Distributed Automation System

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1. Use Cases

2. SGAM Architecture

3. Implementation of architecture

4. Architecture evaluation
1. Use Cases

- State estimation, forecast, network update, measurement collection
- LV, MV, control center power control, block OLTCs, FLISR
- Purchase of energy and flexibility, activation of flexibility
1. Use Cases

Use Case description - example

<table>
<thead>
<tr>
<th>Steps</th>
<th>Information producer</th>
<th>Information receiver</th>
<th>Function</th>
<th>Information exchanged</th>
<th>Requirement</th>
</tr>
</thead>
</table>
| 1     | SAU(PSAU).MMS        | SAU(SSAU).MMS        | Data Report  | Switch Status         | TT = 100 ms ...
| 2     | ...                  | ...                  | ...          | ...                   |             |

**Actors**

- SAU(PSAU).MMS
- SAU(PSAU).RDBM
- SSAU(PSAU).IEC104
- DMS.MMS
- Sensor

- SAU(SSAU).MMS
- DMS.Modbus
- SAU(PSAU).Functions
- SAU(PSAU).Modbus
- DMS.IEC104
- IED(PSIED).MMS
- IED(PSIED).functions

**Functions**

- Data acquisition
- Data report
- Data storage
- Signals sampling
- Statistical calculation

**Information exchanged**

- Switch status
- Voltage measurement
- Current measurement
- Power/energy measurement

**Requirements**

- Requirement: transfer time
- Requirement: Transfer rate
- Requirement: Synchronization
- Requirement: Availability
2. SGAM architecture
General description and link to use cases

1. Business framework
2. Functions to be implemented
3. Data models in the main automation standards
4. Communication protocols
5. Components, both hardware and software to take part to the automation system
2. SGAM architecture
Business layer and mapping to component layer

Business layer
- Business actors are connected by business transaction
- Each one has a business goal
- Business actors are mapped onto components
2. SGAM architecture
Component layer

Each Automation actor is defined in terms of
- Interfaces
- Database
- Functions

New automation actors developed:
- Substation Automation Unit
- Distribution management system (DMS)
- MicroGrid Central Controller

Also present in function layer and UCs

Interfaces
- MMS
- Modbus
- Web Services (WS)
- IEC 61850-90-5
- DLMS/COSEM
- Relational database management system (RDBMS)
- Time series database (TSDB)

Database

Functions
- Data report
- Data storage
- Check flag
- CIM parsing
- Data reconstruction
- Detect error
- Fault isolation
- Load forecast
- Missing data
- Optimal power flow
- Power quality control
- Power quality indexes
- Algorithm performance index
- Second fault isolation
- State estimation
- State forecast
- Statistical calculation
- Data acquisition
- Protection update
- Reading/Writing IEDs setting

Also present in function layer and UCs

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2. SGAM architecture

Function layer

Functions are mapped to:
- Actors
- Use cases
- Zones and domains of Smart Grid Plane

Function list:
- Bid acceptance/modification
- Bid submission
- Check flag
- CIM parsing
- Commercial optimal planning
- CRP activation request
- CRP Validation request
- Data acquisition
- Data Curation and Fusion
- Data reconstruction
- Data report
- Data storage
- Detect error
- Dynamic info derivation
- Fault detection
- Fault isolation
- Load area configuration
- Load forecast
- Market clearance
- Market infos
- Missing data
- Non-convergence detection
- open/close switch
- Optimal power flow
- power flow
- power quality control
- power quality indexes
- Protection update
- algorithm performance index
- Reading/Writing IEDs setting
- Second fault isolation
- Signals sampling
- State estimation
- State forecast
- Statistical calculation
- synchronization
- Validation reply
- Validation request

Control Center Power Control
MV Power Control
MV State Estimation
LV real time Monitoring
MV real time Monitoring
2. SGAM architecture
Information layer

IEC 61850 – data models

<table>
<thead>
<tr>
<th>Logical node</th>
<th>Data object</th>
<th>Data Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATCC</td>
<td>BndCtr</td>
<td>ASG setMag</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AnalogueValue</td>
</tr>
</tbody>
</table>
## 2. SGAM architecture

### Communication layer

<table>
<thead>
<tr>
<th>Steps</th>
<th>Information producer</th>
<th>Information receiver</th>
<th>Function</th>
<th>Information exchanged</th>
<th>Requirement</th>
</tr>
</thead>
</table>
| 1     | SAU(PSAU). MMS       | SAU(SSAU). MMS       | Data Report | Switch Status         | Transfer Time = 500 ms  
Transfer Rate = 1000 kb/s  
Synchronization accuracy = ...  
Availability = ... |
| 2     | ...                  | ...                  | ...       | ...                    |             |

![Diagram of SGAM architecture](image-url)
2. SGAM architecture
One step toward implementation

Function layer
- Functions have been realized in WP4 (FLISR), WP5 (Monitoring and LV, MV, control center control), WP6 (business and commercial aggregator)
- Functions are adapted in order to read and write from a standardized IDE4L database

Information layer
Exchanged data are clustered onto classes and mapped to
- CIM data models for static data and business related data
- 61850 for real time data

Communication layer
- The requirements of the information exchange grouped onto technology classes

Component layer
Each component is implemented as
- Software/Hardware interfaces
- Database
- Functions

Smart Grid Coordination Group, CEN-CENELEC-ETSI, Tech. Rep., 2012
3. Implementation of the architecture
Interfaces, Database, Functions (Algorithms)

Generic SAU, DMS, MGCC, IED

Software Interfaces
- DLMS Client/Server
- MMS Client/Server
- Modbus Master/Slave
- Web Services
- 104 Master/Slave

Algorithms
- State estimation
- Power Control
- Measurement collection
- Statistics calculation
- Power quality indexes calculation
- FLISR
- ....
3. Implementation of architecture

Database structure

**Measure & Command Model**
- Physical devices, logical devices, logical nodes, data objects and data attributes with real time data
- Set of information to parameterize the communications interface to each physical device (such as IP addresses, TCP ports, users and passwords, etc.)

**Network Model**
- Network topology and parameters of lines, customers and generators

**Management Model**
- Represents the models related to an algorithm.
- Instantiate, parameterize and control the execution of a specific algorithm

**Bridge Model**
It is the connection schema for all other schemas.
- Relations among Measure & Control real time quantities with the network topology
4. Evaluation of IDE4L architecture

Information Exchange

Regular information exchange between PSAU and SSAU

<table>
<thead>
<tr>
<th>UC</th>
<th>Information Producer</th>
<th>Information Receiver</th>
<th>Data Exchange</th>
<th>Amount of Data (AD)</th>
<th>AD PSAU [-]</th>
<th>AD SSAU [-]</th>
<th>Reporting Rates[frames/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV SE</td>
<td>PSAU</td>
<td>SSAU</td>
<td>Estimation at point of connection (V.P.Q)</td>
<td>9</td>
<td>2250</td>
<td>9</td>
<td>0.02</td>
</tr>
<tr>
<td>LV SF</td>
<td>PSAU</td>
<td>SSAU</td>
<td>weather forecast (temperature, irradiation, wind speed for 24h)</td>
<td>72</td>
<td>18000</td>
<td>72</td>
<td>0.001</td>
</tr>
<tr>
<td>MV SF</td>
<td>PSAU</td>
<td>SSAU</td>
<td>Forecast point of connection for 24 hours</td>
<td>216</td>
<td>54000</td>
<td>216</td>
<td>0.001</td>
</tr>
<tr>
<td>LV SE</td>
<td>SSAU</td>
<td>PSAU</td>
<td>Estimation at point of connection (V.P.Q)</td>
<td>9</td>
<td>2250</td>
<td>9</td>
<td>0.02</td>
</tr>
<tr>
<td>LV SF</td>
<td>SSAU</td>
<td>PSAU</td>
<td>State forecast at connection for 24 hours</td>
<td>216</td>
<td>54000</td>
<td>216</td>
<td>0.001</td>
</tr>
<tr>
<td>DM</td>
<td>SSAU</td>
<td>PSAU</td>
<td>3 indexes with dynamic status of the grid</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Event information exchange between PSAU and SSAU

<table>
<thead>
<tr>
<th>UC</th>
<th>Information Producer</th>
<th>Information Receiver</th>
<th>Data Exchange</th>
<th>Amount of Data (AD)</th>
<th>AD PSAU [-]</th>
<th>AD SSAU [-]</th>
<th>Maximum Transfer Time[s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV SE</td>
<td>PSAU</td>
<td>SSAU</td>
<td>SWI-BRE status</td>
<td>3</td>
<td>46875</td>
<td>187.5</td>
<td>300</td>
</tr>
<tr>
<td>LV SF</td>
<td>SSAU</td>
<td>PSAU</td>
<td>SWI-BRE status</td>
<td>3</td>
<td>46875</td>
<td>187.5</td>
<td>300</td>
</tr>
</tbody>
</table>

Example – Unareti demo grid
4. Evaluation of IDE4L architecture
Hierarchical distribution of automation

Number of nodes monitored/controlled by each actor in each use case in IDE4L architecture

<table>
<thead>
<tr>
<th>Use cases</th>
<th>DMS</th>
<th>PSAU</th>
<th>SSAU</th>
<th>IED</th>
<th>MGCC</th>
<th>CAAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring (DATA CONCENTRATION)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV Monitoring</td>
<td>0</td>
<td>0</td>
<td>250</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>MV Monitoring</td>
<td>0</td>
<td>250</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>LV State Estimation</td>
<td>0</td>
<td>1</td>
<td>250</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MV State Estimation</td>
<td>0</td>
<td>250</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LV State Forecast</td>
<td>0</td>
<td>1</td>
<td>250</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MV State Forecast</td>
<td>0</td>
<td>250</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dynamic Monitoring</td>
<td>10</td>
<td>250</td>
<td>62.5</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FLISR</td>
<td>0</td>
<td>250</td>
<td>250</td>
<td>1</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Commercial Aggregator Energy Planning</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FLISR</td>
<td>0</td>
<td>250</td>
<td>250</td>
<td>1</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>MV Power Control</td>
<td>0</td>
<td>250</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LV Power Control</td>
<td>0</td>
<td>0</td>
<td>250</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Control Center Power Control</td>
<td>2500</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Example – A2A demo grid
Assumption
- Assuming the control center controlling 10 primary substations
- 250 buses in LV and MV
- 100% PMU coverage in MV and 25% in LV
- In case of network reconfiguration the Control center may act on all MV switches

Example – Unareti demo grid
4. Field and Lab demonstration
Use Case mapping, KPIs

Use Case mapping and KPIs
• All use cases have been assigned to demonstrators
• Each use case has a set of Key Performance Indexes (KPIs) in order to evaluate the performance of the architecture (deliverable 7.1)

Field demonstrators
• Real loading/generation conditions
  • real PQ issues
  • real congestions
• Real amount of information exchanged
• Real components

Lab demonstrators
• “Real” → “Realistic” (past data or collection of statistics)
• Tests with different time windows and simulation steps → check different issues of PQ, congestions
• It is possible to introduce errors/issues in different parts of monitoring/control chain
Conclusions and Exploitation of IDE4L architecture

1. Use cases
   - 29 use case detailed descriptions (11 monitoring, 11 control, 7 business)
   - List with description of actors, information exchange, functions and communication requirements

2. SGAM architecture
   - SGAM communication, information, component, business detailed SGAM layers in .xls and enterprise architect files

3. Architecture Implementation
   - 61850, CIM information mapping for whole set of information exchanges in UCs in .xls tables to facilitate standard implementation of architecture
   - Database structure and sample communication interfaces

4. Evaluation of architectures
   - Architecture metrics definition and results
Thank you!

www.ide4l.eu