CIM CGMES-extensions for the TSO-DSO data exchange in the EU-project „TDX-ASSIST“

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Abstract

In this paper, it is investigated if an exchange of grid-related data in TSO/DSO system use cases of the EU-project TDX-ASSIST can be sufficiently performed with the CIM-CGMES version 2.4.15 data model. For those use cases which cannot be mapped onto CGMES, novel extensions of the data model are proposed. The proposals are a work in progress state and will be finalized in the upcoming deliverables of TDX-ASSIST. Our work aims at a wide usage of CGMES to exchange grid-related data.

1 Introduction

The increase in decentralized generators and storages in distribution grids, combined with a gradual decrease of power plants in transmission grids, has led to various initiatives to intensify the information exchange between distribution system operators (DSO) and transmission system operators (TSO). The voltage level boundary between TSOs and DSOs is country specific; for example, the German TSO 50Hertz Transmission GmbH and connected DSOs at 110 kV established a 10-point plan [1], to enlist generators, storages and loads in distribution grids to provide ancillary services and coordinate activities between TSO and DSOs. Also, the German VDE application rule 4140 [2] defines measures for a coordinated interoperation of DSOs and TSOs, to resolve system security issues. On European level, the Generation and Load Data Provision Methodology (GLDPM) [3] was developed in 2017 for a more reliable capacity calculation between European market areas. GLDPM sets out requirements for the delivery of generation and load data, needed by TSOs to create a common grid model. It specifies that particular DSOs shall provide grid-, load- and generation data to TSOs, such that TSOs can consider decentralized generators and loads in operational grid planning [4].

The EU-project TDX-ASSIST [5], consisting of TSOs, DSOs, ENTSO-E and research institutions, aims to develop novel Information and Communication Technology (ICT) tools and techniques for scalable and secure information systems and data exchange between TSOs, DSOs and market participants. Essential to the data exchange between grid operators is a standardized data model, which specifies relations, hierarchy and a storage format. ENTSO-E adopted the Common Information Model (CIM, [7]) for this purpose and based on this, created the Common Grid Model Exchange Specification (CGMES) for TSO data exchanges in the field of system development and operation [7, 8]. TDX-ASSIST includes demonstration activities in which grid-related data is exchanged between TSOs and DSOs. The goal of this paper is to investigate, if the present CGMES data model is sufficient to represent grid-related information within these demonstrations, or if extensions of CGMES are required.

2 Background

2.1 The TDX-ASSIST project

The EU-project TDX-ASSIST focuses on TSO-DSO interoperability, communication between DSO and other market participants and information or data access portals that enable business processes involving relevant actors in the electrical power sector. The project does not primarily focus on security measures (though these are important), but on novel ICT tools and techniques such as [5]:

- Interface specifications for TSO-DSO data exchange based on use case analysis and CIM standards.
- Interface specifications for data exchange between DSOs and market participants based on use case analysis and relevant IEC standards.
- Role-based access control to securely accommodate new data requirements and unbundling processes.
- ICT protocols and integration with defined interfaces.

2.1.1 Business- and system use cases

One of the first steps in TDX-ASSIST was the creation of 10 “business use cases” (BUCs). These BUCs, listed in Table 1, depict business processes and represent relevant scenarios for the study of improving interoperability and scalability between TSOs and DSOs and other market participants. From theses BUCs, 18 “system use cases” (SUCs) were derived, which are a high-level specification for implementation and hence form the basis for the demonstration activities in TDX-ASSIST. The information content exchanged within an SUC between actors (TSOs, DSOs or market participants) is summarized in so-called “business objects” (BOs).

2.1.2 TSO/DSO demonstration activities

This section summarizes three demonstration activities in TDX-ASSIST that focus on TSO/DSO interactions.

Table 1: The BUCs of TDX-ASSIST [6].

BUC	Name of business use case (BUC)	Related to Demo
1	Activation of DSO-connected resources for balancing purposes in market environment	Slovenia
2	Coordination of distributed flexibility services in a market place	France
5 & 6	Optimize reactive power management by the TSO and DSO for Voltage control purposes	France
7	Coordination of operational planning activities between TSO and DSO	Portugal
8-1	Optimize work programs (TSO, DSO, and SGU works)	France
8-2	Coordination between TSO and DSO for distribution network reconfiguration	France
9	Coordination of long-term network planning between TSO and DSO	Slovenia
10	Improve system real-time supervision and control through better coordination (TSO, DSO and SGUs)	Portugal
11	Improve fault location close to the TSO-DSO interface	Portugal

2.1.2.1 Slovenian Demo

In this real-life demo, an innovative, secure and scalable ICT environment is created for TSO-DSO data exchange between Slovenian TSO ELES's National Transmission Control Centre (TCC) and DSO EG's Distribution Control Centre (DCC). Some use cases are active DSO participation in a balancing market and coordinated long term planning between DSO and TSO.

2.1.2.2 French Demo

This software-based demo evaluates multiple TSO-DSO data exchanges through software validation tools, such as DISNET (validate network exchanges), RiseClipse (validate network datasets) and Enterprise Service Bus (validate information exchange).

2.1.2.3 Portuguese Demo

This demo consists of two parts: (1) validating the ICT data exchange, e.g. for operational planning, between TSO REN and DSO EDPD, using software tools, and (2) a field test of optimal power flow tools in the EDPD grid, demonstrating the deployment of flexibility services and congestion management.

2.2 The CIM CGMES data model

The Common Information Model (CIM) was developed by EPRI in North America and is now a series of IEC standards (61970, 61968, and 62325) [7]. CIM has three primary uses: 1) facilitate a standardized exchange of power system data between organizations, 2) allow the exchange of data between applications within an organization, and 3) to exchange market data between organizations. ENTSO-E has adopted CIM and, based thereon, created the Common Grid Model Exchange Specification (CGMES) for TSO data exchanges in the areas system development and operation [8]. Recently, in the context of GLDPM [9] and research, CGMES is also investigated for data exchange between different grid operators. The current CGMES can be used to represent multi-TSO grid models, composed of mutually disjoint "Model Authority Sets" (MAS) [8] as shown in Figure 1. Distinct TSOs are responsible for maintaining an up-to-date MAS of their network (called TSO set). The boundary between TSO sets is defined through MAS called Boundary Set (BS). If, for example, a transmission line crosses between two TSO sets, a topological boundary point may be placed on this line. This point is then contained in a BS.

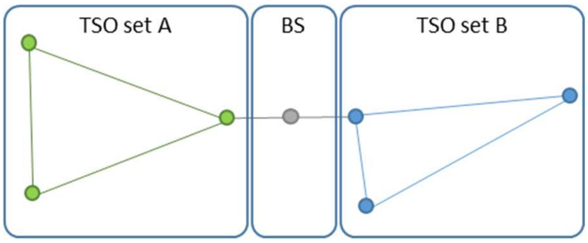

Figure 1: Sketch of CGMES Model Authority Sets

CGMES is specified in UML and consists of "profiles" that represent data sub-models in specific applications. In this paper, it is investigated if the current CGMES version 2.4.15 can be used, or needs extensions, to exchange grid-related information in selected SUCs of TDX-ASSIST.

3 CGMES extension method

3.1 Identifying relevant business objects

In the SUCs of TDX-ASSIST, 57 BOs were specified, which are exchanged between different actors. For the CGMES-analysis, 18 BOs were selected, based on the criterion that they are explicitly used to convey grid (related) data between these different actors.

3.2 Performing a gap analysis

In a first step, a gap analysis was carried out for each of the 18 BOs to determine whether the current version of CGMES already covers the information content of the object, or whether there are any gaps. Since CGMES is specified as an object oriented model, for each individual piece of information within a BO, it was attempted to create a mapping between this information and a suitable class or attribute of CGMES.

3.3 Proposal of CGMES extensions

When a mapping between a BO and existing classes and attributes in CGMES was not possible, a proposal for new classes and attributes was formulated in UML. It must be stressed that these proposals are still under discussion with CIM-experts in TDX-ASSIST and may be enhanced or changed in the upcoming project deliverables.

4 CGMES extension results

4.1 Identified business objects

The following sections show first preliminary CGMES analysis results on seven out of the 18 selected BOs, as listed in Table 2. A full analysis of all 18 BOs will be published in Deliverable 1.8 and 1.9 of TDX-ASSIST.

Table 2: BOs selected for the CGMES-gap analysis.

No.	Business object (BO)	Analysis in section
1	Peak demand forecast (external) information	4.2.1
2	Consumption and production historical profiles (external) for long-term planning	4.2.2
3	Network model equivalent (external) in observability area	4.2.3
4	Send measurements in the observability area	4.2.4
5	Request measurements in the observability area	4.2.5
6	TSO/DSO planned works (external) information	4.2.6
7	Consumption and production forecast for operational planning purposes	4.2.7

4.2 Analysis results per business object

This section shows the CGMES-gap analysis and extension proposals for each of the seven selected BOs.

4.2.1 Peak demand forecast (external) information

4.2.1.1 Short description of business object

This BO is required for the information exchange between DSO and TSO to create long-term grid development plans. These describe the expansion and strengthening of grids in the face of new challenges (e.g. increased share of renewable energies). A necessary information is the peak injection and demand forecast. It describes a simultaneous significant consumption or injection of electrical energy, in varying degrees of detail. The attributes used for the forecast are the value and corresponding point in time for demand or injection and information about the area that the forecast serves (ID of substation, observability area, system operation and transformer).

4.2.1.2 CGMES gaps and proposed extensions

For the representation of forecast data, existing classes from the CGMES "Equipment" profile (that describes electrical equipment in a power system model) can be used. To cover a schedule of peak demand or injection, a new class "PeakDemandSchedule" is proposed, which inherits from the class "RegularIntervalSchedule". The class "RegularTimePoint" is used for the values (demand/injection) and time points: the attributes "value1" and "value2" are used for demand and injection values. This can be pointed out in the inherited attribute "description" of "PeakDemandSchedule". The "GeographicalRegion", "Substation" and "PowerTransformer" classes can cover the forecasting area. In order to assign this area to the forecasts, a new association between "PowerSystemResource" and "BasicIntervalSchedule" is proposed. For this BO, an observability area ID should be assigned; however, this ID is not yet covered by CGMES. One possible concept for this is proposed in Section 4.2.4. The CGMES extension proposals are shown in Table 3.

Table 3: CGMES extension proposals for BO 1.

Proposed new CGMES class	Proposed new attributes	Proposed new associations
PeakDemandSchedule		From BasicIntervalSchedule to PowerSystemResource

4.2.2 Consumption and production historical profiles for long-term planning

4.2.2.1 Short description of business object

In addition to information on peak demand forecasts, certain load profiles of demand and generation of the previous year(s) are also considered in grid expansion planning. The BO in this subsection describes the exchange of historical aggregated time series between system operators. The BO contains the following information: active and reactive power and the corresponding time point for consumption and production, information about the considered area (ID of substation and observability area), type of consumption (e.g. residential, industrial, services) and production (e.g. wind, PV, CHP) and remuneration of production (market participation or feed-in tariffs).

4.2.2.2 CGMES gaps and proposed extensions

Different approaches are feasible to represent time series of historical or predicted data in CGMES. For example, the "LoadModel" diagram allows defining different load groups to which corresponding loads of actual energy consumers are assigned. One approach could be to generalize the structure of the "LoadModel" in a way that it is applicable for production for also representing historical time series of energy sources. A second approach would be, to use classes from the "Meas" package of the CGMES "Equipment" profile. A collection of instances of "AnalogValue" class can be summarized to a historical profile. The measurement is associated to a corresponding "PowerSystemResource", thus the assignment of spatial information ("Substation", "GeographicalRegion") is also possible. A third approach using a new "EnergySchedule" class is presented in more detail as follows.

It is proposed to add a new class "EnergySchedule" which inherits from "RegularIntervalSchedule" and which thus represent a time series with two values. Value1 represents active power and value2 reactive power. In addition, it is proposed to add an association between the "BasicIntervalSchedule" class and the "PowerSystemResource" class. This association would allow to assign all kinds of schedules to all kinds of power system resource (e.g. "Substation", "EnergyConsumer"). With regard to the assignment of an observability area ID, reference is made to the proposal in Section 4.2.4.

The BO also includes financial remuneration information. Due to the grid-data content of CGMES, such information is not considered in this analysis.

Finally, for a better description of the meta-data of a time series, some general CGMES extensions are proposed. Namely, a new "ScheduledDataInfo" class containing the attributes "scheduledDataKind" to represent the kind of data of value1 and value2 (e.g. max, min, average, sum) and the attribute "scheduledDataQuality" to represent the quality/characteristic of data of value1 and value2 (e.g. measurement, replacement, forecast, set point). The extension proposals are summarized in Table 4 below.

Table 4: CGMES extension proposals for BO 2.

Proposed new CGMES class	Proposed new attributes	Proposed new associations
Energy-Schedule		Generalization of "RegularIntervalSchedule"; association between "BasicIntervalSchedule" and "PowersystemRessource
Scheduled-DataInfo	scheduledDataKind	e.g. associated with "BasicIntervalScedule" class
	scheduledDataQuality	

4.2.3 Network model equivalent in observability area

4.2.3.1 Short description of business object

This BO represents a network equivalent model in an observability area of a grid operator. Its primary use is the coordination of operational planning between TSOs and DSOs. According to the TDX-ASSIST definition, it shall include an observability area and request ID, a time period of validity, a status (in validation, validated, changes requested) and a type (complete, partial). The network equivalent should consist of a set of substations, lines and transformers which connect the substations, reactors and capacitors connected to them, and significant grid users (SGUs). The type "partial" means that only some parts of the network are modeled and that the BO is intended to be used for updating an already existing equivalent model at the receiver side.

4.2.3.2 CGMES gaps and proposed extensions

The main CGMES UML resource for this business object is the "Equivalents" package, which contains representations of equivalent branches, injections and shunts. Those can be used for simplified representation of lines, transformers, reactors, capacitors and SGUs. The super-class for these elements is "EquivalentEquipment", which in turn inherits from "ConductingEquipment". As such, the elements in EquivalentEquipment can be connected by "Terminals", which can again be associated with "ConnectivityNodes" from the CGMES Core package. Either of the latter two elements may represent a simplified substation model. On the other hand, a full substation model from the core package cannot be associated to an equivalent network from the equivalent package by design of the inheritance chain. Such association is not intended by CGMES. Hence, the option described first is preferred.
CGMES does not contain a representation of the request and observability area IDs; these are handled in section 4.2.4-5. Finally, for the representation of the BO information "validity time period" and "status information", a new class "EquivalentInformation" with a 1:1 association to "EquivalentNetwork" is proposed. The time period can be modeled by the standard "DateTimeInterval" compound from the CIM Domain package. Status information (e.g. in validation) may be modeled either by strings or new enumeration types; the latter is preferred for reasons of unambiguity, as strings leave too many options (e.g. could be "in validation", "iv"; "i/v", and so on).

Table 5: CGMES extension proposals for BO 3.

Proposed new CGMES class	Proposed new attributes	Proposed new associations
EquivalentInformation	timePeriod, status, type	1:1 relation to Equivalents::EquivalentNetwork
<<Enumeration>> NetworkEquivalentStatus		
<<Enumeration>> NetworkEquivalentType		

4.2.4 Send measurements in the observability area

4.2.4.1 Short description of business object

In the SUC of this BO, real-time measurement data of a large, possibly multi-TSO-DSO, grid is stored in an "collaborative information platform". To and from this platform, grid operators can send and request real-time measurement information (e.g. power flows) from their respective observability area. The information request itself will be discussed in the next section 4.2.5. In the current section, the information payload that is received <u>from</u> the information platform, titled "send measurements from observability area", is explained. The BO contains an ID of the observability area of the TSO or DSO, as well as typical grid measurement information such as voltages, power flows and time stamps at particular buses, lines, transformers, generators or loads in the grid.

4.2.4.2 CGMES gaps and proposed extensions

Most of the BO payload, such as power flow measurements and time stamps, can be contained in CGMES, as it already has appropriate classes for such measurements in its "Equipment" profile. However, one particular information that may not have a trivial representation in CGMES is the "observability area" grid operators.
In particular, an observability area of a grid operator may extend into the area of other grid operators, to adequately perform load flows and security calculations [10] while taking into account influences of neighbor grid elements. Considering the MAS in Figure 1, it should be noted that:

- If the observability area of "TSO A" only <u>partially</u> extends into the grid of "TSO B", there is no trivial way to specify this information using the MAS.
- If "TSO A" requests real-time measurements from all elements in their observability area, from an information platform, they cannot request "*Need measurements from TSO set B*" as this request may provide too much (unnecessary) data. In some cases, "TSO A" may really need measurements from the entire adjacent MAS, though this is considered a special case, rather than a general rule.
- The same reasoning can be applied if "TSO A" requests measurements from some connected DSO grids. As DSOs may not want to provide their full grid information, a MAS concept from CGMES may not be sufficient for this type of data exchange.

To model this situation in CGMES ("Equipment" profile), a possible extension by two new container classes "InternalObservabilityArea" and "ExternalObservabilityArea" is proposed, which inherit from one abstract "ObservabilityAreaContainer" class that has similar properties as the existing "EquipmentContainer". Through the features of such a container, every grid element in the CGMES data model of "TSO A" can be associated to exactly one "internal" or "external" observability area object. These area objects together form an "ObservabilityArea" of TSO A. The table below summarizes the extension proposal.

Table 6: CGMES extension proposals for BO 4.

Proposed new CGMES class	Proposed new attributes	Proposed new associations
ObservabilityArea Container		From Equipment, Terminal. It inherits from ConnectivityNodeContainer
ObservabilityArea	gridOperator-Name	From Internal and External ObservabilityArea and to a SubGeographicalRegion
InternalObservability Area		To ObservabilityArea, also inherits from ObservabilityAreaContainer
ExternalObservability Area		To ObservabilityArea, also inherits from ObservabilityAreaContainer

4.2.5 Request measurements in the observability area

4.2.5.1 Short description of business object

In the SUC of this BO, the information content described in the previous Section 4.2.4 is requested by a grid operator from a "collaborative information platform". We now discuss the request itself.

4.2.5.2 Request modelling

CIM and CGMES do not define how serialized information is transmitted or how it can be requested. IEC 61968-100 defines an implementation profile. It uses popular integration technologies such as web services and Java Message Service. Also, the use of an Enterprise Service Bus is considered [11]. The standard defines messages for the request of CIM messages and the resulting response, which are divided into different parts [12]:

- Header: meta-data of the message (e.g. Message Id)
- Request: optional parameters for request messages (e.g. Start/End Time for time based queries)
- Reply: status information about the request (like OK)
- Payload: contains the CIM/CGMES objects in defined format (XML, binary etc.)

This method can be used to query selected CGMES objects from a source. Another approach would be to provide the objects via a REST interface [13].

4.2.6 TSO/DSO planned works information

4.2.6.1 Short description of business object

Maintenance or expansion work in a power grid can have an impact on connected transmission or distribution grids, which requires coordination and optimization of works planning. The underlying use case for this BO concerns the exchange of planned works in the distribution and transmission grid and the validation process regarding different time horizons (year-, month-, day-ahead).
The information content of this BO can be summarized as follows: data on the validation process (request ID, status, iteration), information on the type (type of work, description, priority), time period (start, duration) and spatial data (observability area ID, bus ID) of the planned work, as well as associated limitations (unavailable equipment, apparent power limit, reactive power set point). In addition, the BO should include optional attributes about inadmissible periods of planned work and the corresponding justification that can be exchanged during the validation process in case of negative feedback.

4.2.6.2 CGMES gaps and proposed extensions

CGMES version 2.4.15 currently does not offer a trivial way to display information about planned works. Therefore, a new class "PlannedWorkSchedule" is suggested, which inherits from the "RegularIntervalSchedule" class and contains the necessary attributes to cover the information to be exchanged. Due to the inherited association with the "RegularTimePoint" class, time series can be mapped with active power limitations (value1) and reactive power specifications (value2). Analogues to the proposals in Sections 4.2.1 and 4.2.2, an association between the "BasicIntervalSchedule" class and the "PowerSystemRessource" class is necessary in order to assign unavailable equipment and spatial information. For this BO, an observability area ID should be assigned; this ID is not yet covered by CGMES. One possible concept for this is proposed in Section 4.2.4.
It is suggested to add a further new "PeriodsNotAllowedForScheduling" class, which also inherits from "RegularIntervalSchedule" and contains a "justification" attribute. This class should be associated to "PlannedWorkSchedule", to describe inadmissible periods.
Note that the European Style Market Profile IEC62325-451-2, containing the classes "Scheduling document", cover a lot of information that is to be exchanged with regard to the underlying BO. Since the use case is not a market-, but a network operation process, the profile is not considered in the context of this analysis. Table 7 summarizes the extension proposals.

Table 7: CGMES extension proposals for BO 6.

Proposed new CGMES class	Proposed new attributes	Proposed new associations
PlannedWork Schedule	referencedRequestID	Generalization of "RegularIntervalSchedule" class, new association between "BasicIntervalSchedule" class and "PowerSystemRessource" class
	validationStatus	
	revisionNumber	
	typeOfWork	
	priority	
PeriodsNot-AllowedFor-Scheduling	justification	Associated with "PlannedWorkSchedule" class
	disabled	

4.2.7 Consumption and production forecast for operational planning purposes

4.2.7.1 Short description of business object

This BO is applied in the use case for exchanging disaggregated consumption and generation forecasts for the purpose of coordination of operational planning activities between TSO and DSO up to 72 hours ahead. The information content of this BO structurally corresponds to the information in BO 2 in Section 4.2.2., the only difference being that it is forecast data instead of historical data.

4.2.7.2 CGMES gaps and proposed extensions

Due to the parallels regarding the information content of BO 2 and 7, the same approaches and thus the same proposed extensions of CGMES as for BO 2 are suitable to cover the SUC sufficiently.

With regard to a further approach, it should be noted, that the class "GenUnitOpSchedule", included in the CIM base model IEC61970, represents a current operating plan of generator units. However, this class has not yet been included in CGMES and is not intended to provide both active and reactive power values. Therefore, an adaption of this class and according extensions of CGMES would be necessary.

It should also be mentioned that in market-specific use cases, the same information as in this BO needs to be exchanged with the market. For this purpose, the CIM European Market Style Profiles Schedule_MarketDocument IEC 62325-451-2 can be used.

5 Conclusion

In this paper, novel extensions of the CIM CGMES data model were proposed, to accommodate data of seven business objects (BOs) from TSO/DSO data exchange use cases of the EU-project TDX-ASSIST. In cases where CGMES did not have sufficient classes or attributes to accommodate the BO data, new classes, attributes and associations were proposed and systematically shown.

The proposed CGMES extensions in this paper are a work in progress state and part of TDX-ASSIST Working Package WP1; they will be further evaluated and updated by CIM-experts and finally, be published in upcoming WP1 project deliverables. Hence, the finalized CGMES-extensions may serve a dual purpose: (1) they form input to the demonstration activities of the project and (2) can serve as proposals for extending CIM CGMES and further strengthening this format, to accommodate not only TSO-TSO, but also TSO-DSO data exchanges more widely.

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7 Literature

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