Digital Substations

With the Future built in
Digital substation – Assignment of the 6 aspects

1. Digitalization of Station Level
   - Non-conventional Instrument transformers (LPITs)
     - Provide primary values to the merging units based on new principles

2. Digitalization of Process Level
   - Merging Units (MU)
     - Converts analog primary values of the LPITs in digital information (Sampled Measured Values)

3. Cyber Security
   - Sensors
     - Provide more information on current status of the electrical equipment

4. Asset Management
   - IoT
     - Value-adding central applications
     - Big data analytics IT/OT integration

5. Grid Operation
   - Digital Control Room
     - More data acquisition, intelligent decentralized applications, cyber security
     - Digital protection and automation with station bus based on IEC 61850

6. Integrated Engineering
   - Digital Control Room
     - BIG data analytics IT/OT integration
NCIT’s for GIS

January, 2019
Do you know …

<table>
<thead>
<tr>
<th>Non Conventional Instrument Transformers (LPITs) will reduce HV switchgear size by 30%</th>
<th>You can achieve higher performance in measurement</th>
<th>You can save cost by reduced wiring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non Conventional Instrument Transformers weigh 90% less</td>
<td>You gain flexibility throughout lifetime to adapt easily to future needs</td>
<td>Remote maintenance and testing saves cost</td>
</tr>
</tbody>
</table>
Digital Process Level
Size reduction of 30% and weight -1,500 kg

Inductive Current and Voltage Transformers (conventional)

Current and Voltage Sensors (non-conventional)

Shown: GIS Clean Air 145 kV
Digital Process Level
Summary - Shown: GIS Clean Air 145 kV

Previously

- Control Center
- Substation Controller
- Station bus
- Parallel wiring
- Protection House
- Station bus
- Substation Controller
- Station bus
- Protection House

Digital

- Control Center
- Substation Controller
- Station bus
- Process bus based on IEC61850-9-2
- Protection House

Copper cabling
Analog values
3.2 m
5 m
50 – 250 m
Digital Substation Controller

LPIT
Merging Unit
Fibre optic cabling
Ethernet IEC 61850-9-2

3.5 m
2.9 m
3.2 m
5 m
50 – 250 m
DIGITALIZATION OF PROCESS LEVEL - GIS LPIT
Conventional /Low Power Instrument Transformer Technology

Conventional Instrument Transformer Technology

Inductive Voltage Transformer (VT) + Inductive Current Transformer (CT)

1 x Electric Field Probe for Voltage Measurement + 2 x Rogowski Coils for Current Measurement (redundant) = Cast resin partition with integrated voltage and current sensors

Low Power Instrument Transformer (LPIT) Technology

3.2 m + 5.5 m = 8.7 m

2.9 m + 3.7 m = 6.6 m
Conventional and Low Power Instrument Transformer
Pictures CIGRE 2014

Measurements:

2 x current measurements per phase;
1 x voltage measurement per phase.
Pilot customers

- Pilot customer
- In operation pilot mode in Verkhouse substation, Finland
  - Hybrid solution (conventional transformers plus LPIT)
  - No “hot” connection to e. g. trip coils
  - Connection to the SCADA system (direct comparison of values and reactions)
Pilot customer, Configuration of Hybrid solution example
LPIT Technology in gas isolated switchgears
Optical CTs for AIS
Current state of technology – product presentation
Characteristics of optical current transformers - Trench

- **Environmental aspects**
  Environmental friendly insulating system “Clean Air”

- **More compact CT Design**
  Small and light-weight units compared to conventional CT design

- **High-performance measurement behavior**
  Wide dynamic range due to saturation-free measurement principle

- **Improved operational safety**
  Galvanic separation between primary and secondary side

- **Reduced losses**
  No magnetic losses and no ferro-resonance effects

- **Reduced cabling effort**
  Single fiber-optic cable instead of several copper cables with large cross-sections

- **Passive system**
  No electronic components within the optical CT
Proposed installation scheme for new and future projects
New SIPROTEC 5 based MU – coming from 2019 Q3.

- Optical CTs
- IO245 for TOCTs
- Protective relay with process-bus input (SIP5)
- Outdoor
  - Patch panels
  - ≥1 km
- Indoor
  - GPS antenna
  - Master clock
  - Sync transceiver
  - Or PTP/IEEE1588
- Time sync

Option: Ethernet-Switch (RSG 2288)
Option: Meter with process bus interface
SIPROTEC 5 Merging Unit – One base module adapts to all sensor types

### Key functions

- Digitalization of all primary data close to the process
- Adapts to all sensors
- Direct tripping of CB
- Trip circuit supervision
- Backup protection functions
- CB wear monitoring
- Adapts to your requirements

### SIPROTEC 5 6MU85

<table>
<thead>
<tr>
<th>6MU85 equipped with</th>
<th>CT</th>
<th>VT</th>
<th>Rogowski Coil</th>
<th>Field Probe, RC-Divider</th>
<th>Optical CT</th>
<th>BI</th>
<th>BO</th>
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<tr>
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SIPROTEC 6MU85 planned for Q3 2019
SIPROTEC 5 Merging Unit 6MU85 –
Perfectly tailored fit to your requirements

<table>
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<tr>
<th>Aux-PS</th>
<th>Single</th>
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<tr>
<td>CT</td>
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<table>
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<th>Aux-PS</th>
<th>Redundant</th>
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<tr>
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<tr>
<td>VT</td>
<td>4 MCIT</td>
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<td>BI</td>
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<td></td>
<td>4 … 20 mA 4</td>
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<tr>
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</table>

PCIT … Protection CIT, MCIT … Measurement CIT
SIPROTEC 6MU85 planned for 2019; currently available SIPROTEC 6MU805

Perfectly tailored fit
- Adoptable to multiple CT, VT, LPIT inputs
- Scalable BI and BO
- Direct “high speed” tripping of circuit breaker <1 ms
- Collection of additional data (temperature, pressure, tap changer positions, …)
- Redundant power supply
- Expendable by a 2nd row
DIGITALIZATION FROM PROCES LEVEL TO STATION LEVEL
SIPROTEC 5 based MU’ and SIPRPTEC 5 protection devices
SIPROTEC 5 process bus
Benefits using process bus

1. No secondary voltage or current anymore on terminals.
2. No secondary wiring in relay protection or secondary cabinets.
3. More safe substation operation as less maintenance faults.
4. Less maintenance – cheaper to run (reduces OPEX).
5. Less boxes (reduces CAPEX).
Digital Grid
Cyber Security
Cyber Security needs a holistic approach

People
Awareness and understanding of cyber security

Products
- Support of CIA criteria (Confidentiality, Integrity, Availability)
- Comply with industry standard

Processes
- Covers the whole product life-cycle
- Foster solution and operational requirements
Cyber Security
The Threats are real

First on CNN: U.S. investigators find proof of cyberattack on Ukraine power grid

Cyber-blackmailers are coming for hospitals, power grids and universities
Cyber Security
The Threats are Real

Possible Attackers
• Criminal Organizations
• States
• Political activists
• Script Kiddies
• Insiders
• …

Unauthorized access
Misuse of administration rights
Attacks via Internet
Malware
Tampered Firmware
Cyber Security
The Threats are Real

Conditions:
- Critical Infrastructure
- 24 h Operation
- Windows and Linux standard components
- Interfaces to unsecure networks
- Interfaces to office networks
- Legacy components
- Proprietary technology
- Mix of components from different vendors with different technologies
Customer point of view
Cyber Security needs a holistic approach

Are you prepared for Cyber Security?

Power System Operator
- Organization
- Processes
- Infrastructure

Cyber risks
Cyber Regulations & Standards

Achieve
Mitigate
Comply

Business targets
Cyber Security – Improved system security with certified secure substation framework based on IEC 62443

Cyber security measures

- Access control and account management
- Security logging and monitoring
- System hardening
- Security patching, Backup and restore
- Malware protection
- Data protection, data integrity and system architecture
- Secure remote access

Siemens Secure Substation framework certified by TÜV SÜD according to
- IEC 62443-2-4 – Integrator processes
- IEC 62443-3-3 – Technical functionalities
Asset Management
IoT connectivity to Energy IP
Substation Device Management (SDM)

Benefits
• Transparency of current installed base
• Simplified documentation and reporting
• Efficient Cyber Security patch management
• Enabler for support, field activities asset management
Main Value Stories - Substation Device Management

„Transparency of Installed Base“

- Provide up-to-date version information „on mouseclick“
- Standard Protocols: IEC 61850, SNMP, WMI
- Query also 3rd party devices

„Savings in Documentation“

- Reduce time for documenting SW/FW changes
- Reduce travel time/cost to substations
  - Generate asset inventory lists and reports
  - Preventive maintenance planning

Enabler for „Cyber-Security Patch Management“

- Get automated and dedicated patch information from Siemens CERT Database by Siemens Security Experts
- Facilitate evaluation of patch information
  - service model: SL1-SL4

Enabler for „Operational Services“

- Speeds up orientation in substation installed base for remote service engineers
- service model: e.g. Operational Service)
Architecture Overview – Substation Device Management

Remote Monitoring and Analysis

Substation Automation & Protection Assets

Advanced Device Management

EnergyIP™ SDM

Connection to SVM DB (CERT)

…

Monitoring and analysis platform EnergyIP™

Substation Data (Version information)

EnergyIP™ ISDM – Local Collector

Protocols: IEC 61850, SNMP, WMI

Protection relay

Substation PC

RTU

Router/Switch

…

Long video on the SDM website:

http://www.siemens.com/substation-device-management

SDM runs on:

Siemens Private Cloud

Enterprise Private Cloud

On premise
Cyber Security EM DG Products - Keeping the Substation Secure and Up-to-date

Siemens side

- Siemens ProductCERT
  - Central Database
- Security Researchers
  - Pentesters
  - Free-time Hackers
  - IT-Security Contractors
- CERT network
  - US ICS-CERT
  - BSI
- 3rd Party Vendors, OSS

Operator side

- Asset Owner’s Patch Management Process
  - Patch qualification/testing/deployment
- Security Advisories
- Siemens Digital Grid Products
  - R&D
  - Service
  - Sales
- Security Newsletter
- Service Contract
- Defect Database

Central Database

Single point of contact

Responsible Disclosure process

Monitoring and Information

Monitoring

Notification

CERT network

3rd Party Vendors, OSS

IT-Security Contractors
EnergyIP™ ISDM – Asset Information

Information delivered by EnergyIP™ ISDM via standard protocols, automatically from supported devices

**Main attributes** (automatic)
- Component Name
- Serial Number
- Software / Firmware Version
- Ordering-Number (MLFB)
- Vendor Name
- IP-Address
- Hardware Version (if delivered by device)

**Additional attributes** (manual entry)
- Topology Information (substation / voltage level / bay)
- Expected SW/FW Version
Automated Security Testing
Cyber Security Automated Testing
Necessary Security Tests

Control Center ← DMZ → Remote Access

Security Tests
- Port Scans
- Hardening checks (e.g. CIS CAT)
- Windows Patch level scan
- Default user/password check
- Known vulnerabilities scan
Cyber Security Automated Testing
Necessary Security Tests

Tool based security testing is a must have!
Cyber Security Automated Testing
Large Number of Security Test Tools Available
Purpose of SiESTA

- Enable simple security testing during implementation, FAT, SAT and operation lifecycle phases with one local test appliance
- Offer recommendations and templates for dominant standards like IEC 62443
- Foster Siemens-wide community to share test configurations and experiences
Cyber Security Automated Testing
SiESTA: Reports – Formal and customizable

User friendly and clear final test report with descriptions.
5 Grid Operation Support
Wide Area Monitoring with SIGUARD PDP and PMU

Benefits

• Fast real-time monitoring of your grid
• Automated detection of power swings, islanding and overload (blackout)
• Archiving of dynamic grid data
• Precise reporting and condensed information
• Situational awareness on first sight
• Decision-making support for better grid utilization
Benefits

- Efficient use of typicalls and project data
- A single master data is set for all work steps
- Seamless automatic data exchange between engineering steps
- High degree of data quality
- Reduced time to operation
- Optimized refurbishment by easier updating of documentation and testing
Integrated Engineering

Future Vision
- Interface between planning and specification
- Datamodel based specification supported by tools
- Standardized interface between customer and supplier
- Semiautomatic project engineering based on bay templates
- Feeding the engineering deliverables back to the customer

SITIPE Platform
- Single line diagram
- Secondary drawings
- Device Configuration
- Test Cases

Supplier Engineering Process
- Primary (basic) engineering
- Secondary engineering
- Protection devices, configuration
- RTU Configuration
- HMI configuration
- Test engineering
- Asset management

Traditional Approach
- Planning and specification completely decoupled
- Book writing
- Exchange of .pdf-s
- Copy/Paste with abundant entering of data
- No link between engineering and operation suite

Utility

Operation / Data mining

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Energy Management | Digital Grid
SITIPE Integrated Configuration

IEC 61850 SCL?

Project specific data

Circuit Diagrams Engineering

Protection devices configuration

RTU

HMI configuration

Project Builder

Templates Store

Project specific Protection (SIP5, other IEDs) configuration

Project specific RTU (PAS/A8000….) configuration

Project specific HMI configuration

Project specific test scenarios

IEC 61850 SCL?
Grid IoT Solutions
FOR DIGITAL SUBSTATION
January 29th, 2019

siemens.com/digitalgrid
Evolution in Substation Automation – From Standard Cabling to Digital Substation 4.0

1st generation – Standard cabling

- Mimic board
- Fault recorder
- Protection
- RTU
- Parallel wiring

2nd generation – Point-to-point connections since 1985

- Control Center
- HMI
- Substation controller
- Other bays
- Serial connection
- Parallel wiring

3rd generation – Digital Station Bus since 2004

- Control Center
- IEC 61850
- Substation controller
- Switch
- Station bus
- Parallel wiring

Digital Substation 4.0 - Process Bus and IoT Connectivity

- IEC 61850
- Digital and analog Merging Unit
- Parallel wiring
- Digital Merging Unit
- 3rd Party
- Process bus
- Station bus
- 011010 011010 01 01 01 10
- EnergyIP powered by MindSphere
- Apps and Data Analytics

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Substation Automation Systems (Today)  
Typical Network with IEC 61850 Station without IoT connectivity

IEC 61850

SIPROTEC 5
SIPROTEC 4
SIPROTEC Compact
SICAM A8000
SICAM PQ Q200/Q100

Control Center Level
SPECTRUM 5/7
IEC 60870-5-104

Station Level
SICAM PAS
SICAM SCC

Field Level

~ 50 Data Objects / IED
Selected amount of Data Objects:
• Status messages (primary Equipment)
• Alarms and faults as group alarms (primary and secondary Equipment)
• Measured values (current, voltage, frequency)

~ 150 Data Objects / IED
Required amount of Data Objects:
• Status messages (secondary Equipment)
• Alarms and faults also as single messages
• Protection messages (for example general excitation, fault records, fault location)
• Measured values (V, I, Z, Temperature, pressure, etc.)

~ 1000 Data Objects / IED
Big amount of Data Available:
• Measure values (V, I, Z, Temp, etc.), calculated values which include Partial results of protection and automation functions
• Setting parameters
• Detailed protection messages (e.g., phase excitations, loop and direction information) & status messages
Substation Automation Systems (Today’s Future)
Unlocking Full Potential – Digital Substation V4.0 with IoT

- Data consolidation and visualization
- Applications, e.g. SIPROTEC Dashboard
- Value-Added services (e.g. data analytics)

SIPROTEC 5
SIPROTEC 4
SIPROTEC Compact
SICAM A8000
SICAM PQ Q200/Q100

IEC 60870-5-103, ...

IEC 61850, Modbus, IEC 60870-5-104, ...

SICAM A8000 IoT Gateway

IEC 61850

EnergyIP
powered by MindSphere

SPECTRUM 5/7

IEC 60870-5-104

Control Center Level

Field Level

Station Level

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Grid IoT Services
IoT Enablement and Objective

<table>
<thead>
<tr>
<th>Protection Relays</th>
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<tr>
<td>Automation Devices</td>
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<tr>
<td>Field Devices</td>
<td></td>
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<tr>
<td>Sensors</td>
<td>(e.g. Sensformer)</td>
</tr>
<tr>
<td>Third Party Devices</td>
<td></td>
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<tr>
<td>Other „Things“</td>
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**IoT Platform**

EnergyIP
powered by MindSphere

“Increasing reliability, efficiency and security in network operation through in-depth data analysis and correlation”

http://demo.gds-energy.siemens.cloud:8081/
Grid IoT Services
Scalable Pilot Offering Benefits – Illustrated Example

Transparency
Improved transparency of network assets through the use of analytics and dashboard views:
- Measured Data Object
- Calculated Data Object
- Controllable Data Objects
- Integer Values, etc.

Understanding
Improved knowledge of assets and network behavior:
- Equipment/Device Specific Data
- Cycles and Trends
- Correlations

Improving & Increasing Efficiency
- Optimizing of the Operational & Maintenance Expenses.
- Better Planning of Capital Expenses

Improving Maintenance
Scheduled Maintenance acc. to ‘Real assets Operation’:
- Adapted maintenance freq.
- Less Spare Parts & consumables
- Less corrective maintenance
- Etc.

Exploration of new business models
- Optimization of the Operational & Maintenance Expenses.
- Better Planning of Capital Expenses

Traditional Business
Increased OpeX costs due to equipment aging and unfavorable Operating Conditions (incl. severe failures)

Traditional Operation
Partial transparency of network assets through traditional and limited data:
- Measured Values
- Alarms
- Protection messages
- Etc.
DIGITAL TWIN
Export Simulation Files
SIPROTEC 5 – DIGITAL TWIN
Testing of Substation Systems

DIGITAL TWIN

DIGSI 5

Emulated SIPROTEC 5
(2 devices with GOOSE & PDI)

Process Simulation

SICAM

Real IED(s)

Via SCL simulation
(e.g. SICAM PTS)

Other Siemens IEDs
or 3rd party

Engineering network (e.g. Port J, 192.168.0.x)

Production network (e.g. Port E, 172.16.10.x)
First release at Hannover Fair 2019

- Training of device handling
- Process Data Simulation (analog and digital values)
- Test of CFC-Logic and customer specific application
- Test of communication
  - to SICAM substation automation systems
  - IEC 61850 GOOSE between devices e.g. interlockings
  - Protection Data interface
  - To Engineering PC with DIGSI 5
- Fault analysis e.g. replay of records
Contact

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