European Network of
Transmission System Operators
for Electricity

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QUALITY OF DATASETS AND CALCULATIONS

FOR SYSTEM OPERATIONS

THIRD EDITION

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OPERATIONAL DATA QUALITY TASKFORCE/
SG NETWORK MODELS AND FORECAST TOOLS

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SUMMARY

The document "Quality of Datasets and Calculations" aims to increase the quality of data that is exchanged in order to support the following processes:

- Coordinated security assessment
- Flow-based and NTC based capacity calculations
- Outage planning coordination
- Inter-TSO compensation for the use of national transmission systems by cross-border trade
- After-the-fact analysis of events
- Ad-hoc system studies

Quality is a concept that can be expressed as the "fitness for purpose" for a particular process. This document contains the following sections:

- Introduction
- Validation rules for structure and syntax (UCTE DEF)
- Validation rules for the physical network description
- Requirements and validation of the operating assumptions

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INTRODUCTION

A few decades ago, the main purpose of the interconnected ENTSO-E grid was an overall- and border-crossing-optimisation of the operation of the grid in both a technical and an economical way and the mutual sharing of ancillary services (frequency and voltage control, active and reactive power reserves, network restoration, etc.). The system evolved with the background of integrated electricity companies, where the responsibilities for production, trading, transmission and distribution were in the same company. In such an environment it was relatively easy to manage the system and avoid congestion.

With the on-going deregulation of the energy markets, this prerequisite is no longer given. The deregulation of the electricity markets compelled the electricity companies to be unbundled. This means that the different functions (production, trading, transmission and distribution) are performed by independent companies. Especially the traders want to have as less restrictions as possible or they want to know in advance at least from the transmission system operators (TSOs) what these restrictions are. This makes it necessary for the TSOs to be able to forecast the grid situation of the following day and in the current business day, to identify possible congestions and to assess necessary remedial actions in order to manage these congestions.

The deregulation has increased the need for power companies, and TSOs in particular, to exchange data on a regular basis. This information exchange promotes the reliable operation of the interconnected power networks owned and operated by different utilities. TSOs use a variety of formats to store their data, whether it is asset and work scheduling information in a proprietary internal schema within a database, topological power system network data within a control system, or static files used by simulation software.

In order to facilitate the exchange of data, the UCTE Data Exchange Format was developed (first version: developed in 2001, but entered into force on the 1st of September 2003, second version came into force on the 1st of May 2007). The so-called UCTE DEF is a legacy of the original coding of products written in an era when disk space and memory was severely limited. As such the UCTE DEF consists of simple, column-oriented, fixed width structures that favour compactness over verbosity and directly mirrors the application’s original internal data structures (i.e. FORTRAN record layouts).

In its 28th meeting, held on 28 November 2013, the ENTSO-E System Operations Committee approved v2.4 of the CGMES to be used as the baseline exchange standard for the implementation of the CGM methodologies. The purpose of the Common Grid Model Exchange Standard (CGMES) is to define the interface between ENTSO-E members’ software in order to exchange power system modelling information as required by the ENTSO-E and TSO business processes. The CGMES is based on the following existing or expected IEC CIM standards valid for the CIM UML16v25:

- IEC 61970-301: Common Information Model (CIM) Base
- IEC 61970-302: Common Information Model (CIM) for Dynamics Specification
- IEC 61970-452: CIM Static Transmission Network Model Profiles

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- IEC 61970-453: Diagram Layout Profile
- IEC 61970-456: Solved Power System State Profiles
- IEC 61970-457: Common Information Model (CIM) for Dynamics Profile
- IEC 61970-552: CIM XML Model Exchange Format
- IEC 61968-4: Application integration at electric utilities – System interfaces for distribution management - Part 4: Interfaces for records and asset management

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CONTENTS

1 VALIDATION OF STRUCTURE AND SYNTAX

1.1 UCTE DATA EXCHANGE FORMAT

The UCTE Data Exchange Format is a column based, fixed width exchange format, based on FORTRAN record definitions. This section describes the UCTE format adopted for data exchange and provides all the necessary instructions about its use. The data refer to load flow and three phase short circuit studies and describe the interconnected extra high voltage network. Equivalent network elements should be avoided as much as possible.

1.1.1 FILENAME CONVENTION

The file name convention is:

<yyyymmdd>_<HHMM>_<TY><w>_<cc><v>.uct, with

yyyymmdd: year, month and day,

HHMM: hour and minute, for Daylight Saving Time 0230 is used for the first hour, whereas B230 is used for the second hour

TY: File type (FO = Day Ahead Forecast, SN = Snapshot, RE = Reference, LR = Long Term Reference, 2D = two days ahead forecast, ‘hh’ = Intraday Forecasts where ‘hh’ is for example ‘02’ for two hours ahead intraday forecast)

w: day of the week, starting with 1 for Monday,

cc: the ISO country-code for national datasets, “UC” for UCTE-wide merged datasets without X nodes and “UX” for UCTE-wide merged datasets with X nodes[1],

v: version number starting with 0. If the version is “x”, the file is to be ignored.

The filename must be in uppercase for reasons of file management on the ftp-server. Files that do not comply with the file name convention cannot be used in an operational process.

Requirement	Severity	Rule
FILE-NAME-01	FATAL	The file name has to comply to the file name conventions
FILE-SIZE-01	FATAL	File size has to be greater than 240 Bytes[2]

[1] For the individual German datasets the coding schede is used from the table in this chapter

[2] This value is justified by the values used in the RG CE DACF files and can be updated if deemed necessary.

1.1.2 FILE STRUCTURE

The data are contained in an unformatted standard US ASCII file without any control characters, moreover it is strictly forbidden to use diacritic signs. Only the current published version of the UCTE format is to be used. It is not allowed to add non-defined information into the described sections of the file. The file is divided into blocks in which determined data are put successively in a defined manner:

The following blocks are defined:

- COMMENTS (C)
- NODES (N)
- LINES (L)
- 2 WINDINGS TRANSFORMERS (T)
- 2 WINDINGS TRANSFORMERS REGULATION (R)
- Optional: 2 WINDINGS TRANSFORMERS SPECIAL DESCRIPTION (TT)
- Optional: EXCHANGE POWERS (E)

Each block is introduced by a key line consisting of the two characters "##" and of the character given above in brackets. The end of a block is given by the next key line or the end of the file. No "end command" is to be used. The sequence of the blocks in the file is recommended as above.

The information of the above defined blocks is written in lines and the contents are separated by a blank. This blank (empty space) has to be respected strictly.

The comment block (##C) at the top of data should describe at least the provider of the file. Additional comment blocks introduced by (##C), and containing comment lines may be given at any place of the file.

The following validation rules are used to check for completeness of the file and prerequisites for further processing:

Rule id	**Severity**	**Diagnosis/Message**
FILE-FORMAT-01	WARNING	The file is not in US-ASCII DOS format
STRUCT-Z-01	FATAL	The line just after the line with the label ##N doesn't begin with ##Z
STRUCT-General-01	FATAL	A mandatory data block is missing (##N, ##L, ##T, ##R)
STRUCT-General-03	FATAL	Undefined data block detected (only ##C, ##N, ##L, ##T, ##R, ##TT, ##E, ##Z are allowed)

1.1.3 UCTE DEF VERSION IDENTIFICATION

Inside the file it is necessary to have an identification of the used format version in order to ensure an automatic processing of the data. The key line of the comment block "##C" is extended with a supplementary information as follows:

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##C 2007.05.01

The following validation rule is used to check for the correct version of the UCTE DEF and prerequisites for further processing:

Rule id	Attribute	Severity	Diagnosis/Message
STRUCT-Comments-01	Version ID	FATAL	Wrong or missing UCTE DEF version identification

1.1.4 DEFINING SUBSTATIONS AND ENERGY INJECTIONS

Within the NODES block (##N), key lines consisting of the three characters ##Z and the ISO country identification (2 characters) must be introduced. Those key lines assign all following nodes to that country (e.g. ##ZAT for Austria).

It is recommended to choose an appropriate node name and to keep it for all the UCTE data exchanges:

- It shall be possible to uniquely identify each branch[3]
- The unique branch identification shall be identical for every timestamp
- All generators that could be used for redispatch shall be modelled on dedicated nodes (identical for every timestamp)[4]. This implies generator schedules and limits for each generator of a power plant.

[3] This could be accomplished by combining the first 7 characters of the connecting nodes with the optional element name or by combining the country code with the SCADA name in the element name

[4] This does not apply to infeed in decentralized grids

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columns	attribute	Type	contents
1-8	Node	Char	The following 8-character alphanumeric code is used for identifying network nodes unequivocally: • 1st character: Country Code[5] • 2nd- 6th character: Substation identifier[6] • 7th character: Voltage level code[7] • 8th character: Bus bar identifier (optional)
10-21	Substation name	Char	Substation name
23	Status	Integer	0 = real, 1 = equivalent
25	Node type	Integer	0 = P and Q constant (PQ node) 1 = Q and θ constant 2 = P and V constant (PV node) 3 = V and θ constant (global slack node, only one in the whole network))
27-32	Voltage set point	Real	Only mandatory for PV nodes and slack nodes [kV]
34-40	P load	Real	Active vertical load injection [MW]
42-48	Q load	Real	Reactive vertical load injection [MVar]
50-56	P gen	Real	Active power generation injection [MW]
58-64	Q gen	Real	Reactive power generation injection [MVar]
66-72	P min	Real	Minimum permissible generation [MW], only mandatory for reference case data exchanges

[5] Note: in the German control block the first two characters are used to identify the TSO

[6] Note: in the German control block the 3rd-6th characters are use to identify the substation

[7] 0 = 750 kV
1 = 380 kV
2 = 220 kV
3 = 150 kV
4 = 120 kV
5 = 110 kV
6 = 70 kV
7 = 27 kV
8 = 330 kV
9 = 500 kV

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columns	attribute	Type	contents
74-80	P max	Real	Maximum permissible generation [MW], only mandatory for reference case data exchanges
82-88	Q min	Real	Minimum permissible generation [MVar], only mandatory for PV nodes
90-96	Q max	Real	Maximum permissible generation [MVar]], only mandatory for PV nodes
98-102	Static	Real	Optional: Static of primary control [%]
104-110	P nom	Real	Optional: Nominal power for primary control [MW]
112-118	Sk"	Real	Three phase short circuit power [MVA][8]
120-126	X/R ratio	Real	X/R ratio ()[9]
128	PP type	Char	Power plant type (optional): • H: hydro • N: nuclear • L: lignite • C: hard coal • G: gas • O: oil • W: wind • F: other

The following validation rules apply:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-NODE-CODE-01	Node	FATAL	Duplicate node code detected
DATA-NODE-CODE-02	CC	FATAL	The first character of the node code is invalid[10]
DATA-NODE-CODE-03	Node	FATAL	The 8 characters of the node identifier cannot contain other characters than "0123456789ABCDEFGH IJKLMNOPQRSTUVWXYZ_-./+=\" or blank
DATA-NODE-CODE-04	Voltage level code	FATAL	The 7th character of node code should be a voltage level code (only 0,1,2,3,4,5,6,7,8 or 9 are allowed)
DATA-NODE-STATUS-01	Status	FATAL	The status has to be 0 or 1, no other character is allowed.

[8] Only applicable for data exchanges for short-circuit calculations

[9] Only applicable for data exchanges for short-circuit calculations

[10] See table in 0

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Rule id	Attribute	Severity	Diagnosis/Message
DATA-NODE-TYPE-1	Node type	FATAL	The node type has to be 0, 1, 2, or 3. No other character is allowed.
DATA-NODE-PPTYPE-01	Power plant type	WARNING	The node power plant type, if present, has to be H, N, L, C, G, O, W or F. No other character is acceptable.
TOPOLOGY-Connection-01		WARNING	All the X-nodes of the described network, defined in the ENTSO-E Boundary file must be defined in the dataset (i.e. out of operation X-nodes have to be included)
TOPOLOGY-Connection-02		WARNING	An X-node of the described network, cannot be found in the ENTSO-E Boundary file.

Country codes:

Country code nodes (1st character of the Node identifier). Within the German Control Block the first two characters are used.

ISO code (to be used in the ##N section for ##Z.. and in the ##E section):

Country Code nodes	ISO Country Code	TSO	Country	Vulcanus Control Block
A	AL	OST	Albania	AL
B	BE	ELIA	Belgium	BE
C	CZ	ČEPS	Czech Republic	CZ
D	DE		Germany	DE+
D1	DK	Energinet.DK	Denmark as part of the German Control Block	DE+
D2	DE	TenneT D	Germany	DE+
D4	DE	TransnetBW	Germany	DE+
D6	LU	CREOS	Luxemburg as part of the German Control Block	DE+
D7	DE	Amprion	Germany	DE+
D8	DE	50Hertz	Germany	DE+
E	ES	REE	Spain	ES+
F	FR	RTE	France	FR
G	GR	IPTO	Greece	GR
H	HR	HOPS	Croatia	SHB
I	IT	Terna	Italy	IT
J	RS	EMS	Serbia	SMM
K[11]	DK	Energinet.DK	Denmark	DE+

[11] If the Danish data is included in the German Control Block pre-merged file, the node code will be D1

Country Code nodes	ISO Country Code	TSO	Country	Vulcanus Control Block
L	SL	ELES	Slovenia	SHB
M	HU	MAVIR	Hungary	HU
N	NL	TenneT NL	Netherlands	NL
O	AT	APG	Austria	APG
P	PT	REN	Portugal	PT
Q	SK	SEPS	Slovakia	SK
R	RO	Transelectrica	Romania	RO
S	CH	Swissgrid	Switzerland	CH
T	TR	TEIAS	Turkey	TR
U	UA	WPS	Ukraine	PL & UA
V	BG	ESO	Bulgaria	BG
W	BA	NOS BiH	Bosnia Herzegovina	SHB
X	XX	N/A	Fictitious border node	N/A
Y	MK	MEPSO	Macedonia (FYR)	SMM
Z	PL	PSE	Poland	PL & UA
0	ME	CGES AD	Montenegro	SMM
2	MA	ONE	Morocco	ES+
_[12]	KS[13]	KOSTT	Kosovo[14]	KOSTT

Fictitious border nodes are located at the **electric middle** of each tie line. HVDC are as well modelled by using X-nodes, which are linking the Continental Europe Grid to others synchronous areas, or internal HVDC present in the CE ENTSO-E grid. The defined X-nodes are binding for all users. The X-nodes block starts with record ##ZXX.

The following validation rules are used to check for the correct country definition of the dataset:

Rule id	Attribute	Severity	Diagnosis/Message
STRUCT-Z-02	CC identifier	FATAL	The code following the label ##Z has not been defined as an ISO country
DATA-NODE-CODE-6	Node CC identifier	FATAL	The first character of all Node identifiers should correspond to the country code of the #Z section

12 Underscore

13 Temporary country code, as a final one is to be appointed by the relevant UN body

14 This designation is without prejudice to positions on status, and is in line with UNSC 1244 and the ICJ Opinion on the Kosovo Declaration of Independence

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Rule id	Attribute	Severity	Diagnosis/Message
			they belong to

1.1.5 DEFINING LINES, BUSBAR COUPLERS AND TOPOLOGY

Lines, coupling bays, connectivity and topology are defined in the ##L section. Connectivity is defined via the line connectivity nodes, whereas topology is defined via the line status. Note that the line connectivity nodes have to be defined in the ##N data block:

columns	**attribute**	**type**	**contents**
1-8	Line connectivity node	character	The line connectivity node has to be defined in the ##N data block
10-17	Line connectivity node	character	The line connectivity node has to be defined in the ##N data block
19	Line order code	character	Only the following characters are allowed: "0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZ_-." or blank. Note that the line order code must be unique for any set of lines that are connected to the same substations (i.e. have the same set of line connectivity nodes)
21	Line status	integer	The line status defines the topological connection for the following three types of "lines": • Normal line or cable : 0 = in service, 8 = disconnected • Equivalent line : 1 = in service, 9 = disconnected • Busbar coupler : 2 = in service, 7 = disconnected
23-28	Line Resistance	real	Resistance R (Ω), must be zero for busbar coupler.
30-35	Line Reactance	real	Reactance X (Ω), must be zero for busbar coupler. For lines the reactance should be larger than 0.050 Ohm.
37-44	Line Susceptance	real	Susceptance B (µS), must be zero for busbar coupler
46-51	Line Rating	integer	Permanent Admissible Transmission Loading (A)
53-64	Line identifier	character	12 character element name (optional)

The following syntax validation rules apply:

Rule id	**Attribute**	**Severity**	**Diagnosis/Message**
DATA-LINE-DEF-02	Line order code	FATAL	Invalid character used for the line order code
DATA-LINE-STATUS-01	Line status	FATAL	Invalid line status: line status must be one of the values : 0,1,2,7,8,9

1.1.6 DEFINING TRANSFORMERS AND TOPOLOGY

All transformers, their connectivity and topology are defined in the ##T section. Connectivity is defined via the transformer connectivity nodes, whereas topology is defined via the transformer status. Note that the transformer terminals have to be defined in the #N data block:

columns	attribute	type	contents
1-8	NRW Transformer connectivity node	character	Non-regulated winding. The transformer connectivity node has to be defined in the ##N data block
10-17	RW Transformer connectivity node	character	Regulated winding. The transformer connectivity node has to be defined in the ##N data block
19	Transformer order code	character	Only the following characters are allowed: "0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZ_-." or blank. Note that the Transformer order code must be unique for any set of transformers that are connected to the same substations (i.e. have the same set of transformer connectivity nodes)
21	Transformer status	integer	The line status defines the topological connection for the following two types of "transformers": • Real transformer : 0 = in service, 8 = disconnected • Equivalent transformer : 1 = in service, 9 = disconnected
23-27	Rated voltage1	real	Rated voltage 1: non-regulated winding (kV)
29-33	Rated voltage2	real	Rated voltage 2: regulated winding (kV)
35-39	Transformer Snom	real	Nominal power (MVA)
41-46	Transformer Resistance	real	Resistance R (Ω), pertaining to the rated voltage of Rated voltage1
48-53	Transformer Reactance	real	Reactance X (Ω), pertaining to the rated voltage of Rated voltage1. This value cannot be negative for real transformers.
55-62	Transformer Susceptance	real	Susceptance B (μS), pertaining to the rated voltage of Rated voltage1
64-69	Transformer	real	Conductance G (μS), pertaining to the rated voltage of Rated

columns	attribute	type	contents
	Conductance		voltage1
71-76	Transformer rating[15]	integer	Permanent Admissible Transmission Loading (A), pertaining to the rated voltage of Rated voltage1
78-89	Transformer identifier	character	Element name (optional)

The following syntax validation rules apply:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-TRF-DEF-02	Transformer order code	FATAL	Invalid character used for the transformer order code
DATA-TRF-STATUS-01	Transformer status code	FATAL	Invalid transformer status: transformer status must be one of the values : 0,1,8,9

1.1.7 Additional parameters for Phase and Angle regulation

Additional parameters for on-load tap changing transformers and phase shifting transformers are defined in the ##R data block section. Note that the transformer connectivity nodes have to be defined in the #N data block and that the combination of transformer connectivity nodes and transformer order code have to correspond to a transformer that have been defined in the ##T data block section. If this is not the case the data will have to be ignored.

columns	attribute	type	contents
1-19	LTC Transformer identifier	Character	For identification purposes, the combination of transformer connectivity nodes and transformer order code is used
21-25	Phase regulation: voltage change per tap	Real	δu (%)
27-28	Phase regulation: number of taps	Integer	Counted the following way: it is the difference between the intermediate position (neutral) and the positive or negative ultimate position. E.g. a transformer with total 27 taps (+13, neutral,-13) is given as n = 13 in the UCTE DEF)
30-32	Phase regulation: current tap position	Integer	n'

15 Normally Snom = sqrt(3)*TransformerRating*Rated voltage1

34-38	Phase regulation: target voltage for regulated winding	Real	U (kV) (optional)
40-44	Angle regulation: voltage change per tap	Real	δu (%)
46-50	Angle regulation: angle	Real	Θ in ° (see semantic model description at 2.1.2)
52-53	Angle regulation: number of taps	Integer	Counted the following way: it is the difference between the intermediate position (neutral) and the positive or negative ultimate position. E.g. a transformer with total 27 taps (+13, neutral,-13) is given as n = 13 in the UCTE DEF)
55-57	Angle regulation: current tap position	Integer	n'
59-63	Angle regulation: target power flow	Real	P (MW) (optional)
65-68	Angle regulation type	Character	ASYM: asymmetrical SYMM: symmetrical (see semantic model description at 2.1.2)

There are no specific syntax validation rules for this data. Incorrect transformer references are ignored.

1.1.8 ACCURATE MODELLING OF TRANSFORMERS (OPTIONAL)

Specific parameters per tap position can be provided in the ##TT data block. Note that the transformer connectivity nodes have to be defined in the #N data block and that the combination of transformer connectivity nodes and transformer order code have to correspond to a transformer that have been defined in the ##T data block section. If this is not the case the data will have to be ignored.

The parameters of all transformers given in this section (accurate modelling) are ALREADY defined in the ##T and ##R sections (simplified modelling).

- In the simplified modelling, R and X do not depend on the tap position, and the additional voltage Δu is implicitly given by the formula Δu = n' δu.
- In the accurate modelling, R and X depend on the tap position and the additional voltage Δu is given explicitly for each tap position.

One line per tap position is needed in the ##TT section.

columns	attribute	type	contents

columns	attribute	type	contents
1-19	Details Transformer identifier	Character	For identification purposes, the combination of transformer connectivity nodes and transformer order code is used
23-25	Tap position n’	Integer	Tap position identification
27-32	Resistance at tap n’	Real	Ohmic value, see semantic model description at 2.1.2
34-39	Reactance at tap n’	Real	Ohmic value, see semantic model description at 2.1.2
41-45	Voltage change at tap n’	Real	Δu at tap n’ (%)
47-51	Phase shift angle α at tap n’	Real	In degrees (0° for phase regulation)

There are no specific syntax validation rules for this data. Incorrect transformer references are ignored.

1.1.9 SPECIFICATION OF EXCHANGE POWERS (OPTIONAL)

It is possible to specify scheduled active power exchanges between two countries via the ##E data block:

columns	attribute	type	contents
1-2	Country1	Character	ISO code of the data provider and the reference point for the sign convention of the scheduled exchange: • Import implies a negative value • Export implies a positive value
4-5	Country2	Character	ISO code of the country with which a power exchange is scheduled
7-13	Scheduled exchange	Real	Scheduled active power exchange in MW
15-26	Comments	Character	Comments (optional)

The following syntax validation rules apply:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-EXCH-CC-01	Country1	WARNING	Country1 must be the sender of the data

Rule id	Attribute	Severity	Diagnosis/Message
DATA-EXCH-CC-02	Country2	WARNING	Invalid ISO code

2 SEMANTIC MODEL

2.1 UCTE DATA EXCHANGE FORMAT

2.1.1 LINE MODEL

In UCTE DEF we distinguish three types of "lines":

- Real transmission lines and cables
- Equivalent lines
- Busbar couplers

Due to the compactness of the exchange standard the same representation is provided for all three, though with type identification and associated rules for interpretation. The type of line is identified through the line status attribute:

- Normal line or cable : Status 0 or 8
- Equivalent line : Status 1 or 9
- Coupling bay : Status 2 or 7

A transmission line is represented by an equivalent π circuit with a series impedance (R + jX) from node1 to node2 as shown in Figure 1.

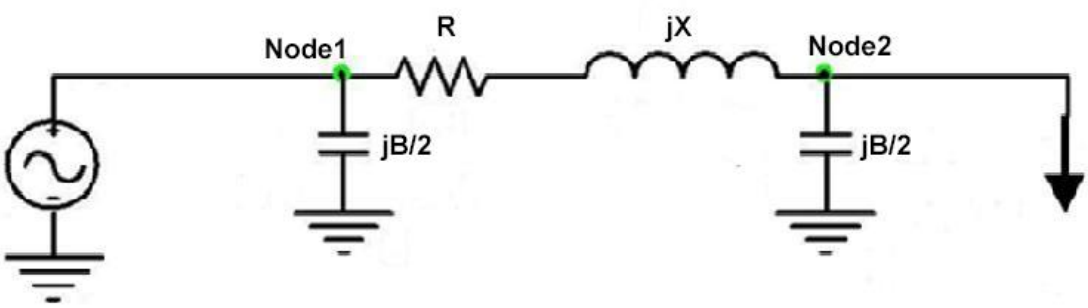

Figure 1. π circuit model of a transmission line

The node on the left side has the generator and the node on the right side has the load. B is the shunt charging susceptance of the transmission line. In a short line of low voltage (e.g., up to 80 km), the shunt charging can be neglected. In a medium length high voltage line (e.g., up to 200 km), nominal shunt charging is divided equally at both the ends as shown in Figure 1. R and X are the transmission line series resistance and reactance between the two nodes.

The following semantic validation rules apply:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-LINE-Resistance-01	Line Resistance	FATAL	Real line resistance cannot be negative
DATA-LINE-Resistance-02	Line Resistance	WARNING	Busbar coupler resistance must be zero
DATA-LINE-Reactance-01	Line Reactance	FATAL	Real line reactance must be defined
DATA-LINE-Reactance-03	Line Reactance	WARNING	Busbar coupler reactance must be zero. For lines this value must be larger than 0.050 Ohm
DATA-LINE-Susceptance-02	Line Susceptance	WARNING	Busbar coupler susceptance must be zero
DATA-LINE-IMAX-01	Line Rating	WARNING	Real line rating must be positive
DATA-LINE-IMAX-02	Line Rating	WARNING	Equivalent line current limit must be positive or blank
DATA-LINE-IMAX-03	Line Rating	WARNING	Busbar coupler current limit must be positive or blank

The following connectivity validation rules apply:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-LINE-DEF-01	Line connectivity node	FATAL	Both line connectivity nodes must be defined
DATA-LINE-DEF-03	Line order code	WARNING	The order code must be unique for all parallel lines that are connected via the same set of line connectivity nodes, regardless of the order of the connecting nodes.
DATA-LINE-DEF-04	Line voltage level	FATAL	Both line connectivity nodes must have the same voltage level, i.e. the same 7th character
DATA-LINE-DEF-05	Line connectivity node	FATAL	Both line connectivity nodes must belong into the same TSO. Except for the lines connected to X-nodes.
TOPOLOGY-Connection-02	Line connectivity	FATAL	Each X-node must be connected to one and only

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Rule id	Attribute	Severity	Diagnosis/Message
	node		one node which is not an X-node
TOPOLOGY-Connection-03	Line connectivity node	WARNING	The number of branches connected to one connectivity node exceeds 40 [16]

2.1.2 TRANSFORMER MODEL

Transformers which provide a small adjustment of voltage magnitude, usually in the range of ± 10%, and others which shift the phase angle of the line voltages are important components of a power system. Some transformers regulate both the magnitude and phase angle. Almost all transformers provide taps on windings to adjust the ratio of transformation by changing taps when the transformer is de-energized. If a change in tap can be made while the transformer is energized, transformers are called on-load tap changing (LTC or OLTC) transformers.

When tap changing transformers are present in the network, the components of the admittance matrix corresponding to the buses connected to the transformers, changes with the tap values.

Due to the compactness restrictions in the UCTE DEF only two winding transformers can be modelled. This means that machine transformers, fixed ratio transformers, on-load tap changers and phase shifting transformers all use the same semantic model. Depending on the availability of phase and/or angle regulation additional parameters can be added. Also an impedance correction table can be specified for more precise modelling.

The basic semantic model for transformers is provided in figure 2:

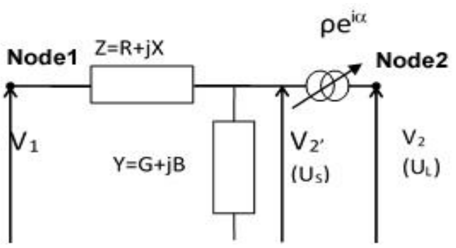

Figure 2. Semantic model for a tap-changing transformer

In the semantic model, Node2 contains the regulated winding.

16 This value is justified by the values used in the RG CE DACF files and can be updated if deemed necessary.

$V_2' = \rho e^{i\alpha} V_2$

$U_S = \rho e^{i\alpha} U_L$, whereas:

U_S : source voltage [kV]

U_L : load voltage [kV]

α : phase angle shifting

ρ : transformation ratio

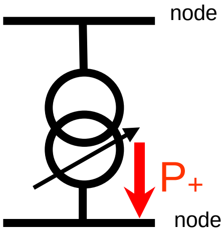

Figure 3. Flow convention in the transformer semantic model

The following semantic validation rules apply for all transformers:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-TRF-Voltage1-01	Voltage (non-regulated winding)	WARNING	Value for the voltage must be between 0.8 Un and 1.2 Un for values of Un > 110 kV[17]
DATA-TRF-Voltage2-01	Voltage (regulated winding)	WARNING	Value for the voltage must be between 0.8 Un and 1.2 Un for values of Un > 110 kV[18]
DATA-TRF-SN-01	Transformer Snom	FATAL	Value must be positive, blank and zero is not allowed
DATA-TRF-Resistance-01	Transformer resistance	FATAL	Blank is not allowed, real transformer resistance must be greater than or equal to zero
DATA-TRF-Reactance-01	Transformer reactance	FATAL[19]	Blank is not allowed, absolute value of reactance must be greater than 0.05 Ω
DATA-TRF-Susceptance-01	Transformer shunt susceptance	WARNING	Blank is not allowed

17 This might occur specifically for reactors wtith a tapchanger that are modeled as equivalent transformers and reactor

18 This might occur specifically for reactors with a tapchanger that are modeled as equivalent transformers and reactor

19 For the time being negative numbers will be marked as “WARNING” as they are used to model the second winding of 3-winding transformer when modelled as three 2-winding transformers

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Rule id	Attribute	Severity	Diagnosis/Message
DATA-TRF-Conductance-01	Transformer shunt conductance	WARNING	Transformer shunt conductance must be greater than or equal to zero
DATA-TRF-IMAX-01	Transformer current limit	WARNING	Current limit must be greater than zero
DATA-TRF-IMAX-02	Transformer current limit (non-regulated winding)	WARNING	Equivalent transformer current limit must be positive or blank

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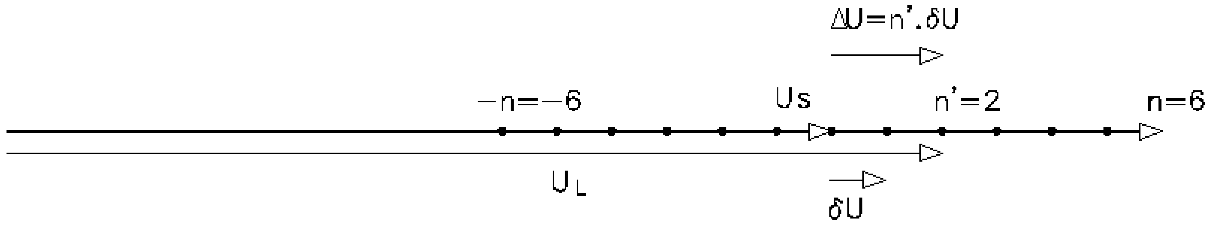
Phase regulation (on-load tap changers) is modelled in the following semantic model:



While in the basic semantic model (figure 2), $\alpha = 0°$ and $\rho = \frac{1}{1+n'\delta u}$.

Figure 4. Phase regulation parameters

The following semantic validation rules apply for all LTC transformers with phase regulation:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-TRREG-PHASE-01	Phase regulation: voltage change per tap	WARNING	For LTCs, transformer phase regulation voltage change per tap should not be zero. Its absolute value should not be above 6%[20]
DATA-TRREG-PHASE-02	Phase regulation: number of taps	WARNING	The number of phase regulating taps cannot be negative and cannot exceed 35 [21]

Angle regulation is modelled by three different semantic models, provided in the figures 5, 6 and 7.

[20] This value is justified by the values used in the RG CE DACF files and can be updated if deemed necessary.

[21] This value is justified by the values used in the RG CE DACF files and can be updated if deemed necessary.

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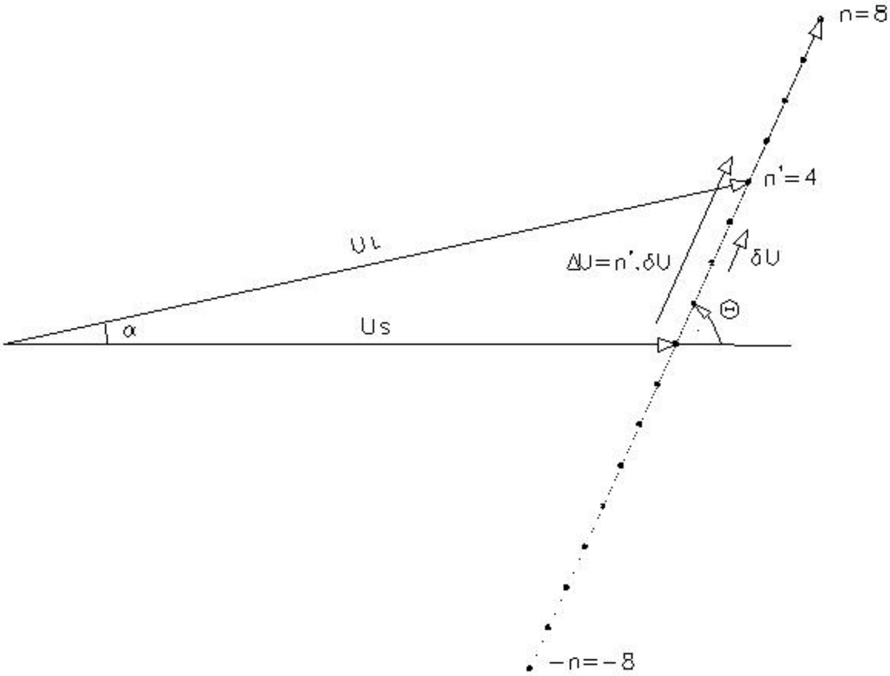
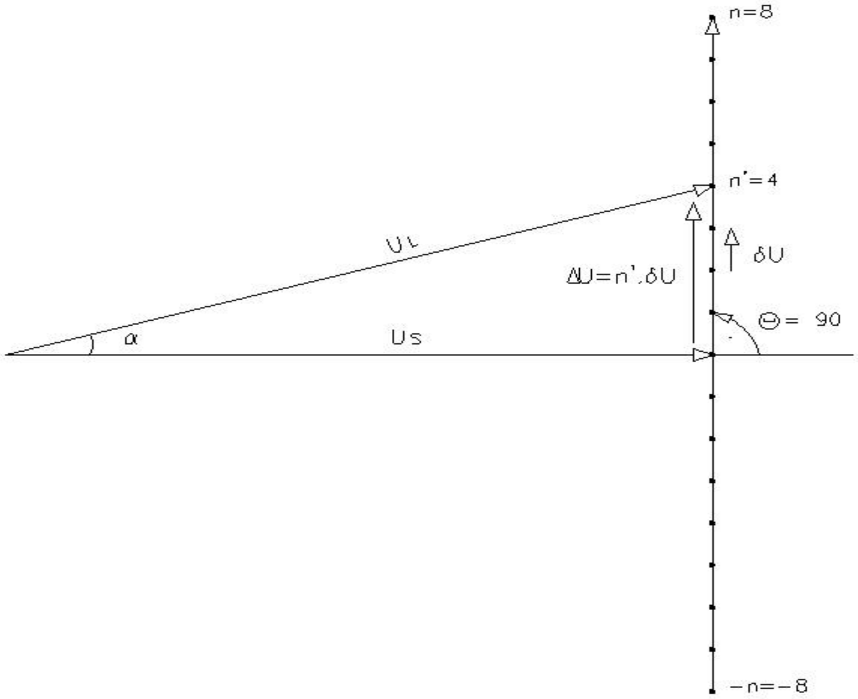


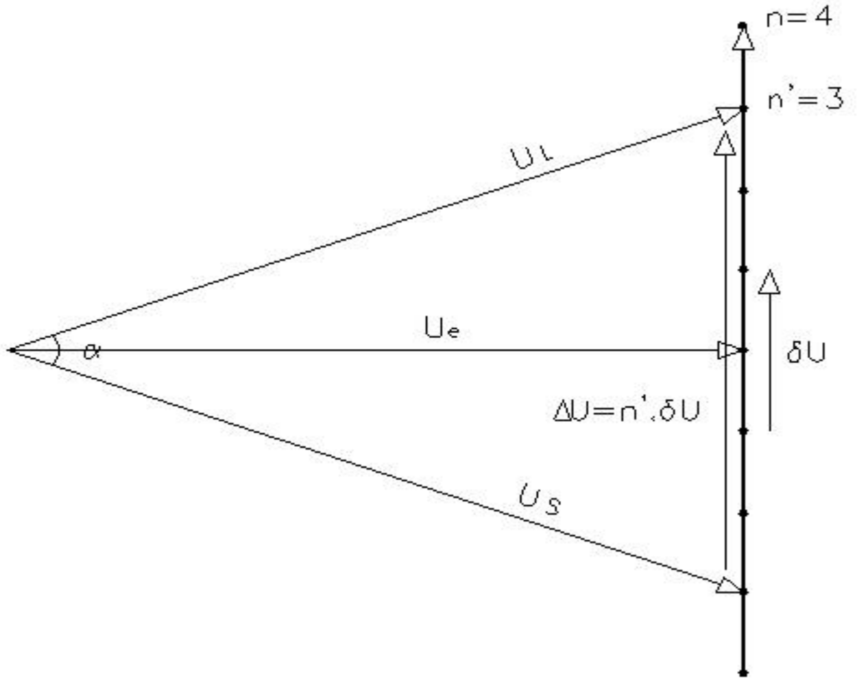
While in the basic semantic model (figure 2), $\alpha = \arctan\left(\frac{n'\delta u \sin\Theta}{1+n'\delta u\cos\Theta}\right)$ and $\rho = \frac{1}{\sqrt{(n'\delta u \sin\Theta)^2 + (1+n'\delta u\cos\Theta)^2}}$

Figure 5. Asymmetrical, Θ≠ 90° (Type = ASYM)



While in the basic semantic model (figure 2), $\alpha = \arctan(n'\delta u)$ and $\rho = \frac{1}{\sqrt{(n'\delta u)^2 + 1}}$

Figure 6. Asymmetrical, Θ = 90° (Type = ASYM)



While in the basic semantic model (figure 2), $\alpha = 2\arctan\frac{n'\delta U}{2U_e} = 2\arctan\frac{n'\delta u}{2}$ and $\rho = 1$. U_e is the central voltage (kV)

Figure 7. Symmetrical (Type = SYMM)

The following semantic validation rules apply for all phase shifting transformers with (angle regulation):

Rule id	Attribute	Severity	Diagnosis/Message
DATA-TRREG-QUADRA-01	Angle regulation: voltage change per tap	WARNING	For Transformer with angle regulation, voltage change per tap should not be zero. Its absolute value should not be above 6% [22]
DATA-TRREG-QUADRA-02	Angle regulation: number of taps	WARNING	The value cannot be negative and cannot exceed 35 [23]
DATA-TRREG-QUADRA-04	Angle regulation: angle	WARNING	The absolute value of the angle cannot exceed 180°
DATA-TRREG-QUADRA-05	Angle regulation type	WARNING	For Transformer with symmetrical angle regulation, type must be indicated as "SYMM"; for Transformer with asymmetrical angle regulation, type must be indicated as "ASYM", Blank type means "ASYM".

The following semantic validation rule applies for all detailed transformer descriptions:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-TapPosition-TAP-01	Tap position	WARNING	Tap Transformer value must be lower or equal in absolute value than the number of taps

The following connectivity validation rules apply:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-TRREG-DEF-01	LTC Transformer identifier	WARNING	Transformer identification (connectivity nodes and order code) must be defined in the 2 windings transformers data definition
DATA-TapPosition-DEF-01	Details Transformer identifier	WARNING	Transformer identification (connectivity nodes and order code) must be defined in the 2 windings transformers data definition
TOPOLOGY-Connection-03	Nodes	WARNING	The number of branches connected to one node exceeds 40 [24]
DATA-TRF-DEF-01	Transformer connectivity node	FATAL	Both terminals of the transformer must be defined
DATA-TRF-DEF-04	Transformer connectivity node	FATAL	Both terminals of the transformer must belong into the same TSO

[22] This value is justified by the values used in the RG CE DACF files and can be updated if deemed necessary.

[23] This value is justified by the values used in the RG CE DACF files and can be updated if deemed necessary.

[24] This value is justified by the values used in the RG CE DACF files and can be updated if deemed necessary.

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2.1.3 ENERGY INJECTIONS AND VOLTAGE CONTROL

The power-flow (or load-flow) problem is concerned with finding the static operating conditions of an electric power transmission system while satisfying constraints specified for power and/or voltage at the network buses. In the UCTE DEF the following bus types are available:

Bus type	Specified quantities	Comments
Slack bus (node type 3)	Θ, |V|	Slack bus is the reference bus. The phase angles of all the other buses are relative to the swing bus angle. The losses in the network are also considered supplied by the swing bus. Swing bus must also adjust reactive power to hold voltage constant at this bus.
Slack bus (node type 1)	Θ, Q	Slack bus is the reference bus. The phase angles of all the other buses are relative to the swing bus angle. The losses in the network are also considered supplied by the swing bus.
PV bus (node type 2)	P, |V|, Qmax, Qmin	Voltage magnitude |V| is held constant as long as Q required is within Qmax and Qmin. If Q required crosses the limits, the bus is considered as a PQ bus with Q specified as the Q limit that has been breached. P=0 for a synchronous condenser. If the reactive power limits are not provided, Voltage magnitudes |V| at these buses are held constant no matter how much reactive power Q is required.
PQ bus (node type 0)	P, Q	Normal Load representation.

Negative energy injections to a bus are interpreted as generation infeed, positive energy injections are interpreted as (vertical) load consumption. In UCTE DEF (vertical) load is modelled as the summed flow over the transformers to the distribution grid.

The following rules[25] are applicable for generators and synchronous machines:

[25] For the time being these rules will not be enforced for UCTE DEF DACF and Intraday files

Rule id	Attribute	Severity	Diagnosis/Message
DATA-NODE-PMIN-01	P min (MW)	WARNING	Minimum permissible active generation must be defined and can be negative if there is only pure generation or positive for mix and/or pumping plants
DATA-NODE-PMAX-01	P max (MW)	WARNING	maximum permissible active generation must be defined and can be negative or positive (for pumping)
DATA-NODE-QMIN-01	Q min (Mvar)	WARNING	In case of PV node minimum permissible reactive generation must be defined
DATA-NODE-QMAX-01	Q max (Mvar)	WARNING	In case of PV node maximum permissible reactive generation must be defined

3 OPERATING ASSUMPTIONS

3.1 INTRODUCTION

There are two basic components of input to any study. The first is the physical network model described in the previous sections, which accounts for the majority of the data. The second is an operating hypothesis for the study – in other words, the answer to the question, 'what operating condition is to be studied?'

Algorithms differ to some extent in terms of exactly what they can accept as part of their operating hypotheses. (E.g. A state estimator can take in a flow measurement, but a power flow cannot.) Studies also vary in terms of the way that an operating hypothesis is formed.

In sum, though, there is much more overlap than there is difference, and it is practical to define one way to describe a 'steady-state hypothesis' that will be useful for all types of network analysis. This description is roughly equivalent to the information that needs to be added to a physical model to create a complete set of input for a power flow.

Complete operating hypotheses are not shared or managed in the same way as the physical network model, however. Instead, there tends to be a collection of different procedures for developing different parts of the operating hypothesis in different analytical situations. While the physical network model should be derived from shared master source material, an operating hypothesis will align with the particular kind of study being run.

To illustrate, consider the question of how a given study would initialize the state of switches and circuit breakers and taps within its steady-state hypothesis. Depending on the kind of study, any of the following actions might be appropriate:

- Initialize from current conditions
- Initialize from the defined 'normal' state that is part of the physical model
- Initialize from another power flow case that has been saved
- Override by adding one or more outages
- Override by adding a pre-stored contingency
- Override with any manual selections

The four main issues that define the system state are the following:

- Device status, defining the topological state of the network (this part includes switching states, bus connections status and transformer tap positions)
- Energy injections, defining the nodal load consumption and generation infeed, necessary to be able to calculate the complex voltages at each bus
- Control Settings, defining the settings to keep the network operating within the desired ranges
- Monitoring, defining the operating limits and constraints

Depending of the process the source of this data may be different.

3.2 YEAR AHEAD EXCHANGE OF NETWORK MODELS

In accordance with OH Policy 4 reference case scenarios are created for winter and summer studies for both NTC determination and outage planning (3rd Wednesday of January and July at 10:30). Also these reference cases are used by TSOs to model the boundaries of their observability areas.

The TSOs shall coordinate the work on their networks for the coming year related to the expected impact of network elements that will come into operation, e.g. new phase shifting transformers (PST) or new interconnectors. Additionally, the TSOs shall use the common grid models to

- coordinate a common operational planning schedule for grid outages
- limit the amount of NTC reductions and to ensure maximum cross-border capacities by optimizing the total length of planned grid outages or by improving the schedule
- ensure an (n-1)-secure grid in each country throughout the year

For all outage periods both load flow and (n-1) calculations are performed to assess the feasibility based on common grid models in which the planned grid extensions, the planned outages for grid elements (from the TSOs) and the planned outages of generators (from the market parties) have been implemented.

Each TSO shall assess whether Outage Incompatibilities[26] arise from proposed Availability Plans of Relevant Assets[27]. This means that the outage planning coordination process relies on Operational Security Analyses that are performed at least on the Year-Ahead CGMs.

CGM built for the Year-Ahead outage coordination process can be used as a starting point for year-ahead and month-ahead capacity calculation. Within each capacity calculation region, TSOs have then the possibility to define additional scenarios and update their IGM if needed.

3.2.1 DEVICE STATUS

The topological situation shall not be updated with any planned outages for maintenance (except for long period of time impacting this season), but only outages due to operational constraints (for example opened line for high voltage issues). The availability of interconnections must be consistent between all IGMs, i.e. all interconnections must be in service.

[26] State in which a combination of the availability status of one or more Relevant Assets and the best estimate of the forecasted electricity grid situation leads to violation of Operational Security Limits taking into account non-costly Remedial Actions at the TSO's disposal (source: NC OPS)

[27] Include, according to definition in NC OPS :
- Relevant Demand Facility,
- Relevant Power Generating Module,
- Relevant Non-TSO Owned Interconnector,
- Relevant Grid Element partaking in the Outage Coordination Process

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In the IGMs grid components that support voltage control shall be available (although they could be switched off for operational reasons).

In order to assess the plausibility of the device status data the following validation rules apply:

Rule id	Concerns	Severity	Diagnosis/Message
DATA-LINE-STATUS-01	Line status[28]	FATAL	Invalid line status: line status must be one of the values : 0,1,2,7,8,9
DATA-TRF-STATUS-01	Transformer status code[29]	FATAL	Invalid transformer status: transformer status must be one of the values : 0,1,8,9
DATA-TRREG-PHASE-03	Phase regulation: current tap position	WARNING	Transformer phase regulation tap must be lower or equal in absolute value than the number of taps
DATA-TRREG-QUADRA-03	Angle regulation: current tap position	WARNING	For Transformer with angle regulation, tap must be lower or equal in absolute value than the number of taps
DATA-TIELINE-STATUS-01	Topology	WARNING	All interconnectors must be in service

3.2.2 ENERGY INJECTIONS

Load pattern and voltage profile shall be based on the realized situation chosen to define the grid condition (state estimator solution) or statistical data, and adjusted to the best estimated value corresponding to the scenario.

The grid condition for each scenario shall contain realistic infeed of RES for the date and time of the scenario. This requires to model RES infeed in distribution grids as generators with a typical infeed and active power limits if the connection point between the distribution grid and the transmission grid is modelled. Applying realistic RES infeed could lead to the need for adjusting the scheduled interchange on a regional basis.

Cases assume availability of all generation units except for long period of time impacting this season. This means that the generation schedule shall be updated with realistic values, based on the assumption that all the conventional generators are available, to meet net positions values that have been agreed, including agreed power flows values on DC interconnections, RES infeed, demand and grid losses. This could thus mean that some generators are switched off in order to meet the minimum generation output requirements. The net generator positions shall be balanced (within their physical limits) to meet agreed net positions of the scenario, using GSK files.

In order to assess the plausibility of the energy injections data the following validation rules apply:

[28] This only applies to the UCTE DEF data exchanges

[29] This only applies to the UCTE DEF data exchanges

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Rule id	Concerns	Severity	Diagnosis/Message
TOPOLOGY-Connection-03	X-node injection	WARNING	Balance of injections at a node must be zero if this node is not connected to any branches (i.e. all lines and transformers out of operation)
DATA-NODE-PLIMITS-01	P gen	WARNING	Active generation must be within operational limits
DATA-NODE-QLIMITS-01	Q gen	WARNING	Reactive generation must be within operational limits
LOADFLOW-Balance-02	N.A.	WARNING	After a load flow calculation, the absolute value of the change of active nodal injection at the slack node of the largest electrical island exceeds 5% of the total active generation including net imports
LOADFLOW-ACPosition-01[30]	N.A.	WARNING	The difference between the sum of the X-node injections and the expected balance as defined in the harmonized AC Net position table is greater than 50 MW
LOADFLOW-ACPosition-02[31]	N.A.	FATAL	The difference between the sum of the X-node injections and the expected balance as defined in the harmonized AC Net position table is greater than 500 MW

3.2.3 CONTROLS

The controls involve the voltage set points for the generator busses including plausible reactive power limits. Optional set points are voltage set points for on-load tap changing transformers and power flow set points for phase shifting transformers.

The following validation rules are used to assess the plausibility of the control settings:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-NODE-QMIN-01	Q min	WARNING	In case of PV node minimum permissible reactive generation must be defined
DATA-NODE-QMAX-01	Q max	WARNING	In case of PV node maximum permissible reactive generation must be defined
DATA-NODE-VOLTAGE-01	Voltage set point	FATAL	Unrealistic voltage set point for PV node and slack node[32]
DATA-TRREG-PHASE-04	Phase regulation: target voltage for	WARNING	Target value must be smaller than or equal to (Un + n*δU%*Un / 100) and greater than or equal to (Un - n*δU%*Un / 100) (where Un is

[30] For TSOs that are part of a subcontrol block, this validation can only be performed after pre-merging the individual operating assumptions into one set

[31] For TSOs that are part of a subcontrol block, this validation can only be performed after pre-merging the individual operating assumptions into one set

[32] Calculated voltage must be between 0.8 Un and 1.2 Un for voltage levels 110 kV and above (Un is the voltage level of the node defined by the 7th character of node code).

Rule id	Attribute	Severity	Diagnosis/Message
	regulated winding		the voltage level of the regulated winding)
LOADFLOW-PV-01	Node type	FATAL	No voltage support nodes (i.e. slack or PV node) have been provided
LOADFLOW-PV-02	N.A.	WARNING	The shift of voltage magnitude on a PV node after load flow calculation is bigger than 5% of the voltage set point
LOADFLOW-PV-03	N.A.	FATAL	The shift of voltage magnitude on a PV node after load flow calculation is bigger than 10% of the voltage set point

3.2.4 MONITORING VALUES

Each TSO shall apply the appropriate thermal limits corresponding to the target season to each Grid Element. Thermal limits include permanent admissible values. The following validation rules are used to assess the plausibility of the monitoring values in relation to the calculated load flow:

Rule id	Attribute	Severity	Diagnosis/Message
LOADFLOW-Voltage-01	N.A.	FATAL	One or more calculated bus voltages are not between 0.8 Un and 1.2 Un (Un is the voltage level of the node)[33]
LOADFLOW-Overload-01	N.A.	WARNING	After load flow calculation, one or more branch flows are higher than 120% of the current limit

[33] Note: Only applicable to voltage levels of 110 kV and above

3.3 Base cases for the capacity calculations D-1 market

The base cases for the capacity calculations for the D-1 markets are created two days in advance. These base cases shall be created for each hour of the business day D (the target day). Since the D-1 markets have not ended when these base cases are created and the market transactions have not been settled, a reference net position table is required for each scenario in order to able to assign infeed values to generators (starting point for the capacity calculations).

As in the flow-based capacity calculations that are operational today, the D-1 market transactions are used for the working days Tuesday – Friday, and scheduled interchanges of last week are being used for bank holidays and the other weekdays, it is reasonable to use this approach for the whole area of ENTSO-E.

However, the RES infeed might be completely different for the target day in comparison to the D-1 transactions, which may lead to incompatible net positions in some regions: there may be insufficient installed generating capacity (in case of extremely low RES infeed in combination with the net position that was used) or there may be insufficient load (due to extremely high RES infeed in combination with the net position that was used).

When this occurs, the time to negotiate changes in the net positions with multiple partners for all affected scenarios is limited when the TSOs have to wait for the D-1 transaction results to become available. Since the first version of the net positions table is arbitrary (except for typical working days/bank holidays/Saturday/Sunday situations), it is recommended to agree on a common reference day for each scenario or to apply a harmonization algorithm to achieve this goal.

The following table provides the details for preparing the reference day net positions table:

Preparation day	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Target day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Scheduled DC links	Scheduled exchange per DC tie-line of the Friday before	Scheduled exchange per DC tie-line of the Monday before	Scheduled exchange per DC tie-line of the Tuesday before	Scheduled exchange per DC tie-line of the Wednesday before	Scheduled exchange per DC tie-line of the Thursday before	Scheduled exchange per DC tie-line of the Saturday before (week ahead)	Scheduled exchange per DC tie-line of the Sunday before (week ahead)
Scheduled AC interchange	Scheduled AC interchange (net position) of the Friday before	Scheduled AC interchange (net position) of the Monday before	Scheduled AC interchange (net position) of the Tuesday before	Scheduled AC interchange (net position) of the Wednesday before	Scheduled AC interchange (net position) of the Thursday before	Scheduled AC interchange (net position) of the Saturday before (week ahead)	Scheduled AC interchange (net position) of the Sunday before (week ahead)
	If needed, e.g. in case of insufficient available generation or reduced transfer capacity, bilateral negotiations can take place to update the scheduled values, but ultimately at 17:00 C.E.T. D-2.						

3.3.1 DEVICE STATUS

Planned outages and relevant topological situation for the target day for each hour of the target realization day. The connection status of interconnectors must be consistent between all IGMs for each timestamp.

The connection status of reactive power components must reflect the expected status. Transformer taps must reflect the expected status, phase shifting transformers must reflect their expected position.

In order to assess the plausibility of the device status data the following validation rules apply:

Rule id	Concerns	Severity	Diagnosis/Message
DATA-LINE-STATUS-01	Line status[34]	FATAL	Invalid line status: line status must be one of the values : 0,1,2,7,8,9
DATA-TRF-STATUS-01	Transformer status code[35]	FATAL	Invalid transformer status: transformer status must be one of the values : 0,1,8,9
DATA-TRREG-PHASE-03	Phase regulation: current tap position	WARNING	Transformer phase regulation tap must be lower or equal in absolute value than the number of taps
DATA-TRREG-QUADRA-03	Angle regulation: current tap position	WARNING	For Transformer with angle regulation, tap must be lower or equal in absolute value than the number of taps

3.3.2 ENERGY INJECTIONS

Load pattern and voltage profile shall be based on forecast data for the target day. If no forecast is available, the System Operator shall produce their best estimate based on historical values.

The RES infeed is based on forecast data for the target day, based on actual weather forecast. Models shall be updated by the most recent forecast for the RES infeed. Until publication time before the opening of the D-1 markets, additional corrections are valid for the parameterization of the capacity calculation process for relieving constraints. This aims to optimize capacity (possible relieving of constraints due to remedial action, better RES forecast). Each TSO decides if and how it wants to adjust a model. Process of updating the models could be repeated, but no longer than the last merging.

Taking into account the planned generator outages for the target day, generator infeed shall be updated with realistic values to meet net positions values that have been agreed, including agreed power flows values on DC interconnections, RES infeed, demand and grid losses. The net generator positions shall be balanced (within their physical limits) to meet

[34] This only applies to the UCTE DEF data exchanges

[35] This only applies to the UCTE DEF data exchanges

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agreed net positions of the scenario, using local GSK files that take into account merit orders and generator limits.

In order to assess the plausibility of the energy injections data the following validation rules apply:

Rule id	Concerns	Severity	Diagnosis/Message
TOPOLOGY-Connection-03	X-node injection	WARNING	Balance of injections at a node must be zero if this node is not connected to any branches (i.e. all lines and transformers out of operation)
DATA-NODE-PLIMITS-01	P gen	WARNING	Active generation must be within operational limits
DATA-NODE-QLIMITS-01	Q gen	WARNING	Reactive generation must be within operational limits
LOADFLOW-Balance-02	N.A.	WARNING	After a load flow calculation, the absolute value of the change of active nodal injection at the slack node of the largest electrical island exceeds 5% of the total active generation including net imports
LOADFLOW-ACPosition-01[36]	N.A.	WARNING	The difference between the sum of the X-node injections and the expected balance as defined in the harmonized AC Net position table is greater than 50 MW
LOADFLOW-ACPosition-02[37]	N.A.	FATAL	The difference between the sum of the X-node injections and the expected balance as defined in the harmonized AC Net position table is greater than 500 MW

3.3.3 CONTROLS

The controls involve the voltage set points for the generator busses including plausible reactive power limits. Optional set points are voltage set points for on-load tap changing transformers and power flow set points for phase shifting transformers.

The following validation rules are used to assess the plausibility of the control settings:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-NODE-QMIN-01	Q min	WARNING	In case of PV node minimum permissible reactive generation must be defined
DATA-NODE-QMAX-01	Q max	WARNING	In case of PV node maximum permissible reactive generation must be defined
DATA-NODE-VOLTAGE-01	Voltage set point	FATAL	Unrealistic voltage set point for PV node and

[36] For TSOs that are part of a subcontrol block, this validation can only be performed after pre-merging the individual operating assumptions into one set

[37] For TSOs that are part of a subcontrol block, this validation can only be performed after pre-merging the individual operating assumptions into one set

Rule id	Attribute	Severity	Diagnosis/Message
			slack node[38]
DATA-TRREG-PHASE-04	Phase regulation: target voltage for regulated winding	WARNING	Target value must be smaller than or equal to (Un + n*δU%*Un / 100) and greater than or equal to (Un - n*δU%*Un / 100) (where Un is the voltage level of the regulated winding)
LOADFLOW-PV-01	Node type	FATAL	No voltage support nodes (i.e. slack or PV node) have been provided
LOADFLOW-PV-02	N.A.	WARNING	The shift of voltage magnitude on a PV node after load flow calculation is bigger than 5% of the voltage set point
LOADFLOW-PV-03	N.A.	FATAL	The shift of voltage magnitude on a PV node after load flow calculation is bigger than 10% of the voltage set point

3.3.4 Monitoring values

Each TSO shall apply the appropriate thermal limits corresponding to the target season to each Grid Element. Thermal limits include permanent admissible values. The following validation rules are used to assess the plausibility of the monitoring values in relation to the calculated load flow:

Rule id	Attribute	Severity	Diagnosis/Message
LOADFLOW-Voltage-01	N.A.	FATAL	One or more calculated bus voltages are not between 0.8 Un and 1.2 Un (Un is the voltage level of the node)[39]
LOADFLOW-Overload-01	N.A.	WARNING	After load flow calculation, one or more branch flows are higher than 120% of the current limit

38 Voltage set point must be between 0.8 Un and 1.2 Un for voltage levels 110 kV and above (Un is the voltage level of the node defined by the 7th character of node code)

39 Note: Only applicable to voltage levels of 110 kV and above

3.4 D-1 AND INTRADAY COORDINATED SECURITY ASSESSMENT

Each TSO must perform **coordinated** Operational Security Analyses D-1 and intraday.

On a D-1 basis and within the intraday periods, each TSO shall perform Operational Security Analyses for assessing that the Operational Security Limits of its Responsibility Area are not exceeded, taking into account all the Contingencies from its Contingency List in order to detect possible Constraints and agree upon Remedial Actions with the affected TSOs and, if applicable, with affected DSOs or Significant Grid Users.

Each TSO shall monitor demand and Generation forecasts and shall proceed to updated Operational Security Analysis when these forecasts lead to significant deviation in demand or Generation. In undertaking the analysis each TSO shall take into account:

- the available updates of Generation and consumption data
- possible significant deviation in demand or Generation due to uncertain weather forecasts
- the results of the D-1 and intraday market processes
- the results of the scheduling processes

On a D-1 and intraday basis, if Constraints are detected by a TSO, this TSO shall evaluate, in line with coordination principles, the effectiveness of the joint Remedial Actions and the technical-economic efficiency of the joint Remedial Action.

3.4.1 DEVICE STATUS

Before the D-1 markets and intraday markets are closed, the scenarios are prepared for each hour of the target day taking into account the planned outages. For planned outages of interconnectors the correct start and end times need to be coordinated latest when preparing the scenarios.

The switch position of reactive power components (such as shunts) must reflect the expected status. Transformer taps must reflect the expected status, phase shifting transformer taps are in their expected position.

Forced outages should feature in all intraday scenarios given the uncertainty over when the affected grid element or system element will be reconnected (worst case situation).

In order to assess the plausibility of the device status data the following validation rules apply:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-LINE-STATUS-01	Line status[40]	FATAL	Invalid line status: line status must be one of the values : 0,1,2,7,8,9
DATA-TRF-STATUS-01	Transformer status	FATAL	Invalid transformer status: transformer status must

40 This only applies to the UCTE DEF data exchanges

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Rule id	Attribute	Severity	Diagnosis/Message
	code[41]		be one of the values : 0,1,8,9
DATA-TRREG-PHASE-03	Phase regulation: current tap position	WARNING	Transformer phase regulation tap must be lower or equal in absolute value than the number of taps
DATA-TRREG-QUADRA-03	Angle regulation: current tap position	WARNING	For Transformer with angle regulation, tap must be lower or equal in absolute value than the number of taps

3.4.2 ENERGY INJECTIONS

The energy consumption (MW/MVAr) for the target day is projected at the LV side of the transformers that connect the transmission level grids with the distribution level grids or large energy consumers. If no forecasts from Market Participants are available, the TSO shall produce its best estimate based on historical values. The loads values shall be updated to match the total generation (including power generating facilities connected to distribution networks at the moment the D-1 market was closed), scheduled interchange (both AC and DC) and grid losses using a Load Shift Key algorithm.

As soon as the D-1 markets have closed and the clearing process has taken place, the generator schedules need to be collected and processed. Updated schedules due to portfolio optimization, internal redispatch (e.g. for economic reasons or due to unexpected high infeed of renewable energy sources) will result in updated versions of the congestion forecast scenarios for each hour of the target day. Hourly updates of the energy injection values are recommended in order to keep track of the development of the grid condition.

In areas where intraday trading takes places, updates for the remaining hours of the target day must be provided hourly. In order to assess the plausibility of the energy injections data the following validation rules apply:

Rule id	Attribute	Severity	Diagnosis/Message
TOPOLOGY-Connection-03	X-node injection	WARNING	Balance of injections at a node must be zero if this node is not connected to any branches (i.e. all lines and transformers out of operation)
DATA-NODE-PLIMITS-01	P gen	WARNING	Active generation must be within operational limits
DATA-NODE-QLIMITS-01	Q gen	WARNING	Reactive generation must be within operational limits
LOADFLOW-Balance-02	N.A.	WARNING	After a load flow calculation, the absolute value of the change of active nodal injection at the slack node of the largest electrical island exceeds 5% of the total active generation including net imports

41 This only applies to the UCTE DEF data exchanges

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Rule id	Attribute	Severity	Diagnosis/Message
LOADFLOW-Vulcanus-01[42]	N.A.	WARNING	The difference between the sum of the X-node injections and the expected balance as defined in Vulcanus is greater than 50 MW
LOADFLOW-Vulcanus-02[43]	N.A.	FATAL	The difference between the sum of the X-node injections and the expected balance as defined in Vulcanus is greater than 500 MW

3.4.3 CONTROLS

The controls involve the voltage set points for the generator busses including plausible reactive power limits. Optional set points are voltage set points for on-load tap changing transformers and power flow set points for phase shifting transformers.

The following validation rules are used to assess the plausibility of the control settings:

Rule id	Attribute	Severity	Diagnosis/Message
DATA-NODE-QMIN-01	Q min	WARNING	In case of PV node minimum permissible reactive generation must be defined
DATA-NODE-QMAX-01	Q max	WARNING	In case of PV node maximum permissible reactive generation must be defined
DATA-NODE-VOLTAGE-01	Voltage set point	FATAL	Unrealistic voltage set point for PV node and slack node[44]
DATA-TRREG-PHASE-04	Phase regulation: target voltage for regulated winding	WARNING	Target value must be smaller than or equal to (Un + n*δU%*Un / 100) and greater than or equal to (Un - n*δU%*Un / 100) (where Un is the voltage level of the regulated winding)
LOADFLOW-PV-01	Node type	FATAL	No voltage support nodes (i.e. slack or PV node) have been provided
LOADFLOW-PV-02	N.A.	WARNING	The shift of voltage magnitude on a PV node after load flow calculation is bigger than 5% of the voltage set point
LOADFLOW-PV-03	N.A.	FATAL	The shift of voltage magnitude on a PV node after load flow calculation is bigger than 10% of the voltage set point

[42] For TSOs that are part of a subcontrol block, this validation can only be performed after pre-merging the individual operating assumptions into one set

[43] For TSOs that are part of a subcontrol block, this validation can only be performed after pre-merging the individual operating assumptions into one set

[44] Voltage set point must be between 0.8 Un and 1.2 Un for voltage levels 110 kV and above (Un is the voltage level of the node defined by the 7th character of node code)

3.4.4 MONITORING VALUES

Each TSO shall apply the appropriate thermal limits corresponding to the target season or hour of the scenario to each Grid Element. Thermal limits include permanent admissible values. The following validation rules are used to assess the plausibility of the monitoring values in relation to the calculated load flow:

Rule id	Attribute	Severity	Diagnosis/Message
LOADFLOW-Voltage-01	N.A.	FATAL	One or more calculated bus voltages are not between 0.8 Un and 1.2 Un (Un is the voltage level of the node)[45]
LOADFLOW-Overload-01	N.A.	WARNING	After load flow calculation, one or more branch flows are higher than 120% of the current limit

[45] Note: Only applicable to voltage levels of 110 kV and above

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4 QUALITY ASSESSMENT OF THE CALCULATIONS

The inaccuracy of the network state obtained by merging of DACF or IDCF files isn't easy to determine because unpredictable intraday modifications (topology, exchanges programs, generations…) lead to differences between forecast and measured flows. In order to have a clear view when it comes to analyse the quality, the most realistic approach to improve the quality would be first to correct all known errors and after that to monitor the differences between the forecast and measured flows on a regular basis and to analyse these differences.

4.1 QUALITY ASSESSMENT OF THE MERGED MODEL (INPUT DATA)

The following merged model quality criteria are used by the SG NM&FT Operational quality Task Force:

Requirement	Severity	Condition
MERGE-01	WARNING	The file for a specific TSO was substituted, no further quality assessment is performed for this part of the merged dataset
MERGE-02	WARNING	X-node status is not consistent (original files)
MERGE-03	WARNING	The operating limits on tie-lines are not consistent on both sides

4.2 QUALITY ASSESSMENT OF THE MERGED MODEL (LF RESULT)

The following merged model quality criteria are used by the SG NM&FT Operational quality Task Force. Note that these warning issues and fatalities refer to single IGM datasets only:

Requirement	Severity	Condition
LF-OVERLOADS-01	WARNING	Excessive equipment overloads (overloads exceeding 120% of the operating limits as provided by all TSOs) [46]
LF-REACTIVEPOWER-01	WARNING	PV node has been changed to PQ node (Qlimit has been reached)[47]
LF-VOLTAGES-01	WARNING	Voltages are not within the operational limits as provided by all TSOs[48]
LF-VULCANUS-01	WARNING	The difference between the sum of the active generation minus the sum of the active loads minus the losses for each control block and the expected balance as defined in Vulcanus is greater than 50 MW
LF-VULCANUS-02	FATAL	The difference between the sum of the active generation minus the sum of the active loads minus the losses for each control block and the expected balance as defined in Vulcanus is greater than 500 MW

[46] Assumed to be provided in the datasets

[47] Node name/identifier has to be provided in the message

[48] Assumed to be provided via a questionaire, for the time being the ± 10% thresholds will be used

4.3 QUALITY ASSESSMENT OF THE MERGED MODEL (AFTER THE FACT)

For post-operation analysis, real-time snapshots are exchanged and finally merged. As this study is performed a posteriori in a time horizon relatively far from the event, some additional checks can be performed to increase the quality of the datasets.

For example, every year, four real-time snapshots are merged, for Winter Peak (10:30) and Off-Peak (03:30) represented by the third Wednesday of January as well as Summer Peak and Off-Peak, which is the third Wednesday of July. This activity is done almost one month after the real-time operation, which implies that more data are available like Realized Control Program, Measured Control Programs, etc. and communication between the merging entity and the individual TSO can be done, in order to correct some inconsistencies, which could have occurred after the conversion of the data from the SCADA system.

This is also an added value in the quality of the dataset in contrary to the 15 minutes snapshot cases, where no data regarding Realized Control Program are available and no communication is foreseen in case of tie-line inconsistencies, for example, but as well a disadvantage as it requires more time before having a consistent merged case.

First, the consistency of status of the tie-lines with the same X-node is really important. Different status (open, close) is considered as fatal error, and therefore the responsible TSOs have to be contacted in order to change their datasets in case it was the wrong status, until the consistency has been reached.

In order to assess the plausibility of the device status data the following validation rules apply:

Rule id	Concerns	Severity	Diagnosis/Message
DATA-LINE-STATUS-01	Line status[49]	FATAL	Invalid line status: line status must be one of the values : 0,1,2,7,8,9
DATA-TRF-STATUS-01	Transformer status code[50]	FATAL	Invalid transformer status: transformer status must be one of the values : 0,1,8,9
DATA-TRREG-PHASE-03	Phase regulation: current tap position	WARNING	Transformer phase regulation tap must be lower or equal in absolute value than the number of taps
DATA-TRREG-QUADRA-03	Angle regulation: current tap position	WARNING	For Transformer with angle regulation, tap must be lower or equal in absolute value than the number of taps
DATA-TIELINE-STATUS-02	Topology	FATAL	The connection status of interconnectors must be consistent between all IGMs

A Real-time snapshot is a picture of the grid at a certain time ‘t’. The flow over a tie-line with the same X-node has to be almost equal on the definition of a X-node in the node section in

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the two IGMs, of course, depending on the location where the flow is measured or calculated, as losses will create a small difference. P(X-node) represents the active power in MW at the X-node.

If |P(X-node) in IGM1 + P(X-node) in IGM2| < 5% * R*Imax^2 of the tie-line, it means the flow calculated in the state estimator was almost the same. If the condition above is not fulfilled, the two involved TSOs have to be contacted, in order to correct this mismatch. A mismatch can occur due to:

- assumptions every TSOs make when modelling the neighbouring grid in the SCADA/EMS system
- the differences in timing of the creation of the IGM in the SCADA system
- lack of measurements (insufficient redundancy)
- errors induced when converting to the UCTE DEF from the SCADA system

In the verification platform, it is possible to check the "Measured Load Flows of UCTE Control Blocks in MW", this value indicates the import/export situation of one control block. After merging and a load flow convergence, the control program of all the control zones are recorded and compared with the value present in Vulcanus.

If |P_i(Load Flow) + P_i(VerificationPlatform)| < 100 MW by excluding the load flow on the HVDC links, it means everything is ok. In case this criterion is not fulfilled, an imbalance in the control program present in the IGM was present, and a new IGM has to be asked to the relevant TSO.

In the verification platform, it is possible to check the "Measured Load Flows between UCTE Control Zones in MW", this value indicates the flows between one control zone and its neighbouring zones. After merging and a load flow convergence, the flow of all the control zones with their neighbouring zones are recorded and compared with the value present in the verification platform.

If |$P_{i\text{->}x}$(Load Flow) + $P_{i\text{->}x}$(VerificationPlatform)| < 100 MW, it means everything is ok. In case this criterion is not fulfilled, for example, a PST is set on a wrong tap position, etc.

After load flow and merging, it is possible to compare as well the flow on a tie line with what was written in the IGM to identify which tie-line has different flow after merging. If a discrepancy exists on a tie line it can be created from a wrong PST tap position.

In order to assess the plausibility of the snapshot data the following validation rules apply:

Rule id	**Attribute**	**Severity**	**Diagnosis/Message**
TOPOLOGY-Connection-03	X-node injection	WARNING	Balance of injections at a node must be zero if this node is not connected to any branches (i.e. all lines and transformers out of operation)
DATA-NODE-PLIMITS-01	P gen	WARNING	Active generation must be within operational limits
DATA-NODE-QLIMITS-01	Q gen	WARNING	Reactive generation must be within operational

Rule id	Attribute	Severity	Diagnosis/Message
			limits
LOADFLOW-TIELINE-01	Active Power	FATAL	|P(X-node) in IGM1 + P(X-node) in IGM2| > 5% * R*Imax^2 of the tie-line
LOADFLOW-Program-01	Active Power	FATAL	|Pi(Load Flow) + Pi(VerificationPlatform)| > 100 MW when excluding the load flow on the HVDC links
LOADFLOW-CBFLOW-01	Active Power	FATAL	|Pi->X(Load Flow) + Pi->X(VerificationPlatform)| > 100 MW

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