
Smart Power Plant and Symphony Plus Applications
Industrial Revolution
Background

Industry 1.0
1712
The first functional steam engine was built by Thomas Newcomen.

Industry 2.0
1870
The first elevated conveyor belt in Cincinnati, Ohio.

Industry 3.0
1969
Richard Morley and Odo J. Struger are the fathers of the programmable logic controller.
In 1969, Morley introduces the first semiconductor-based sequential logic system.

The Future
Industry 4.0
Smart Factory, cyber-physical systems and the Internet of Things.
• Internet of Things, Service and People
Smart Power Plant Definitions

- Smart Power Plant, short for SPP, is the next generation power plant with higher safety, more efficiency, and environment friendly, based on modern digital information processing technology, intelligent sensors and actuators, advanced control and management, and so on.
  - Smart equipment: utilizing advanced sensor and measurement technology, fieldbus protocol, data fusion algorithms to realize intelligent data acquisition, analysis.
  - Smart control: accurate and efficient control based on advanced control algorithms.
  - Smart supervisory: integrate all process data for plant-wide optimization, predictive maintenance, and life cycle management.
  - Smart management: higher efficient operation based on big data analysis and decision supports,
ABB Smart Power Plant Solutions

Smart management
- Virtual Power Plant
- Enterprise Asset Management

Smart supervisory
- Optimax information system
- Predictive maintenance based on historical data analysis

Smart control
- Symphony Plus Control System
- Optimax Optimization

Smart equipment
- Fieldbus devices
- Intelligent Electric Devices (IEC61850)
- Advanced data acquisition and processing devices
Digitalized Power Plant and Fieldbus
What is Digitalized Power Plant?

- Digitalized power plant is mapping physical power plant into digitalization, and reflecting plant into computer.
- From extensive aspect, digital technology will be utilized through the whole life of power plant, from feasibility study, design, building, to operation and maintenance. All factors is described and used as digital elements.
- Currently, digitalized power plant focuses on operation digitalization, as below:
  - Digital control in power generation progress
  - Historical data storage and integration
  - Historical data analysis, extraction, calculation, and show the progress status
  - Predictive maintenance leveraging intelligent device information and historical data analysis.
The relationship of Fieldbus and Digitalized plant

- Fieldbus is the foundation of digitalized power plant, because traditional hard-wired could not get the status, diagnosis information from intelligent field devices, except acquiring analog or digital signals.
- Fieldbus control system could transfer more information native in intelligent devices, to operators, engineers, even to CMMS or MIS.
- Fieldbus control system and intelligent devices are two pillars for digitalized power plant.
  - Intelligent devices include instruments and electrical devices.
  - PROFIBUS/FF technology integrates instrumentation and some electrical devices (low voltage and some medium voltage).
  - Most electrical devices are integrated by IEC 61850.
Symphony Plus’s Unified Fieldbus Approach

**Instrumentation:**  ==> PROFIBUS-PA  
**Drives:**  ==> PROFIBUS-DP  
**Electrical System:**  ==> IEC61850

**IEC 61850**
- AIS  
- GIS  
- Power trsfo  
- MV Switchgear  
- MV Drives  
- Distribution trsfo  
- LV Switchgear  
- Drives  
- LV Products  
- Remote I/O  
- Proxies to other buses  
- Profibus  
- others  
- Valves  
- Instrumentation  
- Substation  
- Power Distribution  
- Low Voltage Distribution  
- Process Control

**PROFIBUS-DP**
- DCS Controller  
- Workplaces  
- Control Network  
- Fieldbus Network

**PROFIBUS-PA**

ABB
Recent Reference
Chongqing Wanzhou 2x1000MW PROFIBUS Project

• Project background
  • Located in Xintian town, Wanzhou District, Chongqing City
  • Plan to build 4 x 1000MW coal fired units. Phase I is 2 x 1050 MW
  • Boiler/Turbine/Generator
    • Dongfang Electric Corp., Ultra Super-critical units (3034.4t/h/29.4MPa/605℃/622℃)

• Technical requirements
  • Integrated DCS
    • Cover boiler, turbine, generator, coal transferring, water treatment, FGD, SCR, and other auxiliary control system
  • Plant-wide operator station
    • Each operator station could monitor and control all equipment in plant, within its privilege and authorization.
  • SIL3 for safety system
    • FSS for boiler safety
    • ETS for turbine safety
Recent Reference
Chongqing Wanzhou 2x1000MW PROFIBUS Project

- **ABB Scope**
  - Plant-wide PROFIBUS application
    - 95 segments of PROFIBUS DP for each unit
    - 100 segments of PROFIBUS PA for each unit
    - 55 segments of PROFIBUS DP for common system and auxiliary system
    - 85 segments of PROFIBUS PA for common system and auxiliary system
    - Total 1684 PROFIBUS DP devices
    - Total 1692 PROFIBUS PA devices
  - Automatic power-up system
  - ABB Uvisor flame detector

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Recent Reference
Shenhua Anqing 2x1000MW PROFIBUS Project

- **Project background**
  - Located in Guangjiwei town, Anqing City, Anhui Province
  - This plant has built 2x300MW, and plan to build 4x1000MW. This project is phase II, 2x1000MW
  - Boiler/Turbine/Generator
    - Dongfang boiler company/Shanghai Turbine Company/Shanghai Generator Company (2910.12t/h/29.15MPa/605°C/623°C)

- **Project requirements**
  - Integrated DCS in plant-wide
  - Cover boiler, turbine, generator, coal transferring, water treatment, FGD, SCR, Air conditioners, coal port and other auxiliary control system
  - Automated Power-up System
  - ABB Uvisor for boiler flame detector
Recent reference
Shenghua Anqing 2x1000MW PROFIBUS Project

- PROFIBUS Configuration
  - Plant-wide PROFIBUS application
    - 105 segments of PROFIBUS DP for each unit (25 non-redundancy segments using ABB RLM01)
    - 75 segments of PROFIBUS PA for each unit
    - 28 segments of PROFIBUS DP for common system and auxiliary system
    - 12 segments of PROFIBUS PA for common system and auxiliary system
  - Total 2776 Profibus DP devices
  - Total 1199 Profibus PA devices
History of PROFIBUS

- Developed by 5 research institutes and 13 companies in 1987
- Approved in German as DIN19245 in 1989
- Approved as Europe EN50170 (Profibus-DP/-FMS) in 1996
- Approved to add PROFIBUS-PA into EN50170 V2 in 1998
- ProfiNet added into IEC61158 in 2003
- PROFIBUS became China National Standards GB/T 20540-2006 in 2006
PROFIBUS Profile

- **PROFIBUS DP** (DP = Decentralized Periphery) Copper/Fiber/Wireless
  - Communication between controller and distributed periphery devices
  - Quick data exchange, lower cost

  - **Cyclic data traffic**
    - Configuration by GSD
    - Parameter configuration
    - Diagnosis

  - **Acyclic data traffic**
    - Device management via FDT&EDD
    - Alarm
    - Compliance with IEC 61131-3
    - Safety PROFI

  - **Cross traffic (Broadcast)**
    - Time Synchronization
    - Supporting SOE
    - PROFIdrive

- **PROFIBUS PA** (PA = Process Automation) Copper
  - Development of process industry
  - Supporting Ex (Haz) Zone 1
  - PA cable for communication and powering field instruments
PROFIBUS products
Symphony Plus with PROFIBUS

Operator Station

Engineer Station

Ethernet/TCP-IP

PDP800 DP Master

Portable diagnosis station

HPC800 Controller

Fiber cable

Twisted cable

PROFIBUS DP

Field

Twisted cable

PROFIBUS PA

Fiber cable

PROFIBUS DP

November 16, 2016
Typical PROFIBUS segment drawing (DP+PA) with S+
PROFIBUS device tested by CNBBC

- Pressure, Differential Pressure, Flow transmitters (Profibus-PA)
  - Rosemount 3051C/3051S1 Series/Yokogawa EJA Series/Siemens SITRANS PDSIII Series/ABB 2600T/E+H PMP71
- Ultrasonic, electromagnetic, mass flowmeter (Profibus-PA)
  - Korone IFC300&MFC300/E+H Promag 50/Siemens Probe
- Radar level meter (Profibus-PA)
  - Magnetrol 7MS series/K-TEK MT5000(DP)/E+H FMP54/VAGA Vage Plus 68.
- Pneumatic Positioner (Profibus-PA)
  - ABB TZIDC/Siemens Sipart PSII/Fisher DVC6200P.
- Chemical analytical meter (Profibus-DP)
  - SWAN/HACH/E+H CPM223(PA).
- Electric Actuator (Redundant Profibus-DP)
  - EMG i-Matic /Rotork IQ3 /AUMA AUMATIC AC / Limtorque Accutronix /Sipos Sipos 5/ Ruiji/Hengchun/Aibosi/Yangzhou Schneider/Suzhou Borui/Chuanyi/Autork etc..
- Others
  - IDAS (Shanghai Yaomin/Huadong dianzhan/Wuxi Bell/Shanghai Weicheng)/MCC(Siemens/Suzhou Wanlong)/Valve terminal (ASCO/MAC/Festo)
Guideline for PROFIBUS application

- **Security and reliability**
  - Keep ‘single fault rule’, that is, single fault could not cause the entire system fault
  - Intelligent devices shall be designed and chosen as communication port redundancy, line redundancy, and master redundancy schemes.
  - If involving protection and inter-lock, suggest to use HART

- **Technical mainstream and availability**
  - Choose mainstream products in market, especially the products tested by PI or other foundations
  - Suggest not to use protocol convertor
  - From the aspect of controller and fieldbus master, it shall have necessary extend space

- **Economic and appropriate**
  - Considering economy, suggest to use PROFIBUS DP+PA solution
  - According the available products and process requirements, choose the most economic and reasonable solution
  - Based on meeting safety and reliability, consider economic configuration to design segments and devices.

- **Scope of NO using PROFIBUS**
  - Protection loop, inter-lock or critical control loops, and fast response control loops, like boiler FSS protection, turbine control, and turbine ETS, etc.
Scope of PROFIBUS application

- Transmitters for monitoring
- Ordinary control loops, and relevant transmitters and actuators
  - High/low pressure heater level control
  - Steam temperature control
  - Feed-water pump, condenser pumps control
  - Hot well level control
  - Auxiliary steam control
  - Lubrication oil control
  - Discharge valve control, etc.
- Motor, VFD could use PROFIBUS and hard-wired combination mode, and hard-wired is used for critical ON/OFF signals.
- Boiler tube temperatures, could be use DCS remote I/O or 3rd party remote I/O, based on the scale and cost
- Soot-blower system, could be used as PROFIBUS
- Flame detectors, could be used PROFIBUS and hard-wired combination mode, and hard-wired is used for FLAME ON/OFF signals
- Auxiliary control system, could be used as PROFIBUS in more devices or processes
Profibus DP Segments

- **Segments connection**
  - Single segment for single port DP devices
  - Redundant segments for dual ports DP devices
  - Redundant segments/RLM01 for single port devices
  - *If long distance, use fiber cable and fiber convertors*

- **Segments setting**
  - Same Baud rate in same segment
  - Communication speed is decided as PROFIBUS DP standards
  - Devices in same segment shall be chose different address, from 3 to 125
  - Each segment could connect up to 31 devices without repeater, or up to 124 devices with repeaters.
Profibus PA segments

- Use DP/PA coupler to connect PROFIBUS PA devices
- Use RLM01 or PROFIBUS fiber convertors to connect DP/PA coupler from redundant lines
- PA segments topology
  - Star
  - Tree
  - Line
  - Hybrid
Symphony Plus for electric integration
What is IEC 61850?

- A global communication standard for Power Distribution and Substation automation
  - Flexible and open architecture
  - Makes electrical devices from different vendors work together (=interoperability)
- Capability to follow the fast changing communication technology and ease of engineering and maintenance
- Enables devices in Power Distribution (IED’s) to be integrated with Process Automation Systems!
Introduction
Electrical components in the Power Plant

Power Automation
- Transformer
- Grid connection
- Protection & Control IEDs
- Generator
- Transformer
- Power Generation
- LV Switchgear
- Motor Controller
- Variable Speed Drive
- Motors
- Process Automation
- HV
- MV
- LV
Electrical integration

Introduction

Process automation

- Sensors + LV consumers
  - Actuators
  - Motors
  - Drives
  - Intelligent drives
  - Magnetic valves

- Auxiliary system low voltage
  - Protection
  - Control

- Generator
  - Generator protection/
    - unit protection
  - Excitation
  - Synchronization

- MV consumers
  - Motors
  - Drives

Substation automation

- Auxiliary system medium voltage
  - Protection
  - Control
  - HBT

- Grid connection
  - Protection
  - Control

IEC-60870-5  101/104 /103

IEC-61850

Industrial Ethernet

- LON
- SPA

Modbus
Symphony Plus
CI850: electrical integration interface

PN800 Plant Network

100 MBps Ethernet

Up to 8 CI850s per HPC800

Up to 20 IEDs per CI850

IEC-61850 MMS or GOOSE

100 MBPS Ethernet

Up to 400 Variables per IED
Symphony Plus 系统集成 IEC 61850

- HMI level supports IEC 61850-MMS
- Controller level supports IEC 61850-GOOSE
- Via IEC 61850, operator could get more information in IEDs. Symphony Plus control system could integrate more data from various sources and transfer them to meaningful information for operators and engineers.
- HMI could give the intuitive overview for plant processes. Operators could get alarms, events, trends, and reports by navigation. Sophisticated diagrams help operators get friendly and detailed views for operations.
- Engineering tool is an integrated tool, and supports:
  - Simple and unified tool for all components
  - Check the design faults continuously
  - One database for all applications
  - Seamless data exchange with different devices
IEC 61850 applications
ABB Smart Transformer

Intelligent transformers comprise with transform body, internal or external mounted sensors and controllers, to achieve the measurement, control and monitoring functions.

It is the digitalization extension from primary level to secondary level as transformers.

Via IEC61850, control system could accumulate all transformers’ data, and coordinate them as a whole team, for higher safety.

From end-user view, comprehensive and integrated control system benefits for technical design, monitoring and less footprint.

IEC 61850-MMS

IEC 61850-GOOSE
IEC 61850 Applications
ABB Relion® Relay

- Relion® Relay
  - Full support IEC 61850
  - Supported protocol:
    - Vertical MMS
    - Horizontal GOOSE
  - For details:
    - [www.abb.com/relion](http://www.abb.com/relion)
Safe for operation personnel:
The sensor output is mill voltage (mV), no harm for operation personnel

Higher safety for equipment:
Utilizing advanced Roll’s coil, instead of iron core structure, to avoid transformer fault caused by the saturation of iron core.

More reliable
Replacing transformers by sensors, simplifies switchgear, and lower power consumption, and better environment friendly.

More flexible:
Adjust transformers at any time, even in operation
Digital switchgear
IEC61850 technology

- GOOSE replaces signal wires
- SV replaces CT/PT wires
- Program replaces traditional wired logic
- Rapid project customization
- Fast and accurate commissioning
- Reduce project cost
- Shorten project schedule
Electric integration
Monitoring IEC61850 devices in operator stations

- DCS offers various information embedded in IEDs, like 3 phase power/current, phase voltage, protection set points, via IEC61850 interface
- Send commands to IEDs, to control generators, transformers, distribution panels, motors.
- Integration of process control and electric control improves availability and reduce total ownership cost
Optimax Optimization
OPTIMAX® Optimization package
Customer benefits

**Benefit**
- Reduce fuel consumption, and lower emissions
- Enhance operation flexibility
- Detect and correct potential faults
- Improve predictive maintenance and availability
- Optimize asset lift cycle

**OPTIMAX® Features**
- Monitor operation performance, and advise efficiency degrade parameters
- Tuning control loops
- Optimize combustion and improve boiler control
- Fasten load ramp, start-up
- Co-ordinate multiple units
- Issue early warning, for device fault detection and predictive maintenance
OPTIMAX® Optimization package
Integration approach

Algorithm in controller
Close loop
Open loop
Plant Performance Monitoring

Features

- **Challenges**
  - Power plant operators are in charge to keep up efficiency under continuously changing loads
  - Power plant maintenance staff shall reduce both unplanned outages and maintenance costs.

- **Features**
  - Standard tool library (ISO, ASME, DIN) for easy calculation engineering
  - Calculates deviations between actual and expected performance
  - Converts performance deviation to short- and long-term degradation
Steam Temperature Optimization (SteamTMax)
State space control with observer

- The observer calculates the theoretical internal temperatures in the superheater, making them available to the controller to be used as inter-state variables.
- Non-linear load-dependent behavior: The “K” and “R” vectors are dynamically calculated to provide optimum performance at any load operation point.
- Its predictive capability and ultra-fast integration component, the state controller delivers improved performance without sacrificing robustness.
Unit co-ordination control (MODAKOND)

Coordinated boiler following mode for sliding pressure operation
Sootblower Optimization (SootBlowMax) Challenges and targets

**Challenges**
- Sootblowing cleans the heat exchanger surfaces and increases efficiency, but costs steam or compressed air
- Also cleaning soot free surfaces can cause tube erosion over time

**Targets:**
- Adjust sootblower sequence by cleanliness factors, for maximizing boiler efficiency, and balance of steam consumption and heat rate
- Online computation of surface cleanliness
- Advisor mode with open loop, or close loop optimization:
  - Provides operator guidance as to when to initiate a sootblowing sequence
  - Calculates cleanliness factors per section
  - Sootblowing by cleanliness factors
  - Balance steam consumption and benefits (heat rate improvement from cleaner sections)
- **Payback: 2 years (heat rate)**
Combustion Optimization (CombustionMax) Functions

- NOx – major target and constraint
- Opacity – major constraint
- Oxygen unbalance – Oxygen controlled by secondary air or tertiary air
- Actuator constraint – keep the control loops in normal range
  - Spray valves
  - dampers
Virtual power plant
Monitoring, efficiency and optimization

Architecture and Interfaces

- Hierarchical architecture with Plant Level and Remote Center Systems using the same technology (S+ Operations)
- Standardized protocols to connect all relevant assets into a single system
- Interfaces with other systems for effective operations of renewable plants

Key Features

- Monitoring and diagnostics of the generation fleet through dedicated applications
- Power Management function to turn renewable plants into reliable generation
- Forecasting of power production and energy prices
- Optimization power production based on diagnostics and forecasting
Predictive maintenance and Cloud
Predictive maintenance for DCS
HMI fingerprint

Control system

Software
- Microsoft software
- Security updates
- 3rd party software

Hardware
- HMI hardware
- Hard disk
- File system
- CPU
- RAM

System
- Time Synchronization(*)
- Region setting
- Automatic startup
- Domain diagnosis
- SIDs
- Process
- Connections
- Service status
- Authorization
- Events
- Queue, links
- Register table

Network
- Domain management
- Register in domain
- Package lost
- Throughout of input/output
- Package sequence
- Network interface configuration
- Host file

(*) relative with Harmony hardware
Predictive maintenance for DCS
Fingerprint report for controller level

- Analyze performance, controller CPU load, communication nodes, network load, etc.

**Node Performance Issues**

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Node Issue Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIS Firmware Status</td>
<td>5</td>
</tr>
<tr>
<td>LL Poll Busy ACK</td>
<td>2</td>
</tr>
<tr>
<td>Channel 1/2 Receive Errors</td>
<td>1</td>
</tr>
<tr>
<td>Excessive Non-XR Traffic</td>
<td>1</td>
</tr>
<tr>
<td>CPU Utilization</td>
<td>0</td>
</tr>
<tr>
<td>Output XR Saturation</td>
<td>0</td>
</tr>
<tr>
<td>Input XR Saturation</td>
<td>0</td>
</tr>
<tr>
<td>U/R Bus Saturation</td>
<td>0</td>
</tr>
<tr>
<td>Memory Utilization</td>
<td>0</td>
</tr>
<tr>
<td>Received XR’s per Packet</td>
<td>0</td>
</tr>
</tbody>
</table>

**Module Performance Issues**

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Module Issue Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Firmware Status</td>
<td>9</td>
</tr>
<tr>
<td>Module Status</td>
<td>8</td>
</tr>
<tr>
<td>Memory Utilization (RAM)</td>
<td>6</td>
</tr>
<tr>
<td>CPU Utilization</td>
<td>6</td>
</tr>
<tr>
<td>Segment 2 Cycle Time</td>
<td>4</td>
</tr>
<tr>
<td>Segment 1 Checkpoint Overruns</td>
<td>6</td>
</tr>
<tr>
<td>Memory Utilization (NVRAM)</td>
<td>0</td>
</tr>
</tbody>
</table>

2. **CORRECTIVE ITEMS**

1. **Loop Channel 1 or 2 Receive Error Rate %**: 2 node(s) had an excessive increase in the rate of Channel 1 or Channel 2 receive errors (exceeding 1.0% of loop traffic) during the collection period. 0 node(s) had a significant increase in the rate of Channel 1 or Channel 2 receive errors (in the range of 0.1%-0.9%) during the collection period. Refer to the table and trends in Appendix B.

   **Priority**: **HIGH**
   **Potential Impact**: If issues continue, the loop communication could break, leading to production down time.
   **Recommendation**: Excessive increases in channel receive errors over a span of time usually refer to a hardware issue. A slow increase in these values is acceptable and expected over a period of time. If increased values are unacceptable, make sure jumper associations with these CIUs are inspected. Test loop cables, connectors, and termination units to ensure these modules are recognized. If errors continue, replace cables and/or CIUs.

   **Estimated Time**: 8 hours

2. **Module Status - I/O Out of Specification**: There were 24 controller modules that reported “LIO” or “RIO” flags set in the module status, which indicates bad local or remote I/O status. Refer to the table in Appendix D.

   **Priority**: **LOW**
   **Potential Impact**: No direct impact on performance.
In transformer evaluation it is no need shutdown. ABB site service team will collect some relative information of transformers, like basic parameters, design data, operation historical data, maintenance data, and input into MTMProgram™ software, and then get the transformer performances.

The report categorizes transformer as
- Abnormal
- Alerting
- Normal
Other tools in ABB

- Insulation materials degree of polymerization evaluation tools (DP)
- Advanced Dissolved Gas Analysis (ADGA)
- Calculation software of the ability to withstand short circuit (EDS)

Transformer Performance Evaluation

<table>
<thead>
<tr>
<th>Result: Interpretation and Certainty of evaluation, CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE %</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>75</td>
</tr>
<tr>
<td>70</td>
</tr>
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</table>

### Transformer Performance Evaluation Table

<table>
<thead>
<tr>
<th>Transformer</th>
<th>Rating (MVA)</th>
<th>Voltage (kV)</th>
<th>Capacity (kVA)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFU1</td>
<td>125</td>
<td>33.5</td>
<td>120,000</td>
<td>Plant A</td>
</tr>
<tr>
<td>SFU2</td>
<td>125</td>
<td>33.5</td>
<td>120,000</td>
<td>Plant B</td>
</tr>
<tr>
<td>SFU3</td>
<td>125</td>
<td>33.5</td>
<td>120,000</td>
<td>Plant C</td>
</tr>
</tbody>
</table>
ABB Smart Medium Voltage solutions

Smart control

SCADA

Video monitoring

COM600 Switchgear management

Switch

One-button operation and video monitoring

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Intelligent device management

Switchgear system

Breaker monitoring

Temperature Sensor

Bus Bay

Cable

Switch

Electric switch

Breaker

Electronic trolley

Motor monitoring

Secondary monitoring
ABB Smart Medium Voltage Solutions
Intelligent device management

- COM600 Management
- Switch
- Remote Server
- 2G/3G/4G Mobile
- Remote service
- iUniGear Switchgear
ABB Smart Medium Voltage Solutions
Intelligent device management

- COM600 Management
- Switch
- Remote Server
- 2G/3G/4G Mobile
- Mobile APP for maintenance
- iUnigear Switchgear
Cyber Security
ABB Cyber Security Solutions

- Security Event Monitoring
- Defense-in-Depth Security
- Configuration Change Management
- Compliance Automation
- Application Whitelisting
- Automated Patch Deployment
- Automated Anti-Virus Deployment
- Systems Backup and Recovery
ABB Smart Power Plant Solutions

- **Smart management**
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  - Enterprise Asset Management

- **Smart supervisory**
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Power and productivity for a better world™