Agenda
An Overview of Network Codes, CIM & CGMES

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Standards Development
Current Drivers Resulting In Standardization In Europe

Drivers

- Common energy markets
- Increased trade increase flows across market boundaries
- Large increase in renewable power generation
- Increasing difficulty in predicting power flows
- Huge power flows over congested network boundaries
- Old generation units being decommissioned
- Decreasing system stability

Network Codes is legislation in EU that handle this

- Legislation done by ACER (Agency for Cooperation of Energy Regulators)
- Implemented by ENTSO-E

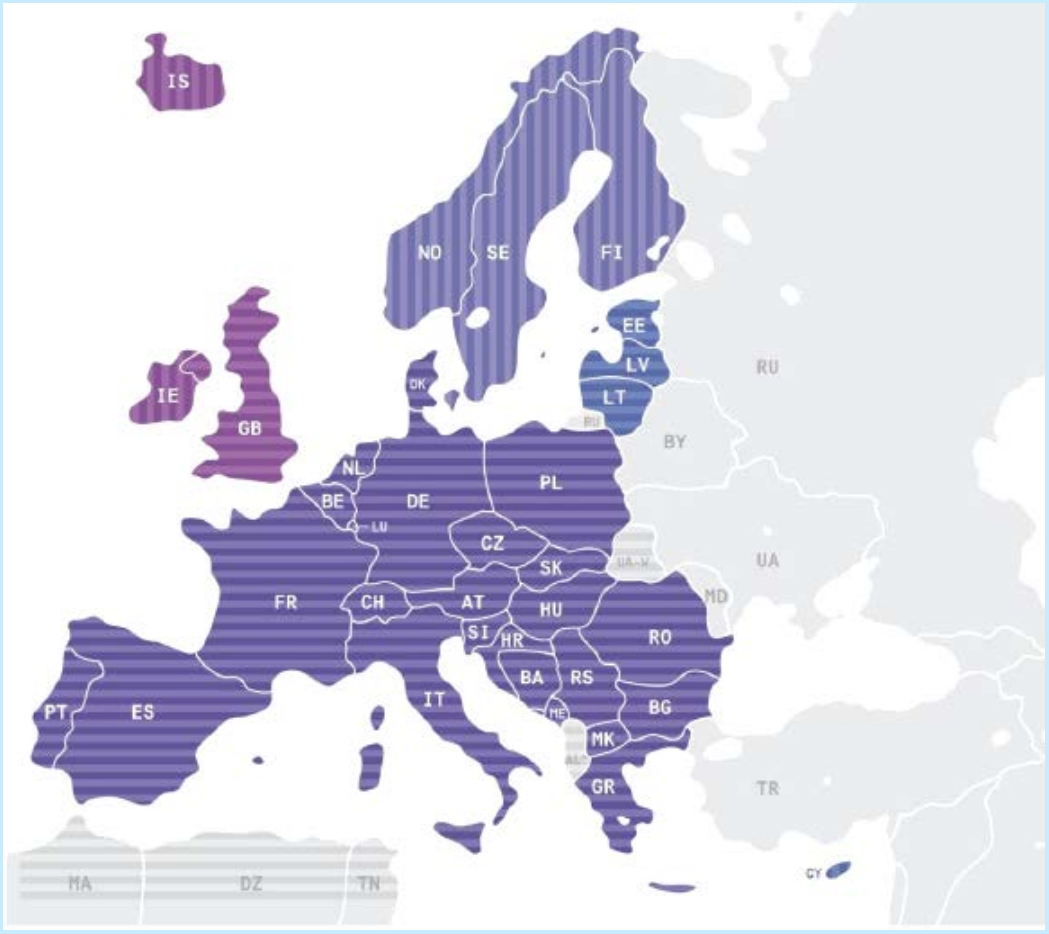
Standards Development
ENTSO-E

About ENTSO-E

- 41 TSOs in 34 countries
- 532 million citizens
- 828 GW production
- 305 thousand km lines

ENTSO-E tasks

- Coordinate development
- Forcast energy needs
- Implement Network Codes
  - competitive market integration
  - renewable production
  - secure supply



Standards Development
Energy Production And Flows in EU

Renewable energy production increase

- Wind
- Solar
- During sunny and windy days the renewable production is substantial, regionally > 25%!

Fossil and nuclear plants being decommissioned

- Loss of inertia and voltage control capability

Large power flows across EU

Power flow congestion an issue

- Hinder free market
- Threaten stability stability

Standards Development
Managing The European Power Network

Operation; SCADA/EMS/DMS/GMS

- Use detailed node-breaker network models and real time measurements
- Each operations department manage their own models but exchange real time measurements

Operational planning

- Use simplified bus-branch models, day ahead forecasts and plans
- Forecasts and plans typically from markets
- Each operational planning department manage their own models

Network planning

- Use simplified bus-branch models, forecasts and plans
- Forecasts and plans typically from studies of social development
- Each planning department manage their own models

Assets management

- Economical and technical data
- Each asset management department manage their own data

TSO/DSO * department
->
Hughe duplication in data management work
->
High risk of data errors

Standards Development
Devleopment And Implementation Of Network Codes

The Network Codes require energy sector to

- Increase cooperation, e.g. TSOs, DSOs, energy providers …
- Share data
- Automate data exchange processes

ENTSO-E got the task to implement standards supporting the Network Codes

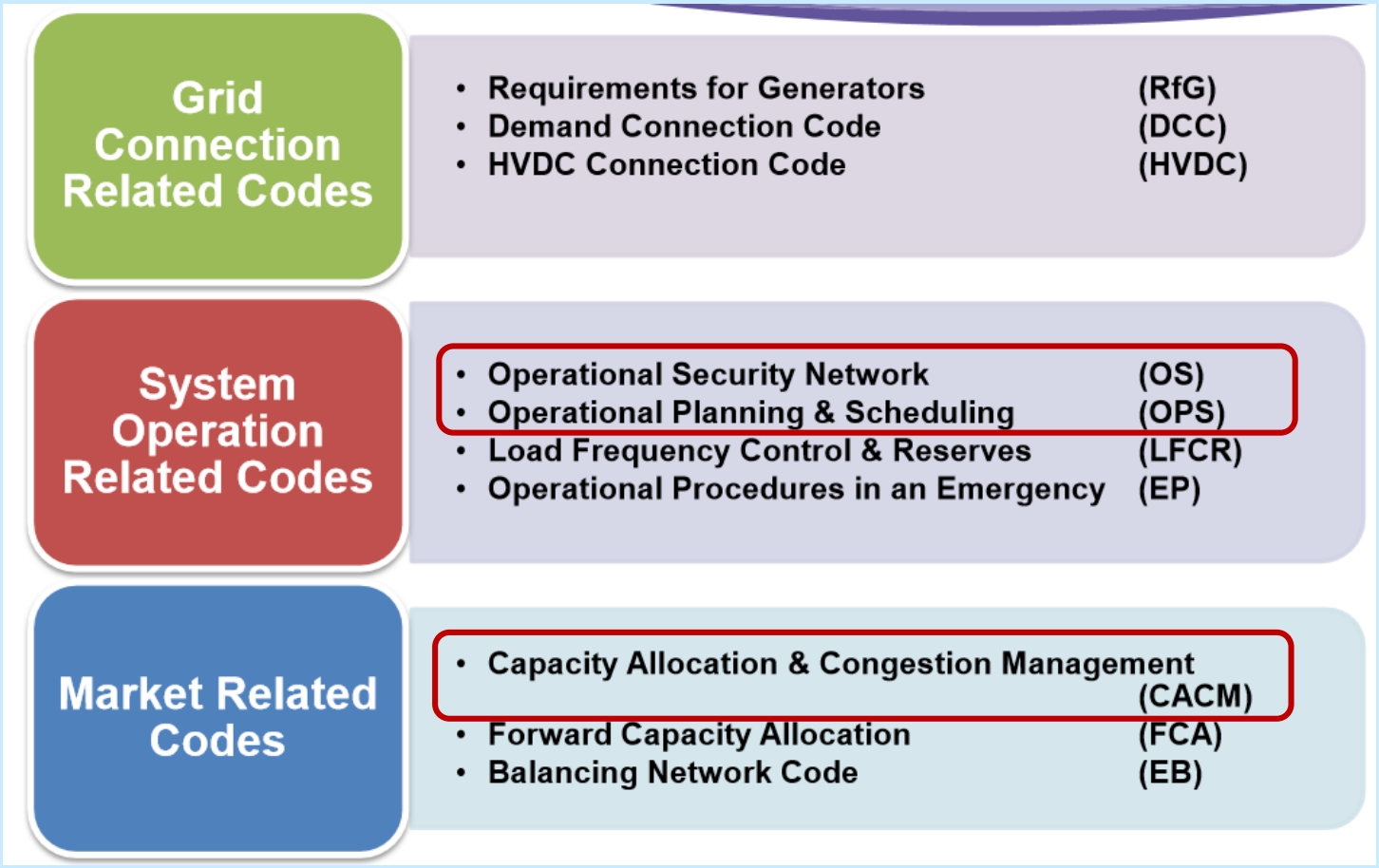
- Selected CIM and developed CGMES profiles

CGMES profiles used for exchange of

- Network models
- Power flow, short circuit and dynamics data

Standards Development

Overview Of The Network Codes And Where CGMS Applies



Standards Development
CGMES Currently Used With NC CACM

Requirements from the Network Code CACM

- Capacity and Congestion management
  - Intra Day Congestion Forecast (IDCF)
  - Day Ahead Congestion Forecast (DACF)
  - Capacity Allocation two days ahead
- Need to exchange network models and schedules for Europe
- Old DEF format needed development
- CIM was investigated as an alternative

Use of CACM

- TSO evaluate network security for day and intra day market data
- RSCI evaluate network security for day and intra day market data of larger regions

Standards Development
What CIM And CGMES Is

An information model in **UML**

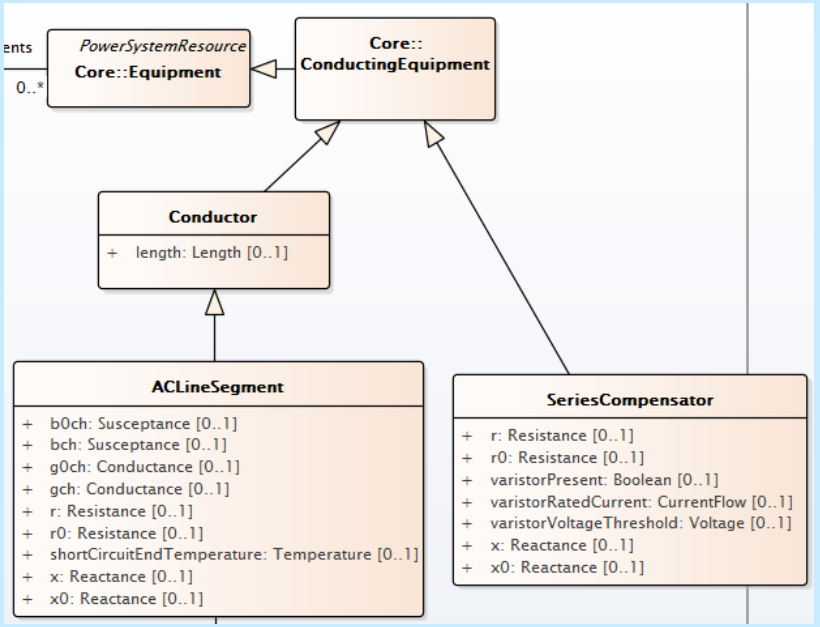
An agreed **canonical** information model

The information model is large

- Not practical to use as is
- Subsets or **profiles** used for actual exchanges

Data is exchanged as XML documents

- XML Schema based documents
- **RDF/XML** documents
- RDF/XML is described by RDFS and OWL
- RDF and OWL designed for the semantic web

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Standards Development
IEC TC57

Working groups and standards

- WG3 and WG7 Communication protocols
- WG10 – IEC 61850 Substation control interfaces
- WG13 – IEC 61970 CIM - EMS API *
- WG14 – IEC 61968 CIM - System interfaces for electrical distribution *
- WG15 – IEC 62210 Data and communication security
- WG16 – IEC 62325 CIM - Deregulated energy market communications
- WG17 Communication system for distributed energy resources (DER)
- WG18 Hydro electric power plants
- WG19 coordination of TC57 standards, in particular CIM and IEC 61850

* Scope is currently changing for CIM

- 61970 – network model for both transmission and distribution
- 61968 – utility related IT/OT work processes

Standards Development
ENTSO-E CGMES

Three versions

- CGMES 1 based on CIM 14
- CGMES 2.4 based on CIM 16
- CGMES 2.5

Consist of

- CIM Canonical UML
- ENTSO-E Canonical UML extensions
- ENTSO-E profile in UML
- ENTSO-E profile in RDFS
- ENTSO-E main document
- Several additional guideline documents

Standards Development
IEC 61970/CGMES Documents, CIM 16 and CGMES 2.4

Canonical CIM	
• UML package	iec61970cim16v33b_iec61968cim12v08_iec62325cim03v01a.eap
• CIM Base	IEC 61970-301
• Dynamics	IEC 61970-302
CIM 16 / CGMES 2.4 profile documents	
▪ EQ – Network equipment	IEC 61970-452
▪ TP – Topology	IEC 61970-456
▪ SV – State Variables (bus-branch power flow input/output)	IEC 61970-456
▪ SSH – Steady State Hypothesis (power flow input)	IEC 61970-456
▪ DL – Display Layout	IEC 61970-453
▪ GL – Geographical Location	
▪ DY – Dynamics data	IEC 61970-457
CIM RDF schema, profile information model	IEC 61970-501
CIMXML data exchange format	IEC 61970-552

Standards Development

IEC 61970/CGMES Documents, CIM 17 and CGMES 2.5

CIM 17-18 / CGMES 2.5 profile documents

- Frames – support automated model management — IEC 61970-459
- Network model projects – support model changes in time — IEC 61970-460
- Area interchange – model power exchange between network areas
- Detailed HVDC
- System protection schemes
- Generic dataset, replace header information in IEC 61970-552 — IEC 61970-452

Standards Development
Network Applications Data Exchange

Network applications calculate with bus-branch data

Real power system has breakers and measurements, they are node-breaker based

Two types of network models

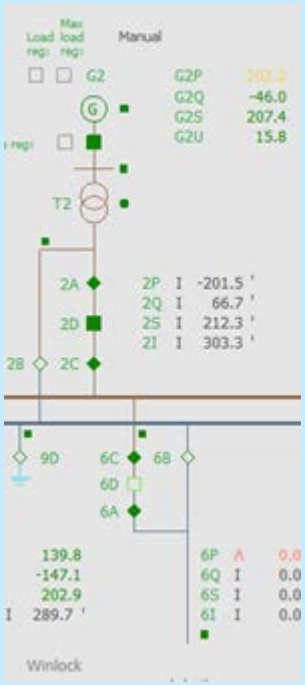
- Bus-branch (BB)
- Node-breaker (NB)

BB models can be derived from NB models

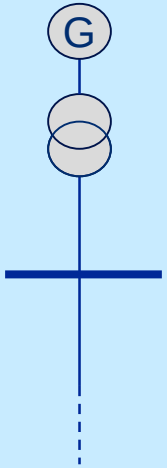
Existing standards for application data is BB

- IEEE
- PSS/E
- PSLF
- DEF
- ...

CIM is both NB and BB

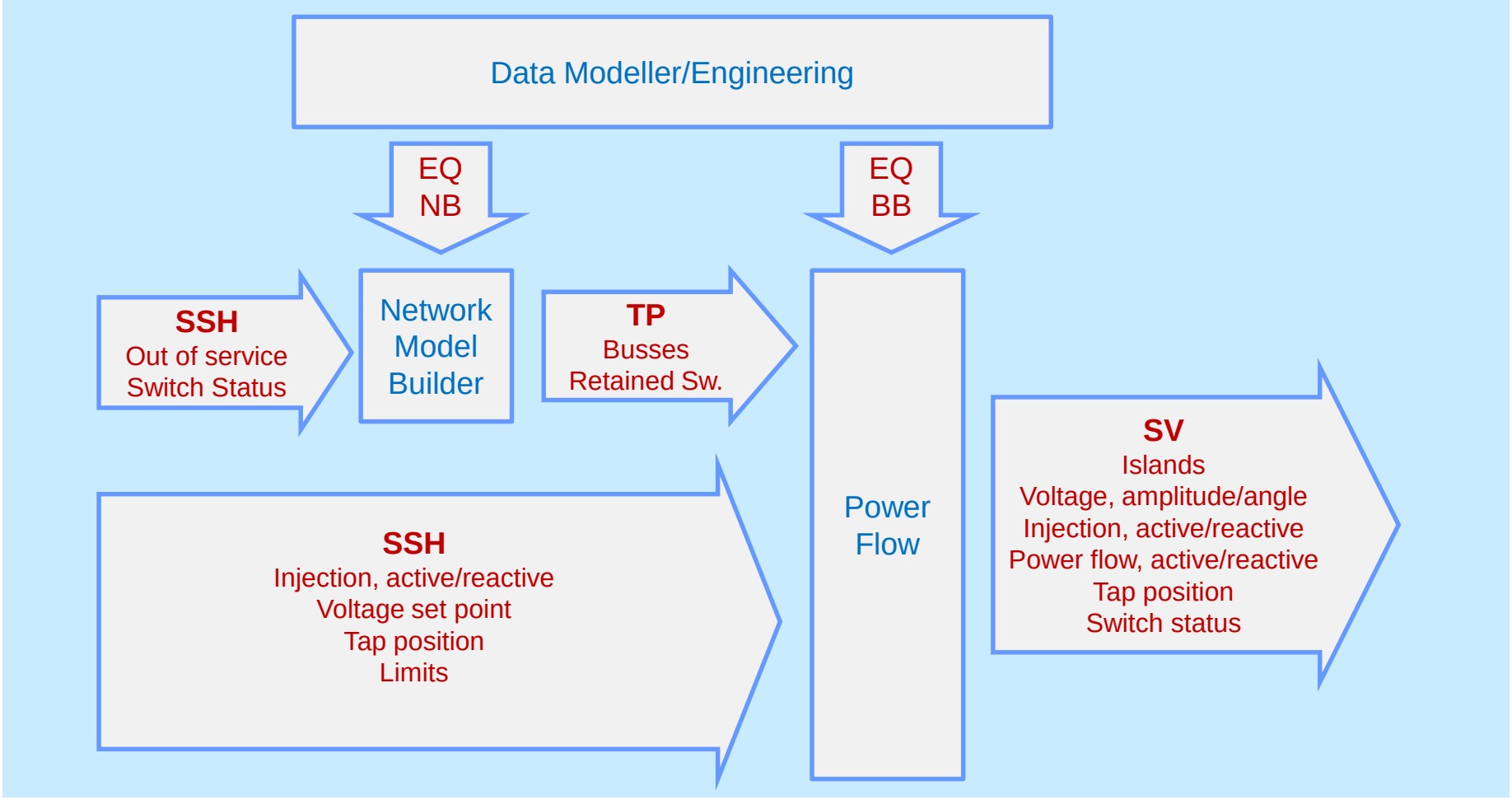


NB to BB



Standards Development

Use of Profiles with Network Applications, Power Flow



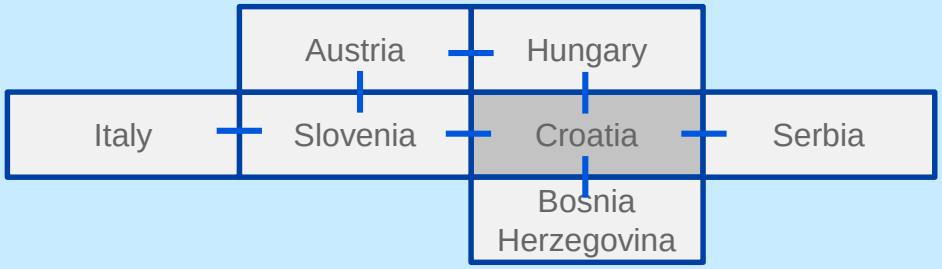
Standards Development
Modularization Of Network Application Model Exchange

Modularization Of Data Sets

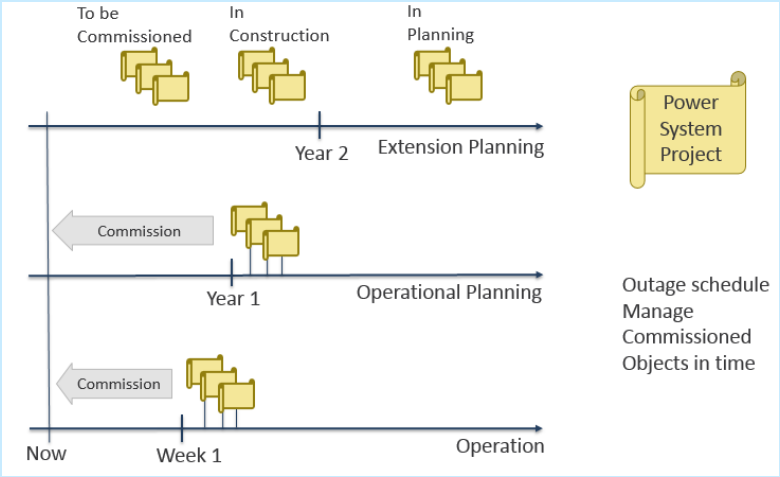
- Frames and Model Authority Sets
- Type of data, Profiles

Modularization In Time

- Power System Projects

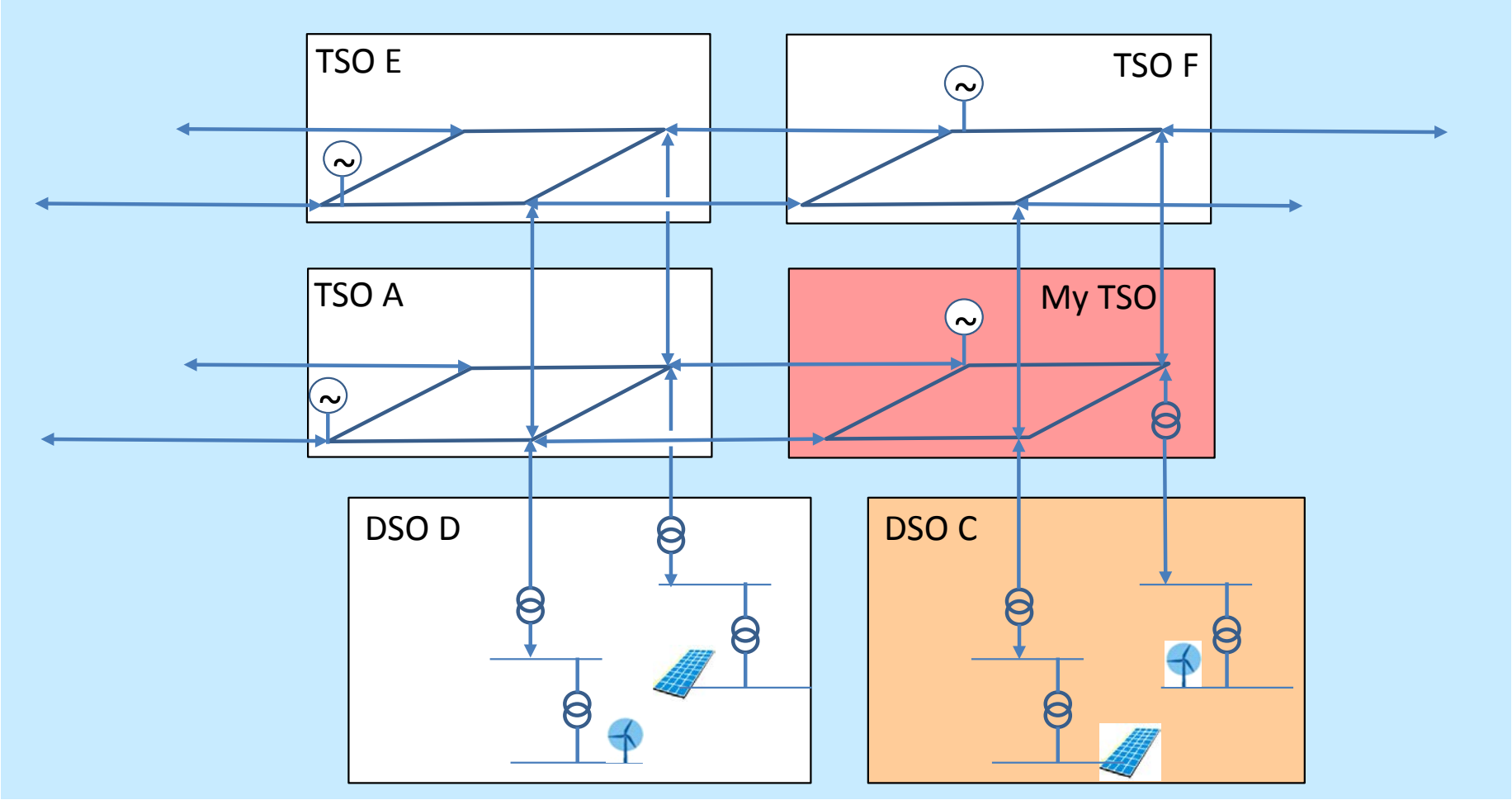


Equipment	**EQ**
Steady State Hypothesis (Power flow inputs)	**SSH**
Topology	**TP**
State Variables	**SV…**



Standards Development

Modularization Of Network Models In Areas (Frames)



Standards Development
Interoperability And Conformance

Interoperability and conformance tests has been organized by EPRI and ENTSO-E

Interoperability tests

- Purpose is to verify
  - The CIM standard enables interoperability
  - Vendor products interoperate

Conformance tests

- Purpose is to verify vendor products conforms with the standard

Currently ENTSO-E host a conformance procedure for CGMES 2.4.15, three levels of conformance

- Bronze, Silver and Gold

ENTSO-E TSO are expected to be conformant to CGMES 2.4.15 during 2017.

Interoperability tests are being planned summer 2017 for next ENTSO-E profile CGMES 2.5

Standards Development
Conformance Tests

Organized by ENTSO-E starting 2014

CGMES 2.4.15 conformance documents

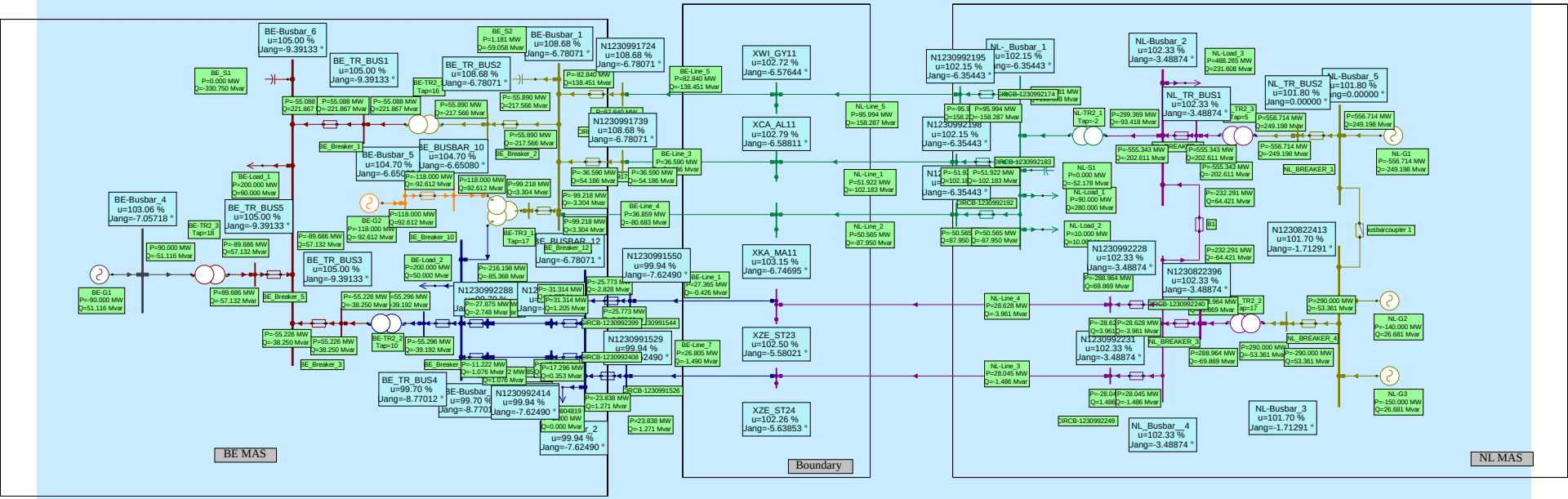
- Application process, application and comments documents
- Function category description
- Use case description
- Function category matrix
- Report template

Test configurations

- Micro grid
- Mini grid
- Small grid
- Real grid

Standards Development

Micro Grid Test Network Example



Standards Development

ENTSO-E CGMES 2.4.15 Conformance Matrix

Test Use Cases short name	Test Use Cases name	Data management			Data visualisation		Power system analysis			
		Import*	Export*	Update and Repository	Diagram layout	Geographical (GIS) location	Load flow (Node-breaker input representation)	Load flow (Bus-branch input representation)	Dynamics	Short circuit
TUC 01	Import of Boundary Set instance data	Bronze	Not required	Not required	Silver	Silver	Bronze	Bronze	Bronze	Not required
TUC 02	Import of Equipment profile instance data	Bronze	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required
TUC 03	Import of Topology profile instance data	Bronze	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required
TUC 04	Import of Steady State Hypothesis profile instance data	Bronze	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required
TUC 05	Import of State Variables profile instance data	Bronze	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required
TUC 06	Import of Dynamics profile instance data	Bronze	Not required	Not required	Not required	Not required	Not required	Not required	Bronze	Not required
TUC 07	Import of Diagram Layout profile instance data	Bronze	Not required	Not required	Bronze	Not required	Not required	Not required	Not required	Not required
TUC 08	Import of Geographical Location profile instance data	Bronze	Not required	Not required	Not required	Bronze	Not required	Not required	Not required	Not required
TUC 09	Import of multiple profiles instance data	Bronze	Not required	Not required	Bronze	Bronze	Bronze	Bronze	Bronze	Bronze
TUC 10	Import of difference instance data of a profile	Silver	Not required	Bronze	Gold	Gold	Silver	Silver	Silver	Silver
TUC 11	Import of a set of difference instance data belonging to multiple profiles	Gold	Not required	Silver	Gold	Gold	Gold	Gold	Gold	Gold
TUC 12	Import of an assembled model	Not required	Not required	Gold	Not required	Not required	Bronze	Bronze	Bronze	Bronze
TUC 13	Export of Boundary Set instance data	Not required	Bronze	Not required	Not required	Not required	Bronze	Bronze	Not required	Not required
TUC 14	Export of Equipment profile instance data	Not required	Bronze	Not required	Not required	Not required	Not required	Not required	Not required	Not required
TUC 15	Export of Topology profile instance data	Not required	Bronze	Not required	Not required	Not required	Not required	Not required	Not required	Not required
TUC 16	Export of Steady State Hypothesis profile instance data	Not required	Bronze	Not required	Not required	Not required	Not required	Not required	Not required	Not required
TUC 17	Export of State Variables profile instance data	Not required	Bronze	Not required	Not required	Not required	Not required	Not required	Not required	Not required
TUC 18	Export of Dynamics profile instance data	Not required	Bronze	Not required	Not required	Not required	Not required	Not required	Silver	Not required
TUC 19	Export of Diagram Layout profile instance data	Not required	Bronze	Not required	Silver	Not required	Not required	Not required	Not required	Not required
TUC 20	Export of Geographical Location profile instance data	Not required	Bronze	Not required	Not required	Silver	Not required	Not required	Not required	Not required
TUC 21	Export of multiple profiles instance data	Not required	Bronze	Not required	Silver	Silver	Silver	Silver	Not required	Not required
TUC 22	Export of difference instance file of a profile	Not required	Silver	Bronze	Gold	Gold	Gold	Gold	Not required	Gold
TUC 23	Export of difference instance files of a set of multiple profiles instance data	Not required	Gold	Silver	Gold	Gold	Gold	Gold	Not required	Gold
TUC 24	Export of an assembled model	Not required	Not required	Gold	Gold	Gold	Silver	Silver	Silver	Silver
TUC 25	Manage boundary set	Not required	Not required	Not required	Not required	Not required	Bronze	Bronze	Not required	Bronze
TUC 26	Manage node-breaker level of model representation	Not required	Not required	Not required	Not required	Not required	Bronze	Not required	Not required	Not required
TUC 27	Manage bus-branch level of model representation	Not required	Not required	Not required	Not required	Not required	Not required	Bronze	Not required	Bronze
TUC 28	Manage node-breaker model to bus-branch model exchange	Not required	Not required	Not required	Not required	Not required	Silver	Not required	Not required	Not required
TUC 29	Perform load flow calculation	Not required	Not required	Not required	Not required	Not required	Bronze	Bronze	Bronze	Bronze
TUC 30	Perform short-circuit calculation (symmetrical)	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Bronze
TUC 31	Perform short-circuit calculation (asymmetrical)	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Silver
TUC 32	Perform dynamics simulation	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Bronze	Not required
TUC 33	Manage model assembling (simplified bus-branch)	Not required	Not required	Not required	Not required	Not required	Not required	Bronze	Not required	Not required
TUC 34	Manage model assembling (simplified node-breaker)	Not required	Not required	Not required	Not required	Not required	Bronze	Not required	Not required	Not required
TUC 35	Manage model assembling (advanced-load flow)	Not required	Not required	Not required	Not required	Not required	Silver	Not required	Not required	Not required
TUC 36	Manage model assembling (advanced-all profiles)	Not required	Not required	Not required	Not required	Not required	Gold	Not required	Not required	Not required
TUC 37	Handle power transformer, tap changers and phase shift transformers	Not required	Not required	Not required	Not required	Not required	Bronze	Bronze	Not required	Not required
TUC 38	Handle generation types	Not required	Not required	Not required	Not required	Not required	Bronze	Bronze	Not required	Not required
TUC 39	Handle shunt compensators	Not required	Not required	Not required	Not required	Not required	Bronze	Bronze	Not required	Not required
TUC 40	Maintain hierarchy of the model	Not required	Not required	Gold	Bronze	Bronze	Bronze	Bronze	Not required	Not required
TUC 41	Handle HVDC modelling	Not required	Not required	Not required	Not required	Not required	Silver	Silver	Not required	Not required
TUC 42	Manage dependencies between instance data from different profiles of the CGMES	Not required	Not required	Not required	Not required	Not required	Bronze	Bronze	Not required	Not required
TUC 43	Handle equivalent elements	Not required	Not required	Not required	Not required	Not required	Silver	Silver	Not required	Not required
TUC 44	Handle regulating controls	Not required	Not required	Not required	Not required	Not required	Bronze	Bronze	Not required	Not required
TUC 45	Data handling in Applications (simplified)	Not required	Not required	Silver	Bronze	Bronze	Bronze	Bronze	Gold	Gold
TUC 46	Data handling in Applications (advanced)	Not required	Not required	Not required	Silver	Silver	Gold	Gold	Gold	Not required

Standards Development
Conclusions

Standards are necessary to

- Enforce Network Codes
- Enable efficiency by reducing duplication

CIM and CGMES has been adopted for network related Network Codes in Europe

Adoption of CIM and CGMES in Europe has required a substantial effort

But the adoption is accelerating due to benefits, e.g. reduction of data duplication and automation

The Network Codes will first be implemented by TSOs but DSO and energy producers will follow

Standards Development
Some Abbreviations

CIM	Common Information Model (for power systems)
ISO	Independent System Operator, exist in US
TSO	Transmission System Operator
DSO	Distribution System Operator
EPRI	Electric Power Research Institute, an ISO/TSO sponsored research institute in US
CCAPI	Control Center API
CME	CIM for Market data Exchange
IOP	Interoperability Test
IEC	International Electrotechnical Committee
TCxx	Technical Committee xx
WGxx	Working Group xx
ENTSO-E	European Network of TSOs of electricity, formed by merging UCTE and ETSO
CGMES	Common Grid Model Exchange Standard
UCTE	Union for the Coordination of the Transmission of Electricity
ETSO	European Transmission System Operators