SUBSTATION AUTOMATION SYSTEM : IEC61850 Perspective

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Substation Automation System
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Drivers for Development

- Regulatory Compliance
- Network Reliability
- Cost Improvement
**Introduction**

- IEC 61850 has become a cornerstone technology for substation automation
  - Communication protocol voted in 2004
- Estimated >1,000 projects, >30,000 IEDs from different suppliers
  - Interoperability is proven on real projects
- This is however just the beginning of a new era
  - New applications emerging
  - Extensions of the standard and companion ones
  - Industrialization aspects
Currently:

- >400 IEC 61850 projects at different stages of execution,
- >15,000 IEC 61850 IEDs manufactured

From simple architectures (distribution substation) to more complex ones (industries and rail made of several interconnected substations by IEC 61850)
IEC 61850 in a Nutshell: A Powerful Toolbox

- Communication services: How to exchange data
  - Includes the well advertised GOOSE, i.e. peer-to-peer link
- Data modeling: What data to exchange
  - A dictionary defining unambiguous names in the power area
- Configuration language: How to share data references
  - Formal exchange of XML files between engineering tools

Enabling unprecedented innovations
But ONLY a toolbox
IEC 61850: From physical to logical integration

- Physical integration has been the way to optimize cost since the venue of digital relays, i.e. 15-20 years ago.

- The logical integration is still a very untapped domain, for automation and asset management, at substation/regional/grid levels.

- Current IED might just be IEC 61850 enabled or designed to be fully integrated into a distributed system.
Interoperability possible issues

- Ethernet
  - Configuration
- IEC 61850
  - Standard bugs/interpretations
  - PICS/MICS consistency between devices
  - Number of client/goose accepted
- Distributed function
  - Capability to configure the relevant processing: semantic (for instance dynamic topology detection), downgraded case, etc.
  - Specification and test coverage: nominal, downgraded, performance, endurance
  - Performance: competition between processing resources
  - Version consistency
**Inter-operability: Different Levels**

- **Pure communication** (ex: report, control, goose)
  - Typical function: (ex: report, control, goose)
  - Typical test: Standard interpretation (data model, communication service parameter, optional field, etc.)

- **Supervision, basic control**
  - Typical function: Supervision, basic control
  - Typical test: Tests similar than with conventional protocols

- **Non time critical distributed function** (ex: interlocking)
  - Typical function: Non time critical distributed function (ex: interlocking)
  - Typical test: IED configuration capability (use of the various data attributes, subscription capabilities, ...), redundancy

- **Time critical distributed function** (ex: fast load shedding)
  - Typical function: Time critical distributed function (ex: fast load shedding)
  - Typical test: IED response time when subject to multiple solicitations, redundancy performance

### Inter-operability level

- **0**
- **1**
- **2**
- **3**
Inter-operability
Need for an efficient process

CIGRE B5.32
DKE K952.0.1

Specification
IED Check
(Test Plan)
Test Sessions

(PICS, MICS, Conf.)
SCD creation

Management (coordination, arbitrage, system files generation)

Organization is a must
Do not only ask the suppliers to come with their IEDs
### Pilot projects on Process Bus

**Diagram:**

1. Station Level
2. Substation Computer
3. Process Level

**Table:**

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<tr>
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<th>Phi</th>
<th>Expected Time</th>
<th>Conventional CT/VT interfaced with merging unit</th>
<th>Optical CT/VT interfaced with merging unit</th>
<th>Conventional CT/VT interfaced directly with relay</th>
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<td>Real Time</td>
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<td>412.6 ms</td>
<td>3.150 %</td>
<td>407.8 ms</td>
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<td>249.2 m</td>
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</table>
System Design is Key

Physical architecture is now “simple”

- All devices are on Ethernet
- Need to pay attention to the Ethernet infrastructure especially for redundancy

Logical architecture (data flows) are becoming much more sophisticated

- This is part of the system design activity
- Client/Server, Goose, SNTP and non IEC 61850 flows

Architecture is no longer the sole device interconnection
Logical architecture: Data flow

TRADITIONNAL (> 80%)

- Master
- HMI
- Gateway
- Station Computer
- Protection
- Slave
- Slave
- Bay computer

Central point
Distributed functions limited by performances

IEC 61850 POTENTIAL IMPACT

- Simple and standard clients
- T104, http, etc.
- Client
- IP Routable
- Server
- Fast Peer-to-Peer
- Server
- Server

Non trivial design for innovative schemes
(performances, side effects)
Distributed functions impact on system design

- Specification of the distribution functions is not defined in the IEC 61850 standard
  - A new type of document is needed
- IED Conformance to IEC 61850 is interesting but might not be sufficient to cope with the specification
  - For instance it shall be checked if the IED configuration capabilities (i.e. GOOSE handling) can match the functional requirement
- “Wall to Wall” performance analysis is the next step
  - Communication is one aspect, application handling of the communication is another one

IEC 61850 is only one mean and must be complemented by other capabilities
The system architect

A (“new”) job essential for innovative design and/or mix of different suppliers matching evolving business processes

Both long term view (defining guidelines) and short term perspective (real projects)

Short term

- Guarantee the functional consistency of the various devices working together and the system performances
  - Make sure that distributed functions are fully defined and have acceptable side effects in case of degraded situations
  - Manage the increasing system complexity: version, security, etc.
  - Design with system tests & costs in mind: interoperability, functional validation, performances
Extension Outside The Substation

Essentially IEC61850 has been developed for the communication inside the substation.

Now Additional part of the standard and companion standards are at different stage of expansion as illustrated in next slide.

- IEC61850-7-4xx for naming distributed generation assets
- IEC 61850-90-1 Communication between substation
- IEC 61850-90-2 Communication between control centre
- IEC 62351 for Cyber Security

There is a new grouping called “Real Time Pool”: “This is set of set of substation and Generation plants that communicate one with other inorder to contribute to grid stability”
IEC 61850 Directions

CONTROL CENTERS

AM CENTERS

IEC 61850-90-2

IEC 61850-90-1

SUBSTATIONS
Base IEC 61850

IEC 61850-90-1

SUBSTATIONS

IEC 61850-7-4xx

GENERATION

REAL TIME POOL

IEC 61850 + IEC 62351
Configuration integration – The RTE example (France)

Unifying the engineering tools
## Distributed Application Perspectives (examples)

### Electro-technical scope
- **Region and above**
- **Real time pool**
  - Of Substations, Generations & FACTS/SVC
- **Substation**

### Time horizon
- **< 20 ms**
- **20 - 200 ms**
- **200 ms - 2 s**
- **> 2s**

### “IMMEDIATE AUTOMATION”
- Teleprotection
- Voltage instability detection
- CB Trip
- Virtual busbar voltage

### “FAST AUTOMATION”
- Differential protection
- Fast load shedding
- Synchro-check
- Load shedding
- Auto-recloser
- Inter-tripping

### “SLOW AUTOMATION”
- Grid Islanding
- Oscillation damping
- Voltage regulation
- Interlocking
- State estimation

### “ANALYSIS & ASSET MANAGEMENT”
- Version management
- Fault location
- Thermal monitoring
- Adaptive setting
- Formal specification
- Administration
- Setting

### Additional Features
- Fault location
- Model validation
- Version management
- Thermal monitoring
- Adaptive setting

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*India Habitat Centre*
**Innovation pipe**

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<tr>
<th>Maturity Stage</th>
<th>Technical Category</th>
<th>Concept</th>
<th>Application</th>
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<td>PoE / Wifi</td>
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<td>Cyber-security</td>
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<td></td>
<td>IEC 61850 Standard</td>
<td>Base technology</td>
<td>Processes and tools</td>
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We are covering a large scope of O&G field
Typical Large Onshore Oil & Gas Network Configuration

- HV Grid Connection
- Cable or Transformer Differential Protection
- HV Distribution Switchgear
- Low Impedance Busbar Protection
- MV Motors Protection
- Transformer Differential Protection
- Generator Protection
- MV/LV Distribution Switchgear
- MV Incomer Protection
- Motor Control Centers
- Frequency Protection
- HV Feeder Protection
The Power Management System (PMS) is part of the Energy Management System (EMS) in charge of the electrical supply of the O&G plant with the highest security and lowest interruption levels.

The PMS is directly part of the O&G plant permanent availability.
Monitoring and control system

- Secure
  - Type tested with international utility standard including select before execute, interlocking, scalable redundancy, etc.

- Accurate
  - 1 ms Sequence of Events, Automatic disturbance records upload, State of the art analysis tools.

- Standardization
  - Communication protocols, automation schemes, engineering processes

Get more than what the process control system provides
Monitoring and Control System Architecture Principle (IEC61850)

- Physical architecture is made of a star, single loop or multiple loops.
- Loop is generally preferred since there is an in-built communication redundancy (self-healing) with no central switch extra-cost.
- Loop switch-over < 1 ms.
- Multiple loops are used for large systems:
  - Performances
  - Project phases & installation constraints
  - Faults confinement
- Multiple loops are interconnected using proxy gateways.
Power Management - Architecture

- Base architecture
- Dedicated load shedding network
  - One bay computer per generator and set of loads to be shed
Power Management - Functions

- Load sharing (active and reactive) between generators
- Islanding and reconnection (including synchronization)
- Fast load shedding in case of a sudden generator fault or grid weakness
- Load shedding simulation mode
- Motor start sequences
- Network simulation for contingency analysis
Intelligent Load-Management
Load Shedding
Power Management - Fast Load Shedding

Base Sequence for each island

- Spinning reserve calculation
- Generator i fault simulation
- Impact on spinning reserve
- Spinning reserve < 0
- Load Shedding Level Pre-setting in case of generator i fault

Load Shedding Level
Generator i

Spinning Reserve Exchanges

Bay Module Preset Memory

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Fixing the rules:

- The Operator fills the Priority Matrix according to the site process constraints.
- Each feeder is determined as sheddable or not in the FLS HMI.
- 64 FLS levels available
  - from 0 = Non Sheddable
  - to 64 = the lowest level or the first feeder to open)

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Load shedding – Principle

Automatic FLS update:

1. The topological and measurement data are collected by the LMS every 10s (average)

2. LMS recalculates the shedding matrix for all reflex IEDs
   1. The updated data (topology and measurements)
   2. The priorities defined by the operator

3. Every Reflex IED receives from the LMS the dedicated extract of the matrix

Diagram:
- GTW
- Reflex IED
- Reflex IED
- Reflex IED
- LMS
- Ethernet network
Load shedding – Loss of a generator

Fault happens

1. Generator fault is detected by CB associated trigger on a Reflex IED

2. Trip signal is broadcasted via GOOSE to all feeders’ IEDs

3. According to their database, proper feeders are load shedded
Load shedding – Operator view
Load shedding – Operator view
PROJECT DOLPHIN-PDCS ARCHITECTURE

AREVA

Central Control Room

System Maintenance and Engineer's Room

Areva

T&D

India Habitat Centre
MESSAIED PDMS Architecture

**SS3400A**
- Graphical printer
- Log event printer
- Engineering workstation

**Monitoring workstation**
- Log event printer
- MODBUS Gateways
- ICS
- NGL (future)

**SS3403**
- 11kV Switchboard QB-2 & common IO
  - redundant C264 MODBUS RS485 relays (defined in IO mapping)
- 3.3kV Switchboard QC-4
  - redundant C264 MODBUS RS485 relays (defined in IO mapping)
- 415V Switchboard QD-18
  - redundant C264 MODBUS RS485 communication with EagleNet system (defined in IO mapping)
- 415kV Switchboard QD-18
  - No communication

**33kV Switchboard QA-1**
- redundant C264 MODBUS RS485 relays (defined in IO mapping)

**11kV Switchboard QB-1 & common IO**
- redundant C264 MODBUS RS485 relays (defined in IO mapping)

**415V Switchboard QD-20**
- redundant C264 MODBUS RS485 communication with EagleNet system (defined in IO mapping)

**IRIG-B Clock**

Laptop for maintenance, configuration and Workstation backup

Ethernet 100Mbit/s TCP/IP Multi-mode optical fibre (Not ALSTOM scope)
Conclusion

- IEC 61850 offers fantastic opportunities for cost reduction and process improvement
- The current projects are first a copy of what has been done with the previous technology
- There is a need to change the traditional project engineering to fully and safely benefit from the new standard
- Like for most IT areas the architect role is likely to emerge, in addition to the system integrator

Thanks