CIM for data exchange within a DMS for electric distribution networks

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CIM Users Group Spring 2013 Meeting
• The SmartGen Project
• Project Architecture
• The adoption of CIM
• Testing Phase
• Conclusion
Outline

• The SmartGen Project

• Project Architecture

• The adoption of CIM

• Testing Phase

• Conclusion
SmartGen Project

- **Title**
  - “Study, development and validation of methodologies and tools for the management of active power distribution networks including renewable energy sources”

- **Foundings**
  - Funded by MISE (Italian Ministry for Economic Development) in the context of the Research Projects for the Electric Systems

- **Context: Smart Grids**
  - Operation of generators of any size and technology
  - Load active role in the optimization of operation
  - Availability of more information and wider choice of suppliers
  - Reduction of environmental impact
  - Enhancement of reliability, security and quality of service

Project Consortium

University of Genova - **DINAEI**
Scientific coordinator
DMS architecture, technology survey and enhancement, dissemination

University of Bologna - **DIE**
DMS advanced functionalities and monitoring interfaces

**Enel Engineering and Research**
System requirements, DMS architecture definition, piloting and demonstration

**Softeco Sismat S.r.l.**
Project coordination
System integration, automation and communication software, wholesale market management

s.d.i. S.p.A.
SCADA & DMS design and implementation, innovative power network management

START: January 2011
DURATION: 36 months
COSTS > 2.8 M€
Financing = 1.1 M€
1. ENERGY BALANCE
   - Generation / Demand
   - Load curve control

2. GRID SECURITY
   - Network stability
   - Provision continuity / QoS

WHOLESALE ELECTRIC MARKET

POWER GRID INFRASTRUCTURE
   - Transmission & distribution network
   - Microgrid, VPP/VPU
Project Objectives

• Analyzing scenarios of Smart Grids and active interaction with the electricity market
  – Distributed Generation (DG) and storage
  – Possibility of load control
  – To identify main technical and economical constraints
  – To define future actors (aggregators, price signals, active demand management)

• Defining and implementing the architecture of an innovative DMS (Distribution Management System)
  – Interface to data acquisition and SCADA (Supervisory Control And Data Acquisition) systems
  – State estimation and simulation scenarios
  – Management of optimization problems, control of power flow, voltage and supply of ancillary services from DG, and load dispatch
  – Study of different distribution management modes: normal (system interconnected to the main distribution network), dysfunctional, and/or emergency mode (islanding)

• Demonstrating features and benefits in a real use case
  – Definition of complex reference scenarios
  – Validation of real network functional efficiency
  – Integration of real networks and simulation in pilot sites
• The SmartGen Project

• **Project Architecture**

• The adoption of CIM

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SmartGen Contextualization

POWER GRID
- Transmission
- Distribution (MT/BT)
  - Microgrid
  - Virtual Power Plant
  - Virtual Power Utility
- Technical constraints

MARKET
- Trading
- Ancillary Service
- Economical constraints

EMS
- HV networks

Advanced Functionalities
- Management
- Control
- Forecast
- Simulation
- MV/LV networks

DMS
Architecture - details

TECHNICAL CONSTRAINTS (INFRASTRUCTURE)
- HV
- MV
- LV

TECHNICAL CONSTRAINTS (ELECTRICAL NETWORK)
- HV/MV
- MV/LV

TECHNICAL CONSTRAINTS (SIMULATION)

ECONOMICAL CONSTRAINTS (MARKET)
- TRADING
- ACTIVE DEMAND / DSM
- LOAD/PRODUCTION AGGREGATION
- ANCILLARY SERVICES

ADVANCED FUNCTIONALITIES (ALGORITHMS)
- LOAD FORECAST
- GENERATION FORECAST
- STATE ESTIMATION
- OPTIMIZATION
- OPTIMAL RECONFIGURATION
- FAULT LOCATION

SERVICE BROKER / SCHEDULER

CIM SERVER
- REAL TIME DB
- HISTORIAN DB
- CIM DB

SmartGen DMS

I/O
2. Decentralized control

3. Local control

SmartGen DMS
• **SmartGen DMS based on**
  – SCADA system, for data acquisition from the field
  – CIM Server, as an archive for CIM data
  – Advanced DMS component, with smart features

• **Communication among DMS components:**
  – Data exchange on a regular basis
    - Periodically
    - Upon request
  – Each system based on its own proprietary format to
    - Read input data
    - Store information
    - Write output data

• **Need for a universal model for data structure**
  – Data exchange among the DMS components
  – Connection to external systems
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Adopting the CIM

• CIM constitutes
  – Common language enabling information exchange
  – Universal model providing interoperability

• It implies the development of
  – Conversion module
    • From CIM to the SCADA proprietary format and vice versa
    • From CIM to the advanced-component proprietary format and vice versa
  – CIM-data retrieve functionalities

• CIM-based DMS able to
  – Integrate further CIM-based applications, with no additional implementation
  – Being interfaced with external CIM-based SCADAs or DMSs
  – Communicate with any other external CIM-based system
SmartGen CIM Profile

• CIM versions in SmartGen
  – CIM v14 ENTSO-E 2009 (as exported by DlgSilent)

• SmartGen CIM profile includes:
  – Elements represented by the SCADA
  – Elements of the advanced DMS component

• Standard IEC61970
  – Core
  – OperationalLimits
  – Topology
  – Wires
  – Generation
    • Production
  – LoadModel
  – Meas
  – SCADA
  – ControlArea
  – StateVariables

• Standard IEC 61968 extensions

• Electric Market interface
Communication Architecture

Middleware

SERVICE BROKER / SCHEDULER

SCADA
Power grid
Distribution (MV/LV)

CIM SERVER
CIM data filing

CIM DB
PostgreSQL

ADVANCED FUNCTIONALITIES
LOAD FORECAST
GENERATION FORECAST
STATE ESTIMATION
OPTIMIZATION
OPTIMAL RECONFIGURATION
FAULT LOCATION

ENTSO 2009 CIM v14
<network>_EQ.xml: equipment
<network>_SV.xml: system variables
<network>_TP.xml: topology

CIM xml
GIPE xml

MAT xml

GIPE2CIM interpreter
MAT2CIM interpreter

RDF

MuleSoft
**Conversion module**

- **CIM2MAT**
  - From CIM to the advanced DMS component proprietary format

- **MAT2CIM**
  - From the advanced DMS component proprietary format to CIM
• Conversion module
  – CIM2MAT
    • From CIM to the advanced DMS component proprietary format
  – MAT2CIM
    • From the advanced DMS component proprietary format to CIM
DMS Features - I/O

Input

- CIM: Topology
- CIM: Equipment
- CIM: Measurement

CIM xml → CIM2MAT interpreter → MAT xml → STATE ESTIMATION

Output

- Estimated measurements
- State variables

MAT xml → MAT2CIM interpreter → CIM xml

CIM: StateVariable

- State Variable
- PowerSystemResource: TapChanger
  - `pNetInjection`: ActivePower [0..1]
  - `qNetInjection`: ReactivePower [0..1]
- Sv Tap Step
  - `continuousPosition`: Float [0..1]
  - `position`: Integer [0..1]
- Sv Voltage
  - `angle`: AngleRadians [0..1]
  - `v`: Voltage [0..1]
- Sv Status
  - `inService`: Boolean [0..1]
- Sv Power Flow
  - `p`: ActivePower [0..1]
  - `q`: ReactivePower [0..1]

CIM: Measurement

- Measurement
  - `measurementType`: String [0..1]
  - `sensorAccuracy`: Percent [0..1]
  - `timeStamp`: AbsoluteDateTime [0..1]
- Analog
  - `maxValue`: Float [0..1]
  - `minValue`: Float [0..1]
  - `normalValue`: Float [0..1]
  - `positiveFlowIn`: Boolean [0..1]
- Discrete
  - `maxValue`: Integer [0..1]
  - `minValue`: Integer [0..1]
  - `normalValue`: Integer [0..1]

- IdentifiedObject
  - `Terminal` [0..1]
  - `MeasurementValueSource` [0..1]

- IdentifiedObject
  - `Core::Terminal`
  - `Core::ConductingEquipment` [1]
  - `Core::TopologicalNode` [0..1]
DMS Features - I/O

**Input**
- CIM xml
- CIM:Topology
- CIM:Equipment
- CIM:Measurement

**CIM2MAT interpreter**

**MAT xml**

**FUNCTIONALITY**

**OPTIMIZATION**

**Output**
- MAT xml
- MAT2CIM interpreter
- CIM xml

- Generation set points
- Generation profiles

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**CIM: SetPoint**

**class Control**

- Core::Unit
- ControlType
- Measurement
- Discrete
- ValueAliasSet
- ValueToAlias
- Command
- SetPoint

**class SetPoints**

- IdentifiedObject
- Core::Terminal
- Wires::TapChanger
- ConductingEquipment
- Wires::RegulatingCondEq

**CIM: RegulationSchedule**

- IdentifiedObject
- Core::PowerSystemResource
- Wires::SynchronousMachine
- Wires::VoltageControlZone
- Wires::TapChanger
- Wires::RegulatingControl
- Wires::VoltageControlZone

**SeasonDayTypeSchedule**

**ConductingEquipment**

- Wires::RegulatingCondEq

**Wires::SynchronousMachine**

**Wires::TapChanger**

**Wires::RegulatingControl**

**Wires::VoltageControlZone**

**VoltageControlZone**

**«enumeration»**

**RegulatingControlModeKind**

- voltage
- activePower
- reactivePower
- currentFlow
- fixed
- admittance
- timeScheduled
- temperature
- powerFactor

- discrete: Boolean [0..1]
- mode: RegulatingControlModeKind [0..1]
- targetRange: Float [0..1]
- targetValue: Float [0..1]
class Control

class StateVariables

CIM: Topology

CIM: Equipment

CIM: Measurement

CIM: Command
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• **Software Testing Phase**
  – Simulation of data exchange within the SmartGen DMS
  – Using DlgsSilent simulator
    • Cigré DER extended

• **DMS Field Testing Phase**
  – SmartGen DMS in real networks
    • Italian experimental areas
    • Italian distribution network
Software Testing Phase – Simulated Network
Field Testing Phase – Real Networks

- The ensemble of pilot sites was chosen in order to test (in simulated and/or in field) all the SmartGen functions:
  - State estimation
  - Load/generation forecast
  - Optimization of the working point
  - Optimal (re-)configuration
  - Fault location

- Three sites are identified sites because:
  - They allow to apply and test a comprehensive combination of the DMS functions
  - They already have a good degree of instrumentation
  - More activities aimed at the installation of additional instrumentation will be possible
1 - Experimental Area in Livorno - ENEL

- Area owned by ENEL INGEGNERIA e RICERCA

- Internal network MV and LV:
  - Common services and utilities (300kW)
  - Pilot plants for combustion testing (1900kW):
  - Experimental plants with distributed generation (1200 kW)
  - Experimental storage systems (100 kW)

- Possibility of field tests with no impact on the distributor

- Functionalities that can be demonstrated
  - State estimation
  - Optimization
  - Islanding
The portion of the electricity distribution network managed by AMAIE SpA covers about half of Sanremo’s municipal area and includes both urban and rural areas.

The network is composed of:
- A primary substation (HV/MV 132/15 kV)
  - double bar structure equipped with 2 transformers of 40 MVA.
- 10 MV feeders, typically managed in a radial structure, departing from the substation
- 115 km of MV lines, both cables and overhead lines. MV network managed in compensated neutral
- ~200 secondary substations (MV/LV 15/0,4 kV), among public and private ones
  - Of which about 10% remotely controlled
- ~30,000 users (27,000 for domestic use, 15 for industrial use, 3,000 other)
- ~50 PV plants
  - 1 x 470 kW in MV
  - 10 x (10-100kW) in LV
  - Domestic < 6 kW

Functionalities that can be demonstrated:
- Open/close control function
- Fault location
- State estimation
• Microgrid at a MV/LV substation
  – Photovoltaic plant (20 kWp)
    • Monocrystalline module with 180 Wp.
    • Expected production per year: 24,4 MWh
  – Storage (10kW/12kWh)
    • Lithium battery technology
    • Controllable loads
  – System monitoring and real-time control
• Possibility of field tests with no impact on the distributor
• Functionalities that can be demonstrated
  – State estimation
  – Optimization
  – Islanding
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Conclusion

- **Project advances**
  - Providing enabling technologies for active distribution network management
    - Distributed generation / Load control
  - Design and development of an advanced DMS, also open to future scenarios of the electricity market
    - Network control / energy balance
  - The Consortium includes the entire supply chain and integrates the necessary research skills
    - Distributors / Universities / Product and service companies

- **The adoption of CIM**
  - Provides the SmartGen DMS with interoperability
  - Allows the integration of CIM-based applications, with no additional implementation
  - Enables to interface the SmartGen DMS with external CIM-based systems, without restricted access

- **SmartGen contributes to**
  - Diffusion of CIM as a commonly recognized standard for electrical data representation
  - Extension of CIM for the application to distribution network
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