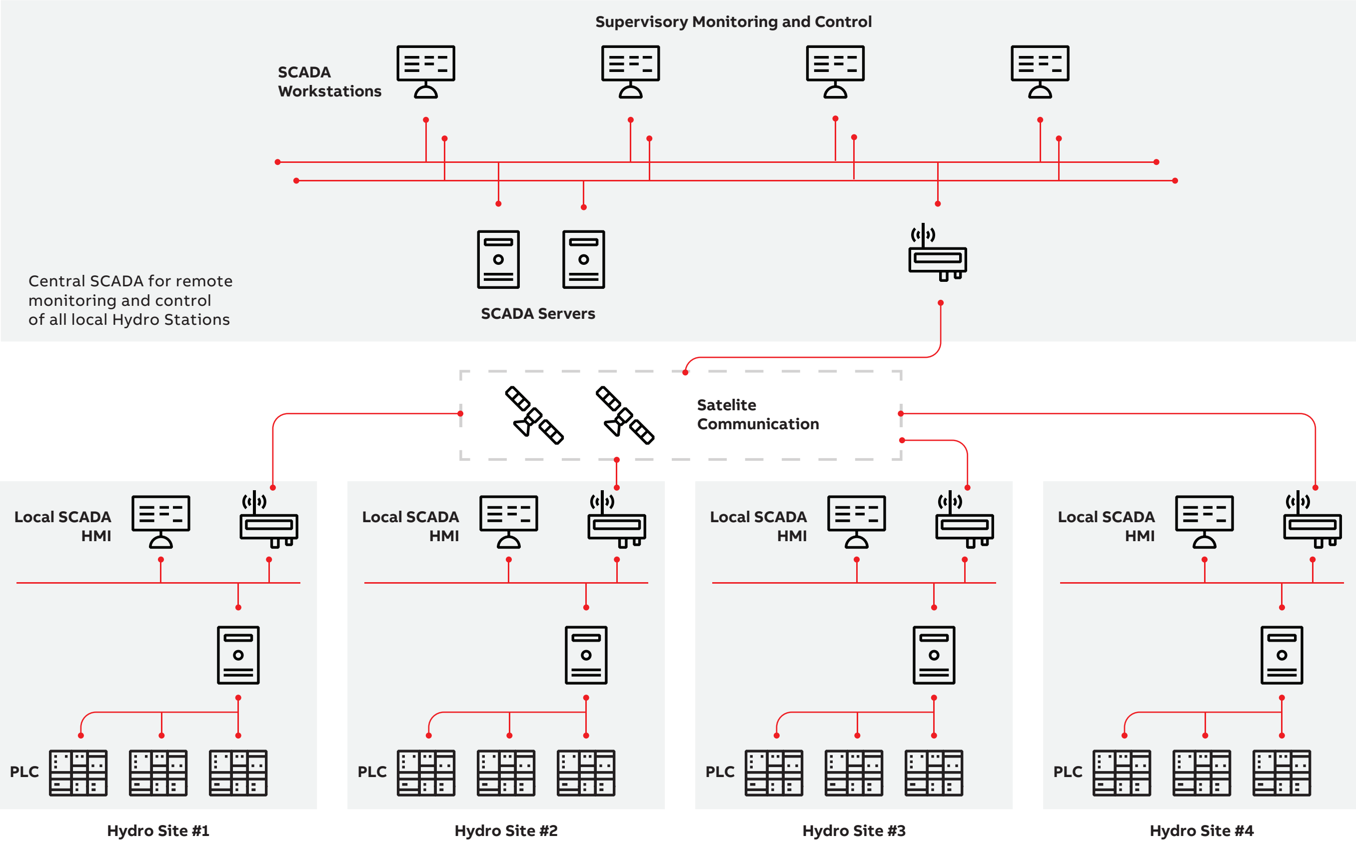
05 A scalable SCADA system

2. Remote monitoring and control

In SCADA systems, a central control center sends control instructions, such as set points and discrete commands, to remote stations. At the remote stations, RTUs receive the instructions and apply control of the appropriate field devices. Supervisory central control includes selecting the remote station or stations and the devices to be controlled and then executing the desired command. Most SCADA systems employ the select-before-operate method to ensure the correct devices are selected and operated in the remote stations.

In some applications, however, the central SCADA system is used to monitor, rather than control, devices in remote locations. For instance, each site in a fleet of geographically distributed hydropower plants is controlled locally. The central control center supervises the plant fleet and takes control of a plant only if necessary. To do so, the central location must be able to issue commands seamlessly to local field devices (so-called command propagation). It must also manage command sessions and communication protocol conversion, preserve loss of data when communication between the central and remote station is interrupted, and be able to select-before-operate (Figure 06).

For solar photovoltaic plants and solar field trackers, wide-scale monitoring with limited control is required. These applications are not process critical and do not need safety systems or high availability. The emphasis is on cost effectiveness. In such applications, the principal need is to aggregate more and more data at the central SCADA station. Since these plants can keep adding solar panels over time, the SCADA system must be able to



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06 Supervisory control of geographically distributed hydropower plants

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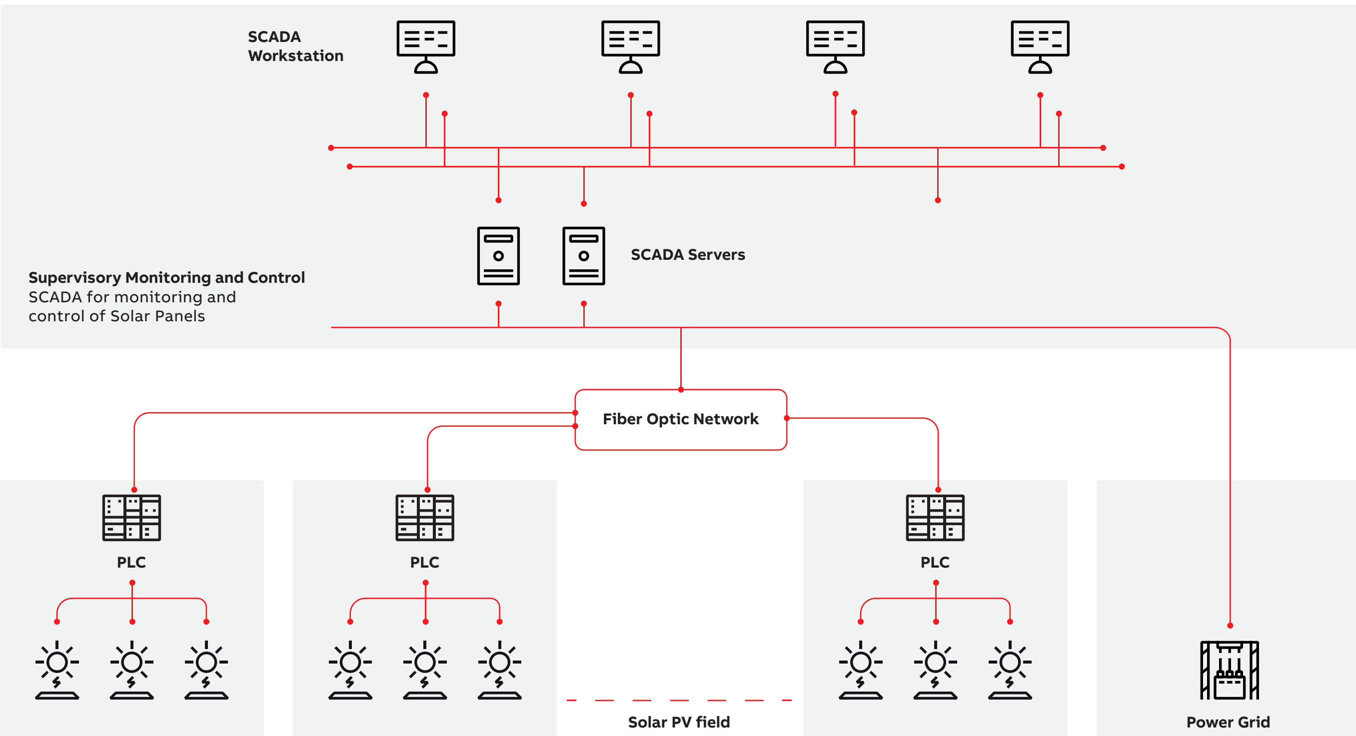
07 Supervisory monitoring of solar photovoltaic plants

address growing capacity requirements by (1) increasing data acquisition and processing capacity, (2) providing more complex visualization of process data handling, such as process graphics with multi-layer visualization, and (3) increasing the number of trends and historian software components (Figure 07).

In a multi-master SCADA system, it is important to be able to switch control of the entire system from one local server to another. In a fleet of remote pumping stations, for example, each station is controlled by its own local SCADA server that can also act as the master server for the whole system. This type of application requires point of control functionality, which allows a station server to take temporary control of another station server over which it usually does not have jurisdiction (Figure 08).



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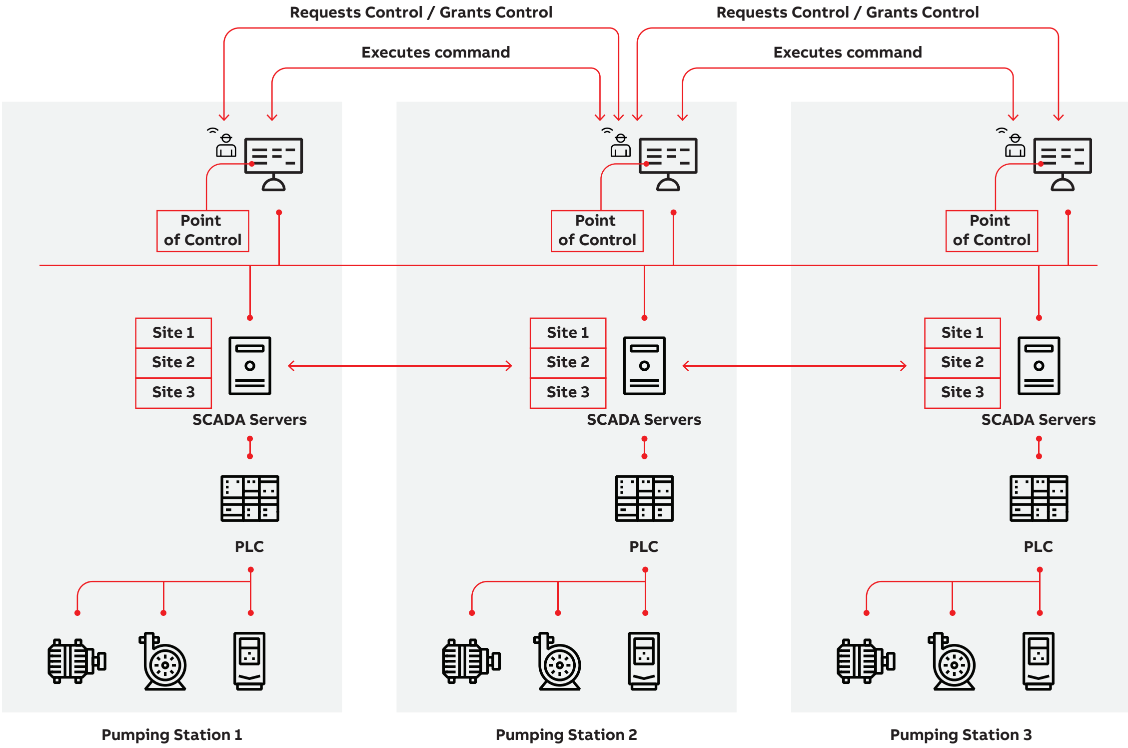
08 Distribution of control in group of pumping stations



In network-centric applications like water distribution networks or water transmission lines, visualization of the complete network with its zones and field devices is crucial. The SCADA system should therefore have an integrated geographical information system and provide seamless navigation between map objects and control objects to make operations effective (Figure 09; see also section 8 below on Integrated GIS.)

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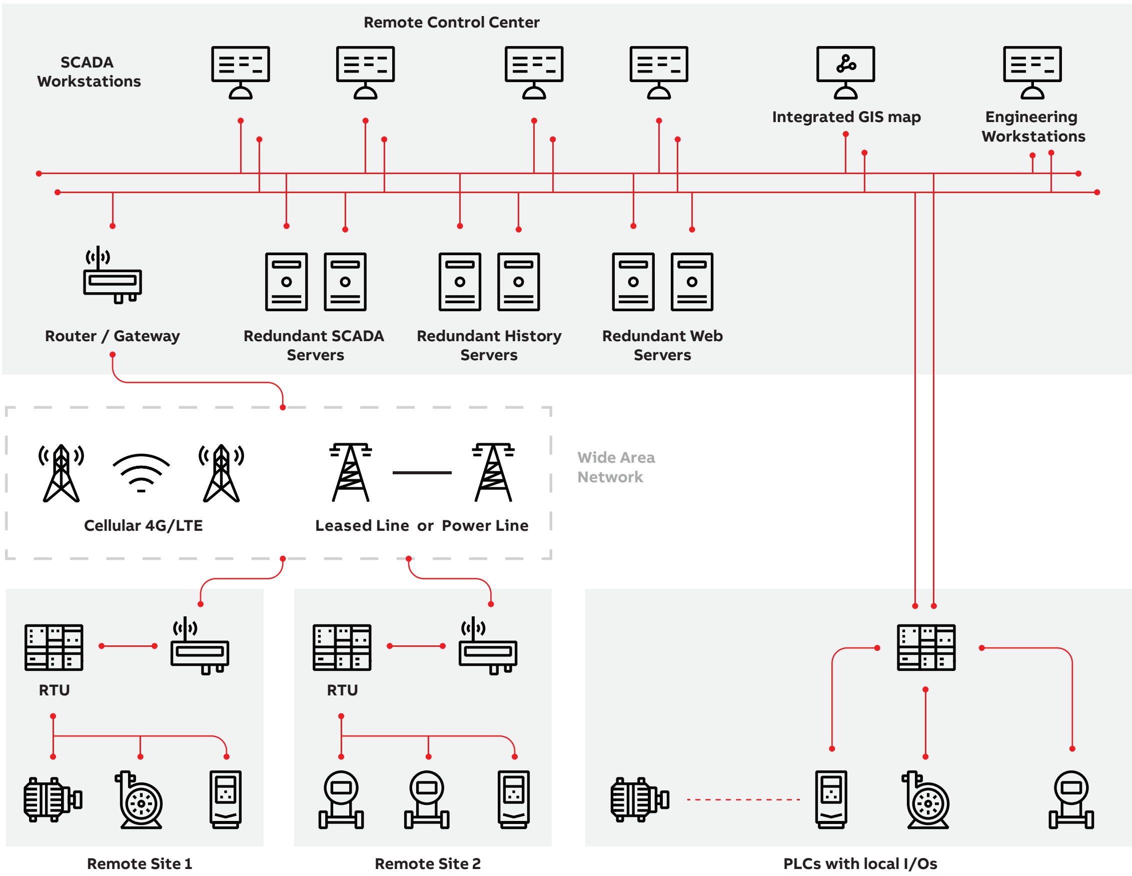
09 Supervisory monitoring and control of a water distribution network



3. Data acquisition and control

A SCADA system typically acquires and processes data from thousands of RTUs and PLCs in multiple facilities across a large geographic area. These devices are usually provided by different vendors, often using different means of communication. A SCADA system should, therefore, interface with all standard communication protocols - including IEC 60870-5-104, OPC, Modbus TCP and IEC 61850 - to communicate with all brands of PLC, RTU and IED in the field and provide complete process, device and electrical integration (Figure 10). Electrical integration is especially important in solar and hydro applications, where it provides visibility and control of the whole plant or network and avoids the cost and inefficiency of installing and operating a separate electrical control system.

Most importantly, the SCADA system should present the data in one consistent and familiar operator environment, regardless of the underlying control system, thereby providing complete visibility into the control process from a single intuitively operated workstation.

The SCADA system should have a polling engine to scan periodically the internal database of the field devices and transfer the data to a SCADA server. Ideally, it should be able to scan thousands of devices from a single server, thereby reducing the cost and complexity of scanning large solar fields, wind farms or water networks compared to platforms that require multiple servers. Because SCADA systems typically communicate with PLCs and RTUs through WAN technologies like 3G, 4G, GPRS, the Internet or satellite – in which interruptions are likely – it is important that the SCADA system stores field data in the server during the disturbance and forwards the data to the central historian when communication is re-established (so-called data buffering).

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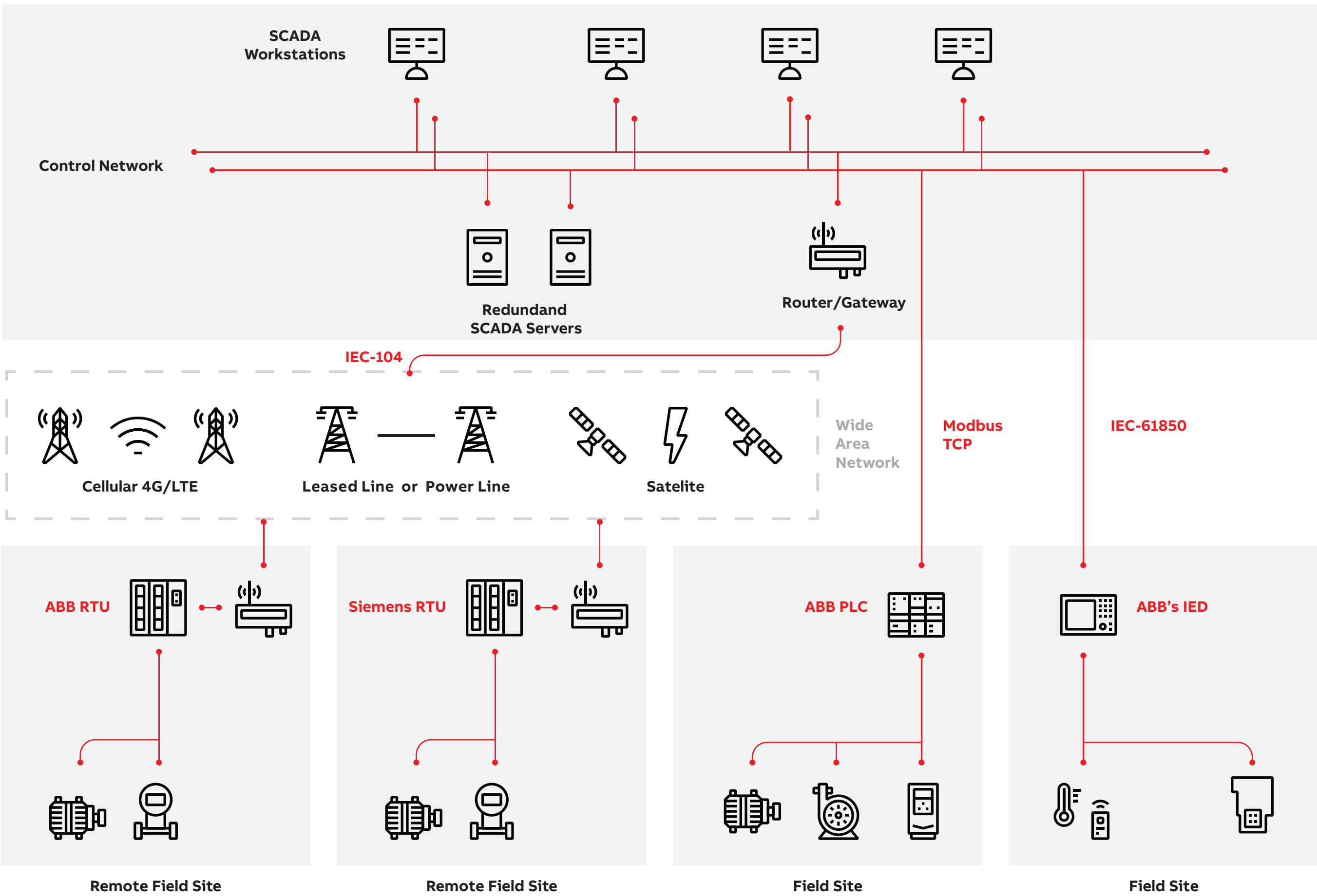
10 Open communication with the RTUs and PLCs of multiple vendors



4. High-performance HMI

Operators – the people who monitor and control the plant, fleet or network – are among a company's most valuable assets. Their ability to make the correct decision at the right time has an immediate effect on productivity, safety and reliability. An essential tool to maximize operator effectiveness is a high-performance human machine interface (HMI).

High-performance HMIs combine fast, intuitive navigation with ergonomic design, simplified graphics and integrated alarm management, all of which help eliminate information overload and heighten operator awareness. They enable each operator – as well as other types of user in management, engineering and maintenance - to personalize their workplace and ensure they are presented only with the information they require, and in its proper context. This leads to greater detection of abnormal situations.

With a high-performance HMI, users can easily assess plant and network health, track critical process values and identify trending situations, which can then be monitored or diagnosed by drilling down to lower level displays – system, subsystem and root-cause diagnostics. Different parts of the process or network can be displayed on multiple screens or split into several windows that can be viewed simultaneously on a single monitor.

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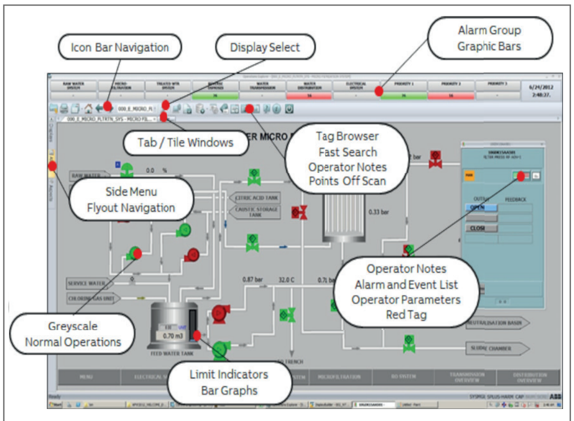
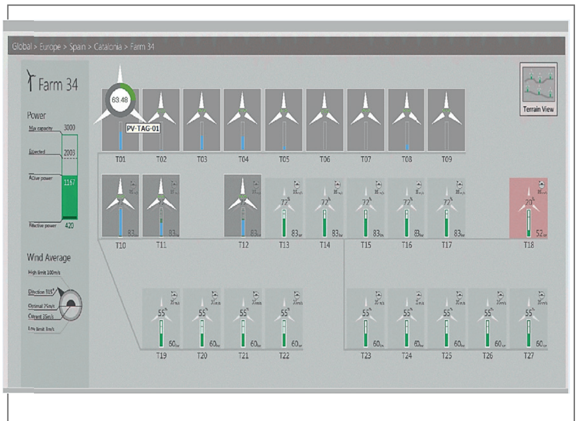
11 Screenshots of a high-performance HMI

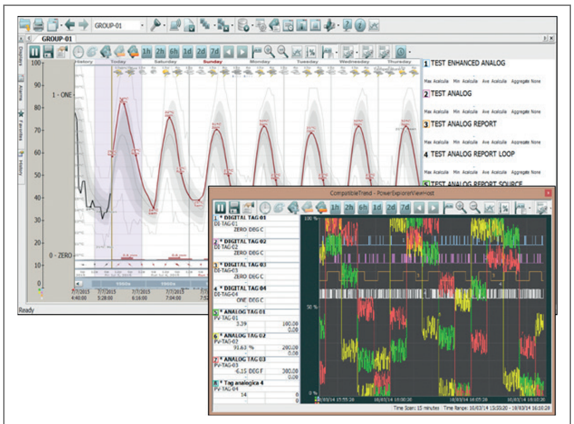


Ergonomic design



Multi-layered Process graphics

Personalized workplace



Advanced Trending

5. Advanced alarm management

Another key feature of a high-performance HMI is that alarm management is embedded in the HMI. Research shows that operators are five times more likely to detect abnormal situations before an alarm occurs – and solve the problem in half the time - than with conventional HMIs that require separate alarm systems.

High-performance HMIs not only make abnormal situations immediately visible on the screen, they also eliminate the hundreds of non-critical or nuisance alarms that compete for the operator's attention in a conventional alarm management system.
Advanced alarm handling and analysis is only effective in concert with an alarm management strategy for each facility or network. The strategy should follow international standards and guidelines like ISA SP 18.2 and EEMUA 191, and it should define the key performance indicators (KPIs) of the alarm system and measure performance against ISA and EEMUA benchmarks.

The combination of an advanced alarm management system, integrated with the plant's high-performance HMI, enables the facility to meet the four principles of effective alarm management:

- Each alarm should alert, inform and guide
- Alarms should be presented at a rate that operators can deal with
- Detectable problems should be alarmed as early as possible
- The cost and benefit of alarm engineering should be reasonable.

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12 Real-time alarm analysis tools in a high-performance HMI

6. Integrated information management

Operational and business decisions depend on having the right information in the right hands at the right time and in the right context. Operators, engineers, maintenance staff, managers and executives have different requirements and viewing preferences for facility information. A fully integrated information management system can support all of them and help each user make timely and correct decisions.

An effective integrated information management system should aggregate data from multiple sources and enable users to view it in formats that make sense to them. Management should be able to track KPIs with or without historical trending. Operators need to seamlessly view both real-time and historical trend data, as well as alarms and events, in a format that enables them to respond quickly and appropriately. And maintenance supervisors want to monitor equipment performance trends and align predictive maintenance with personnel.

An efficient SCADA platform should, therefore, collect data not only from RTUs, PLCs and IEDs, but from other information systems and databases across the facility or enterprise as well. And it should present this data as actionable information on the desktop displays or mobile devices of the right person and in the right context at the right time.

7. Mobile operations

While working in the field or on the move, users need to view SCADA information with mobile devices – laptops, smartphones or tablets. They need to access process conditions, trends, alarms and events and performance dashboards, and be able to compare real-time and historical data simultaneously in one display.

ABB's touch-based Pocket Portal, for instance, puts process data at the user's fingertips. This fully HTML5 web-based application works with any platform (Microsoft, Android, etc.) and any browser and uses protocol encryption and user access control to ensure security. It integrates other mobile apps to support live data visualization of SCADA information, QR Code scanning for maintenance personnel and a safety app to report hazards observed in the field.

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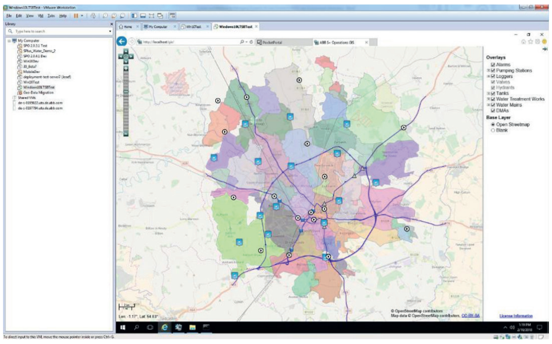
13 Process graphics on a mobile device

8. Integrated GIS



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14 Integrated GIS maps in a SCADA system

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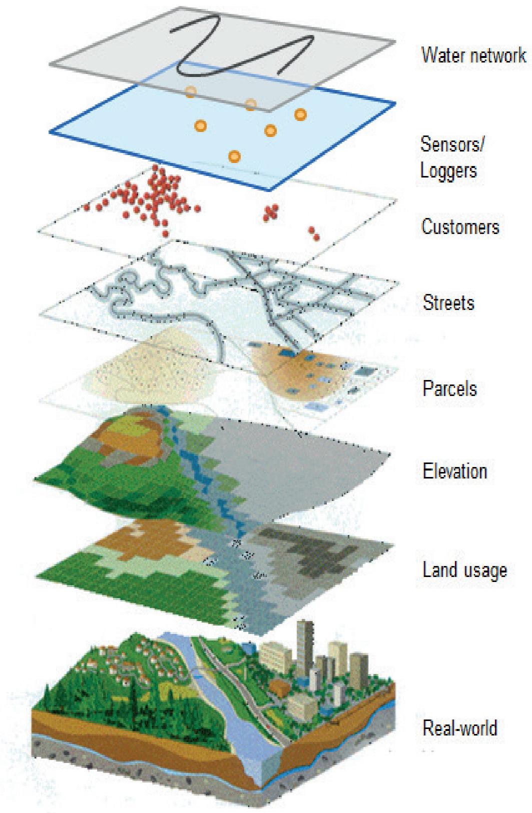
15 Preconfigured GIS layers to visualize networks and assets at multiple levels

A geographical information system (GIS) enables interactive exploration of spatial and process information in wide area applications like hydropower plants and water distribution networks. Traditionally, utilities have purchased and run the two systems separately. Only a few SCADA systems, like ABB's Symphony Plus SCADA, offer the user-friendly benefits of a fully integrated GIS that meet the operational requirements of small and large power and water installations alike.

These benefits include:

- integration of GIS mapping services like ESRI ArcGIS, Google Maps, Microsoft Bing and OpenStreetMap typically used by utilities at their facilities (Figure 14); and
- customizable preconfigured GIS layers, which allow users to pan and zoom over the map of the entire network and visualize the location of assets - pipes, valves, tanks, pumping stations, water treatment works, etc. - without leaving the operations environment. With simple one-click navigation between the two, the time required for spatial investigations is significantly reduced and overall network management improved (Figure 15).



9. Edge computing and big data analytics

Digitalization and the Industrial Internet of Things are driving the power and water industries to new levels of performance, productivity and safety. Many utilities have already embarked on their digital transformation and are reaping the huge benefits that digitalization brings.

The SCADA system is part of that process. The vendor platform it is built on should have the capability to converge operational technology (SCADA or distributed control systems) and information technologies (data processing and management). It should be able to collect, store and analyze data either in the cloud (a datacenter) or on the edge (on-premise), or both – according to company security requirements. Not only should it capture operational data but enable users to visualize and understand the data in real time and translate it into timely and correct decisions that improve plant or network performance.

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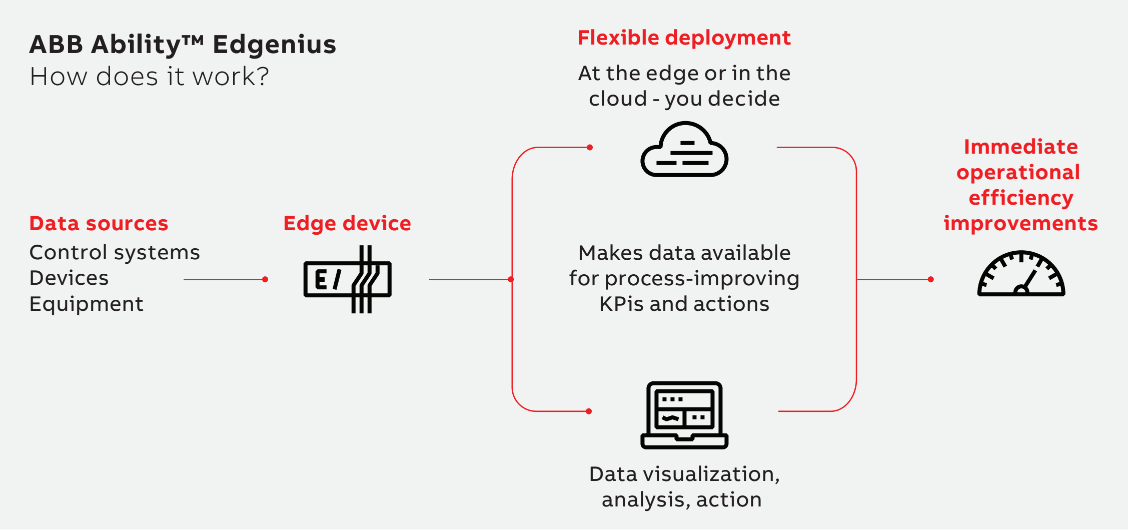
16 Symphony Plus SCADA offers cloud and edge computing through the ABB Ability Edgenius platform



10. Engineering

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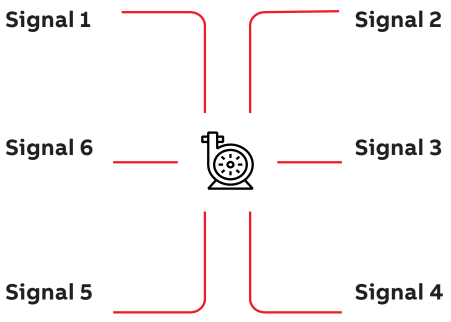
17 Object-based engineering (1)

Most SCADA customers operate in cost-sensitive and highly competitive markets. Engineering – which accounts for a significant amount of the cost of the system – should therefore be simple, streamlined and repeatable. It should be object-based, include bulk engineering templates to achieve greater efficiency and maximum repeatability, and use standardized languages. Installation and configuration should be fast and easy. In object-based engineering, each field device is modeled as an object and related measuring points and signals are engineered as atoms (Figure 17).

For example, a pump is engineered as an object and its I/O signals are engineered as atoms (Figure 18).



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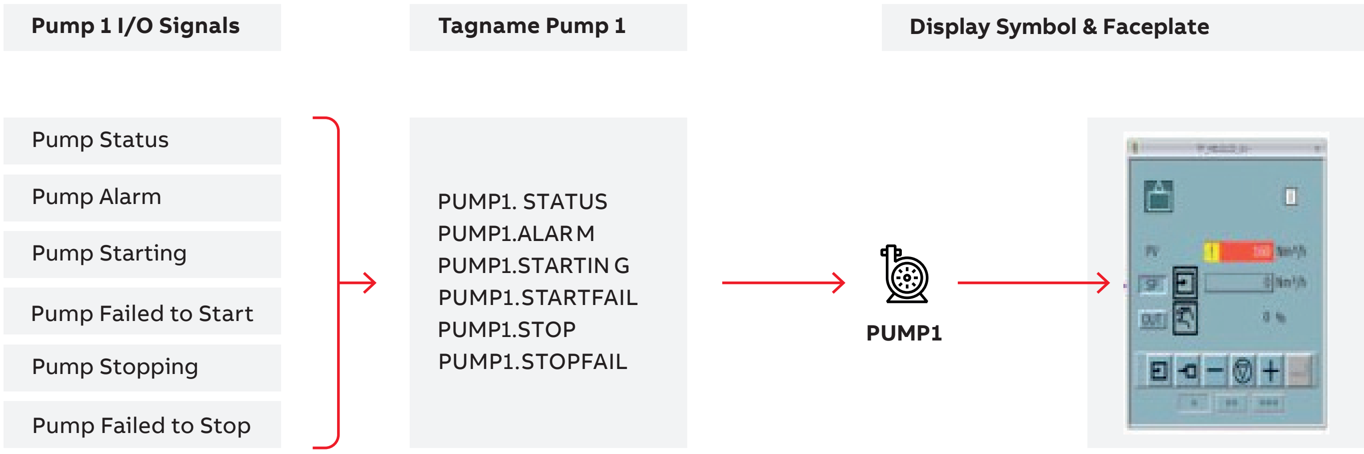
18 Object-based engineering (2)



This approach minimizes project engineering costs, even more so if the customer selects a SCADA vendor that provides preconfigured RTU, PLC and SCADA server applications. With such a vendor the only engineering task remaining is to instantiate objects (pumps, motors, etc.) based on the customer's signal list and/or instantiate signals based on the number of objects.

For instance, in the example below, the customer provides a list of signals and the SCADA engineering tools convert the signals to tags using predefined or customized object models in bulk (Figure 19).

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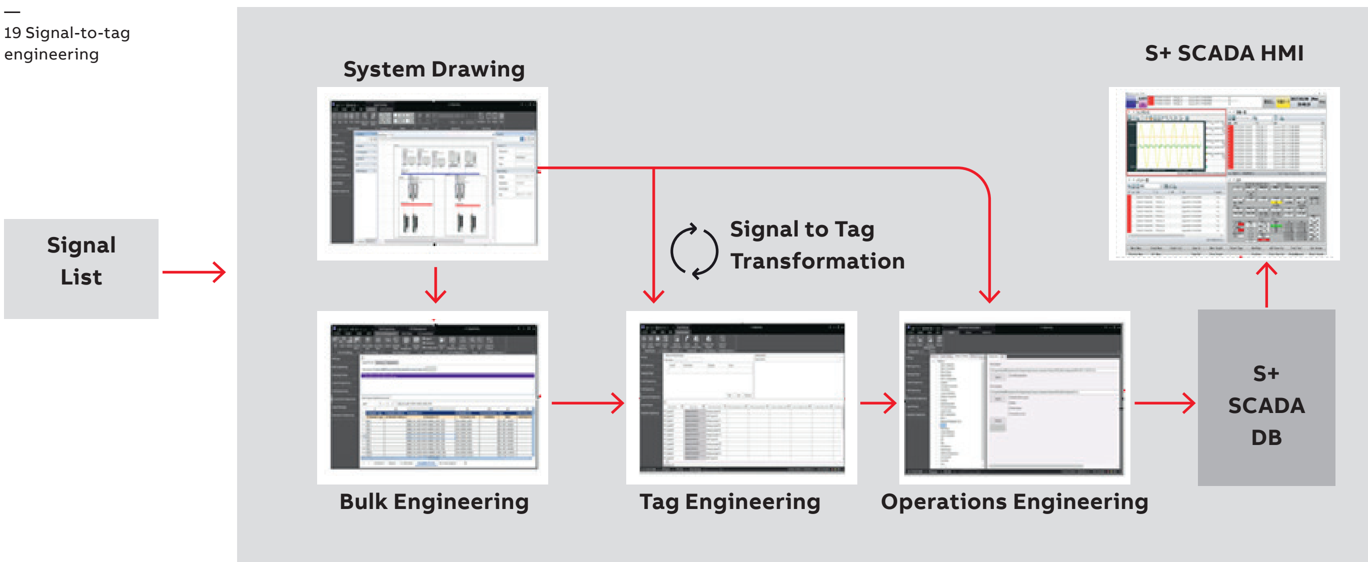
19 Signal-to-tag engineering



11. Easy integration with third-party systems

SCADA systems should provide open interfaces so that third-party systems and applications can be easily integrated and share data. Both vertical and horizontal integration are required: vertically, with enterprise level systems such as enterprise resource planning, supply chain automation and enterprise asset management; horizontally, with peer level systems such as historian, manufacturing execution, distributed control, workflow and mobility solutions.

The SCADA system should offer multiple ways to share data with enterprise level systems, such as by ODBC, SQL Transfer, or by OPC DA, OPC AE and OPC HDA servers. This provides several advantages. For example, an ODBC or SQL interface enables a water utility to integrate with the SCADA system a third-party billing system for water consumption and easily generate non-revenue water dashboards. Similarly, it enables a solar PV plant to easily integrate weather station data to forecast output over the coming hours or days.

12. Built-in security

Power and water utilities are a top target for cyberattack. A 2019 survey of more than 1,700 utilities worldwide found that half reported at least one shutdown or operational data loss per year and a quarter were impacted by mega-cyberattacks. More than half expected an attack on critical infrastructure within the next 12 months. It is, therefore, crucial that the SCADA platform provides robust protection from cyber infiltration and unauthorized access.

ABB's Symphony Plus SCADA, for instance, is designed with inherent security features to ensure a secure and reliable control environment with minimal expenditure of time and effort. In addition to complying with US Critical infrastructure Protection (CIP), NERC standards and regulations, and the IEC 62351-8 security standard, Symphony Plus SCADA defines rights and roles for a user or user groups with very fine granularity and provides sophisticated authorization and role-based access control to ensure a tight guard against unwanted activities.

And, to increase stability, security and robustness in its solutions, ABB has long operated an independent Device Security Assurance Center (DSAC) where cyber security robustness is tested as part of the product development process. All Symphony Plus Ethernet-based devices are continually tested at DSAC in different configurations and with explicit focus on operational performance.

Which SCADA platform meets all requirements?

ABB Ability™ Symphony Plus® SCADA is the only SCADA platform to meet all 12 requirements listed above. Designed specifically for renewable energy and water applications, the platform is part of ABB's market-leading Symphony Plus family of distributed control and SCADA systems. Symphony Plus SCADA maximizes efficiency and reliability through automation, integration and optimization of the entire plant, network or facility. It provides simple, scalable, seamless and secure total automation, including tight integration of all control equipment and information and security systems.

Symphony Plus SCADA meets performance objectives in operations, maintenance, engineering, IT and management. It fulfils utilities' key focus areas of plant productivity, energy efficiency, operational and cyber security, safety and cost of ownership.

Symphony Plus is part of the ABB Ability™ portfolio of unified, cross-industry digital solutions that enable businesses to harness the power of industrial data and generate actionable insights that help them drive performance and productivity improvements. With around 20% market share, ABB is the leader in digitally enabled control and automation, according to industry analysts ARC Advisory and Frost & Sullivan.

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20 The new H2O Power control center in Ontario enables a single operator to manage 48 units efficiently and safely

SCADA solutions that are making a difference

Symphony Plus SCADA is making a difference for all types and sizes of water and renewable energy applications in all regions of the world. Here is a small sample of recently completed projects:

1 **Managing one of the world's largest solar PV plants (Adani, India)**
Unified SCADA system for a 648 MW solar photovoltaic plant, which until recently was the world's largest solar PV plant in a single location, providing 10 percent of India's solar power. The solution includes electrical integration in accordance with IEC 61850 and connection with the regional grid operator and the customer's head office.

2 **Controlling 48 hydropower units in Canada (Ontario, Canada)**
Upgraded SCADA system and new central control room – both designed to maximize operator effectiveness - enabling one operator to remotely control 48 units at eight hydropower plants in the Ontario region (Figure 21).

3 **Protecting a World Heritage site from floods (Venice, Italy)**
Unified SCADA system controls the MOSE flood barrier system, which protects Venice from high water and comprises 78 flood barriers on the seafloor and more than 50,000 control devices.

4 **Modernizing Asian city's aging water network (Hoh Chi Minh City, Vietnam)**
Symphony Plus SCADA solution for the city's modernized water distribution network to help save 50 million cubic meters and $10 million of non-revenue water losses per year.

5 **Carrying water to where it is needed in Africa (North-South Carrier, Botswana)**
SCADA solution to control the pumping stations and 360-kilometer pipeline that transfer water from the remote north to the populous south.

6 **Total water management system for new capital city (Cairo, Egypt)**
SCADA monitoring and control solution and leak detection system for the new water, wastewater and irrigation systems that will supply a population of 6.5 million in Egypt's new capital city, which opens in 2022.

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21 Ho Chí Minh, Viet Nam

For your notes

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