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MEASUREMENT AND INFORMATION SYSTEM FOR ELECTRICAL NETWORKS

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Generation of data of a network in the CIM model from a network modeled in the UCTE "Data Exchange Format" and vice versa

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Last CIM User group held in June in Arnhem, Netherlands, listed some advantages of CIM for UCTE model exchange (refer to “11a Model Exchange WG - Britton - meeting notes.doc” on CIM User group website Meeting Minutes folder). EDF Group releases this document publicly in order to help UCTE and CIM experts to figure out if the harmonization could be established.

This study applies to the technical specification for the converter between the UCTE (DEF) « Data Exchange Format for load flow and three phase short circuit studies » exchange format and the Common Power System Model (CPSM) format based on the International Electrotechnical Commission’s CIM (Common Information Model). CPSM is standardized by the IEC Technical Committee 57 (Energy Management Systems and information exchange) through part 61970-452 (Network Data Exchange Format) in the IEC international standard.

This study demonstrates that it is possible to
- convert from the UCTE format to the CIM format and therefore that there is no incompatibility between data exchanged between European TSOs and North American TSOs,
- convert in the reverse direction from the CIM format to the UCTE format.

Therefore, a product claiming to be CIM compatible can easily process UCTE data.

The advantage of this study is to:
- use the XML (eXtensible Mark-up Language) syntax to handle UCTE data
- use the international CIM (Common Information Model) standard issued by the IEC TC57
- demonstrate that European networks can be topologically matched through the international CIM standard
- show that the information CIM model and the UN-CEFACT methodology of « Core Components » can be used to derive the European DEF exchange format, using the CPSM standard exchange profile
- demonstrate that UCTE format could be derived from IEC international standard, and that would be consistent with the approach retained by ETSO TF14 (which is harmonizing its standard with IEC TC57 wg16).

A similar approach for harmonizing the 2 standards could be set-up between UCTE Working group in charge of DEF format, IEC TC57 WG13 and CIMUg Model Exchange Working Group.

This study has been based on UCTE data exchange format for load flow and three phase short circuit studies V01 which came into force in September 2003. It should be upgraded to version 2 which came into force in May 2007 (http://www.ucte.org/pdf/Publications/2007/UCTE-format.pdf).

Summary

This study applies to the technical specification for the converter between the UCTE (DEF) « Data Exchange Format for load flow and three phase short circuit studies » exchange format and the Common Power System Model (CPSM) format based on the International Electrotechnical Commission's CIM (Common Information Model). CPSM is standardized by the IEC Technical Committee 57 (Energy Management Systems and information exchange) through part 61970-452 (Network Data Exchange Format) in the IEC international standard.
The CPSM format was created to satisfy the needs of the NERC that wanted North American TSOs to exchange data through a standard. The CIM then satisfied this need, and since 1999, interoperability tests based on CPSM between market suppliers (ABB, Areva, Siemens, GE, Sisco, etc.) have taken place.

The CIM and UCTE network models are fairly different

- the former uses a detailed topology, the latter uses a nodal topology,
- data placed at nodes in the UCTE format are scattered in different objects of the CIM model,
- transformers and their on-load tap changers are modeled differently.

Therefore, we will only use one part of the CIM model defined by recommendations of the NERC CPSM profile. This version of this note is conforming with CPSM3 [2].

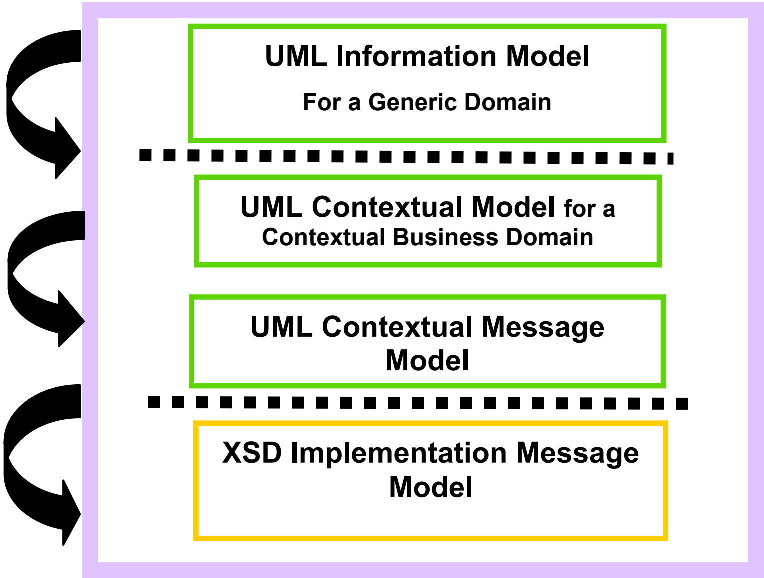
The purpose of this document is to specify a number of transformations to be made on data between two models both in the UCTE to CIM direction and the CIM to UCTE direction.

Our correspondence rules and the CIM objects that have to be created for the CPSM format, are illustrated from UCTE files. Note that two files have been chosen as a function of their size and optional records used in one of the two files. The UCTE 14-node file is the minimum file that uses the fewest optional records (this file is shown graphically in appendix B).

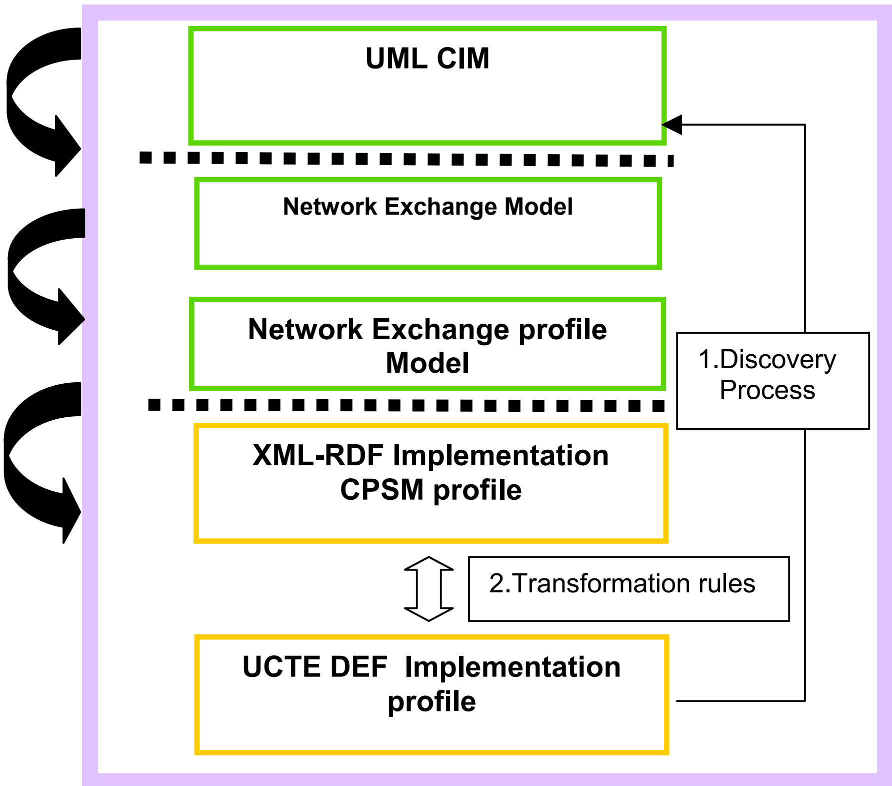
Methodologically, the study is based on the discovery process selected by the UN-CEFACT, namely how to connect a message content model for which objects are expressed with specific semantics (in this case the UCTE's DEF format) to business objects described in a given information model (in fact the CIM).

EDF R&D has validated this specification through the usage of its CIM Box where there which has a converter from UCTE DEF to CIM CPSM format, and from CIM CPSM to UCTE DEF format.

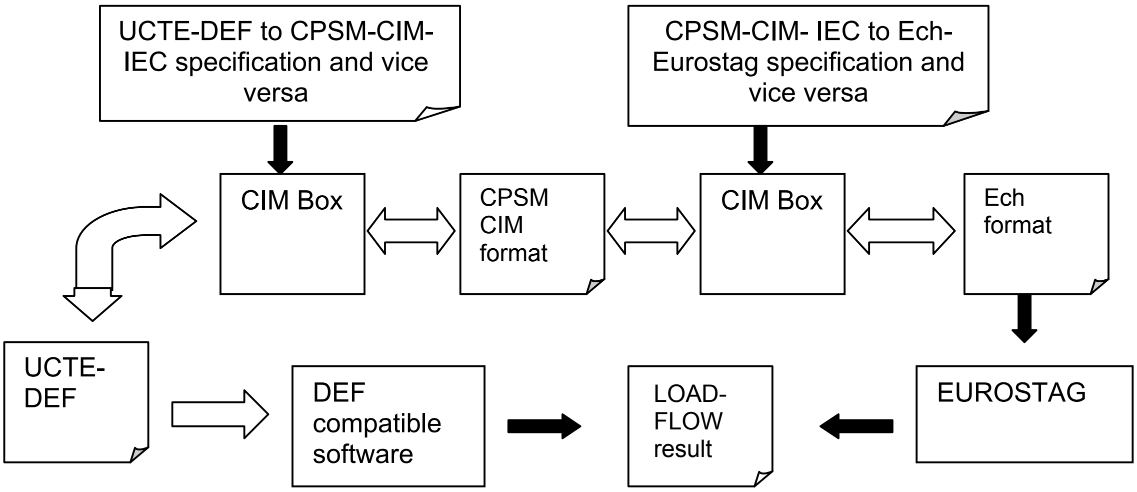
This study shows that it is possible to methodologically convert from the CIM format to the UCTE format and therefore that there is no incompatibility between data exchanged between European TSOs and North American TSOs. In this case, the UN-CEFACT methodology of Core Components is applied, which can be used to derive an exchange format from an information model. The Core Components UN-CEFACT methodology is illustrated in the following figure:



Applied to our study, this gives:



Thus a product claiming to be CIM compatible can easily process UCTE data. The transformation tool is built into EDF R&D's «CIM-Box» and the validation can be made using a CIM Load Flow compatible tool (for example Eurostag or any other CIM product compliant with CIM CPSM format) checking that the result of the Load Flow is consistent with that calculated by a tool compatible with the UCTE format. The following figure illustrates the test sequence:



EDF has realized several tests that process ucte files format in CIM CPSM format, back and forth. Some performances issues are under analysis (for instance processing CIM-CPSM-UCTE XML file to UCTE DEF format has to be improved).

ucte14.uct	57 ConnectivityNodes in CIM xml file
ucteFR.uct	5165 ConnectivityNodes in CIM xml file
ucteEU.uct	22130 ConnectivityNodes in CIM xml file

CONTENTS

1. Foreword

UCTE describes its activities as follow (http://www.ucte.org)

“The Union for the Co-ordination of Transmission of Electricity (UCTE) is the association of transmission system operators in continental Europe, providing a reliable market base by efficient and secure electric "power highways".

50 years of joint activities laid the basis for a leading position in the world which the UCTE holds in terms of the quality of synchronous operation of interconnected power systems.

Through the networks of the UCTE, about 450 million people are supplied with electric energy; annual electricity consumption totals approx. 2300 TWh. “

It is structured through several working groups. One subgroup is called “Network Models and forecast tools” and it delivers UCTE-DEF data exchange format for load-flow and three phase short circuit studies.

ETSO TF14 and IEC TC57 WG16 (Deregulated Markets) are cooperating for deriving ETSO messages from CIM information model which is an international standard.

A similar approach for harmonizing the 2 standards could be set-up between UCTE Working group in charge of UCTE DEF, IEC TC57 WG13 and CIMUg Model Exchange Working Group.

We remind hereafter the advantages listed by UCA CIMUg Model Exchange Working group last June 2007 :

- Advantages of CIM for UCTE model exchange
    - Goal needs to be to get enough accurate modeling to ensure valuable contingency analysis to avoid insecure operating conditions.
    - State estimators currently detect model problems that have to be solved manually. CIM would reduce labor.
    - Better data quality, fewer errors.
    - Data updates can be made more quickly, models stay current.
    - Changes can be tracked easier.
    - DACF (Day Ahead Congestions Forecast) is run every day at all the TSOs, but the results don’t agree. Need to investigate why these differences exist and whether CIM procedures can yield consistency.
    - TSOs are willing to exchange data since the last disturbance.
    - Operators will be able to have better understanding of neighboring networks.
    - It’s a standard!
    - CIM process would produce a common UCTE breaker detail model.
    - Convergence with ESS (ETSO Scheduling System) as ETSO adopts CIM.

2. From the UCTE format to the CIM model

2.1. Preliminaries

This document complies with version 3.0 of the CPSM profile [2]

2.1.1. Comments on the UCTE file

The file is composed of blocks as described in document [3] introduced by key records.

Note that some files may not be conforming.

For example, we have seen cases in which:

- the format of the ##R block is not respected
- the format of the ##T block is not respected

Therefore, it is important to assure that files are conforming and to correct them if necessary.

Some special points:

- Interconnection lines are grouped in their own ##L block.
- In the ##R block, transformers may be present without data. This means that there is no tap changer for them. The corresponding records can be ignored.
- ##C comment blocks may be introduced anywhere in the file. They are skipped while reading.

2.1.2. Equivalent network elements

UCTE files may contain nodes, lines and equivalent transformers. This means that they do not represent a real element, but rather a combination of real elements, the purpose of which is to reduce the size of the network to be studied, or perhaps also to replace the real network for which there are no available detailed data.

No distinction has been made for these elements in the following, but it is worth questioning whether or not it is a good idea to put them in a CIM model which was apparently not designed for that purpose.

2.1.3. Voltage regulations

The concept of a voltage regulation appears in two locations in the UCTE file:

- Transformer tap changer
- Special nodes (PV and slack)

They are modeled as follows:

There must be an item of equipment that does the regulation (TapChanger, SynchronousMachine, StaticVarCompensator, etc.)

This equipment will be associated with:

- An Analog (Measurement sub-type), itself associated with the LineToLineVoltage MeasurementType and with Unit kV;
- A RegulationSchedule with the following attributes:

- BasicIntervalSchedule.startTime = 00:00:00
- BasicIntervalSchedule.value1Unit = kV
- RegularIntervalSchedule.timeStep = 0
- RegularIntervalSchedule.endTime = 00:00:00

A RegularTimePoint will be associated with the RegulationSchedule, with:

- RegularTimePoint.sequenceNumber = 1
- RegularTimePoint.value1 = value of the voltage setpoint in kV
- RegularTimePoint.value2 = not defined

The Analog must be associated with an equipment Terminal to indicate the location at which the voltage is regulated (Measurement.Terminal association).

Finally, the Analog must be MemberOf_PSR of a PowerSystemResource (SynchronousMachine, BusbarSection, StaticVarCompensator, TapChanger, etc.)

Note: The RegulationSchedule curve is constant as a function of time. Therefore, only one point will be provided. There is no precise rule in CPSM3 for describing such a curve. We have chosen to set the timeStep to 0 to signal that the curve is constant. Values of startTime and endTime have been set to zero because they are useless. When a CIM file is read, a priori from any source, it is important to check that the curve only has a single point.

2.2. Global interest objects

Create a BasePower with basePower =100 MVA

Analogs created below must be associated with a MeasurementType (Meas package) that indicates the type of measured magnitude, and with a Unit (Core package) that indicates the unit. Therefore, several MeasurementTypes and several units will be created:

- MeasurementType (LineToLineVoltage)
- MeasurementType (Angle)
- MeasurementType (ThreePhaseActivePower)
- MeasurementType (LineCurrent)
- Unit (kV)
- Unit (Degrees)
- Unit (MW)
- Unit (Amperes)

2.3. Zones

In the UCTE file, zones correspond to countries. The list contains nodes sorted by zone. Nodes are located in a block introduced by a key record ##N. Every time that the zone changes, there will be a key record ##Zxx, indicating that all the following nodes belong to zone xx (where xx is the UCTE code of the country).

For each zone, the following will be created:

- a GeographicalRegion
- a SubGeographicalRegion: that contains the substations in the zone. It is associated with the GeographicalRegion

2.3.1. Example of Zones from the IEEE 14-node file

```
##C 2003.09.01
TEST IEEE NETWORK
##N
##ZFR
FNOD0111                    0 2  402.8       0       0   -4648      338
FNOD0211                    0 3  397.1     434     254    -800     -848
FNOD0311                    0 2  383.8    1884     380       0     -468
FNOD0411                    0 0             956     -78       0        0
FNOD0511                    0 0             152      32       0        0
FNOD0512                    0 0               0       0       0        0
FNOD0621                    0 2  235.4     224     150       0     -244
FNOD0711                    0 0               0       0       0        0
FNOD0871                    0 2  29.43       0       0       0     -348
FNOD0921                    0 0             590     332       0   -423.6
FNOD1021                    0 0             180     116       0        0
FNOD1121                    0 0              70      36       0        0
FNOD1221                    0 0             122      32       0        0
FNOD1321                    0 0             270     116       0        0
FNOD1421                    0 0             298     100       0        0
```

Analysis: one zone exists called FR (ISO country code). This zone is composed of 15 nodes.

Therefore, we will create one GeographicalRegion and one SubGeographicalRegion

In this other example:

```
##N
##ZMA
2FARDI11               0 0         292.700 39.9000 0.00000 0.00000
##ZBY
3BR_WD51               0 0         -36.700 -5.2200 0.00000 0.00000
3BR_WD52               0 0         -40.680 -5.2200 0.00000 0.00000
##ZAL
ABISTR31               0 0         0.00000 0.00000 0.00000 0.00000
ABURRE2                0 0         65.0000 60.0000 0.00000 0.00000
```

Three GeographicalRegion and three SubGeographicalRegion will be created:

MA (Morocco, 1st character of the node = 2, ISO code = MA)

BY (Belarus, 1st character of the node = 3, ISO code = BY)

AL (Albania, 1st character of the node = A, ISO code = AL)

2.4. Topology data

Browse through the nodes (records in block ##N) and branches (records in blocks ##L and ##T) to determine BaseVoltages, Substations and VoltageLevels.

BaseVoltage: The base voltage of the node is indicated by the 7th character in the name of node *Node (code)* that will be denoted C7. In browsing through the nodes, if C7 corresponds to a new value not yet encountered, create a BaseVoltage with nominalVoltage = Voltage(C7) according to the table on page 3 in the UCTE format. (BaseVoltage is aggregated in BasePower).

These codes are: 0=750kV, 1=380kV, 2=220kV, 3=150kV, 4=120kV, 5=110kV, 6=70kV, 7=27kV, 8=330kV, 9=free.

Substation: set of nodes connected by branches of ##T (transformer) blocks or ##L blocks with *Status* = 2 or 7 (busbar coupler), in other words other than lines. This is true whether or not the branch is in service. (Substation is aggregated in SubGeographicalRegion).

VoltageLevel: inside a Substation, all nodes with the same 7th character, in other words with the same base voltage. (VoltageLevel is aggregated in Substation and associated with a BaseVoltage).
HighVoltageLimit and lowVoltageLimit attributes do not appear in the UCTE file. They are present in CPSM. They can be defined to contain a default value:

- VoltageLevel.highVoltageLimit = BaseVoltage.nominalVoltage + 15%
- VoltageLevel.lowVoltageLimit = BaseVoltage.nominalVoltage - 15%

Create a ConnectivityNode for each node and connect it to a VoltageLevel.

Put *Node (geographical name)* in aliasName.

Afterwards, network objects will be connected to each other through Terminals grouped in ConnectivityNodes.

2.4.1. Data analysis

```
##ZFR
FNOD0111                0 2  402.8      0       0   -4648      338
FNOD0211                0 3  397.1    434     254    -800     -848
FNOD0311                0 2  383.8   1884     380       0     -468
FNOD0411                0 0            956     -78       0        0
FNOD0511                0 0            152      32       0        0
FNOD0512                0 0              0       0       0        0
FNOD0621                0 2  235.4    224     150       0     -244
FNOD0711                0 0              0       0       0        0
FNOD0871                0 2  29.43      0       0       0     -348
FNOD0921                0 0            590     332       0   -423.6
FNOD1021                0 0            180     116       0        0
FNOD1121                0 0             70      36       0        0
FNOD1221                0 0            122      32       0        0
FNOD1321                0 0            270     116       0        0
FNOD1421                0 0            298     100       0        0

##L
FNOD0511 FNOD0512 1 2 0.0000 0.0000 0.000000   9999

##T
FNOD0411 FNOD0711 1 0 380.0 380.0       0.0000 15.098 0.000000 0.0000    9999
FNOD0411 FNOD0921 1 0 380.0 220.0       0.0000 40.156 0.000000 0.0000    9999
FNOD0511 FNOD0621 1 0 380.0 220.0       0.0000 18.195 0.000000 0.0000    9999
FNOD0711 FNOD0871 1 0 380.0 27.00       0.0000 12.718 0.000000 0.0000    9999
FNOD0711 FNOD0921 1 0 380.0 220.0       0.0000 7.9425 0.000000 0.0000    9999
FNOD0411 FNOD0211 1 0 380.0 380.0       4.1956 12.730 470.9140 0.0000    9999
```

(see diagram in Appendix B)

According to node names and the code associated with the 7th character, we will create BaseVoltage: 1 = 380kV, 2 = 220 kV, 7 = 27 kV

Substation: Two Substations are created

FNOD0511 (Sub1) containing nodes: D0511, D0512 and D0621

FNOD0211 (Sub2) containing nodes: D0211, D0411, D0921, D0711, D0871

then one for each gray node in the diagram.

VoltageLevel: in Sub1, there are two VoltageLevels, FNOD0511 with nodes D0511 and D0512, and FNOD0621 with node D0621.

In Sub2, there are three VoltageLevels, FNOD0211 with D0211, D0411, D0711, FNOD0921 with D0921, and FNOD0871 with D0871.

then a VoltageLevel for each light gray node in the diagram.

2.5. Naming created objects

The table provided in Appendix A summarizes the following for each UCTE object:

- CIM objects created,
- the corresponding associations,
- naming of created CIM objects.

2.6. Node data

2.6.1. Busbars

A BusbarSection will be created for each node in the UCTE network.

A Terminal has to be created to connect it to the ConnectivityNode corresponding to this node.

Finally, the BusbarSection must be associated with the EquipmentContainer VoltageLevel of the ConnectivityNode.

2.6.2. Loads

Let:

- PL (C34-C40) = *Active load (MW)*
- QL (C42-C48) = *Reactive load (MVAr)*

If PL and QL are zero, do nothing.

Else (both are non-zero, or one of them is zero)

EnergyConsumer inherits from PowerSystemResource/Equipment/ConductingEquipment.

Define the two attributes:

pfixed : PL

qfixed : QL

Set conformingLoadFlag to the value false.

Create 1 Terminal to connect to the ConnectivityNode.

The EnergyConsumer must be associated with the EquipmentContainer VoltageLevel of the ConnectivityNode.

2.6.2.1. Data analysis

PL								**QL**						
34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
						0	b							0
			1	7	.	0	b					6	.	0
				0	.	0	b					0	.	0

An EnergyConsumer is only created for case 2 (pfixed = 17.0, qfixed = 6.0).

2.6.3. Productions

Let:

- SLNOD (C25) = *Slack node*
- PG (C50-C56) = *Active power generation (MW)*
- QG (C58-C64) = *Reactive power generation (MVAr)*
- PMIN (C66-C72) = *Minimum permissible generation (MW)*
- PMAX (C74-C80) = *Maximum permissible generation (MW)*
- QMIN (C82-C88) = *Minimum permissible generation (MVAr)*
- QMAX (C90-C96) = *Maximum permissible generation (MVAr)*

If SLNOD is not equal to 2 (2 = PV node) and the other fields are zero or not defined, do nothing.

Else, create

- a GeneratingUnit (Production package) (GeneratingUnit inherits from PowerSystemResource/Equipment):
- a SynchronousMachine (Wires package) in relation with the GeneratingUnit (SynchronousMachine inherits from PowerSystemResource/Equipment/ConductingEquipment/RegulatingCondEq) and its Terminal to connect to ConnectivityNode:

with GeneratingUnit.initialMW = – PG

GeneratingUnit.minimumOperatingMW = – PMIN (only if PMIN is defined)

GeneratingUnit.maximumOperatingMW = – PMAX (only if PMAX is defined)

GeneratingUnit.ratedNetMaxMW = – PMAX *1.1 if PMAX is defined, else – PG * 1.1

SynchronousMachine.baseMVAr = – QG

SynchronousMachine.minimumMVAr = – QMIN if QMIN is defined, else – QG (or -9999 if SLNOD = 2 or 3)

SynchronousMachine.maximumMVAr = – QMAX if QMAX is defined, else – QG (or +9999 if SLNOD = 2 or 3)

Note: There is a - sign because productions are negative in the UCTE format.

If PG = 0 and (PMIN and PMAX are zero or not defined)

SynchronousMachine.type = SynchronousMachineType.condenser
SynchronousMachine.operatingMode =
SynchronousMachineOperatingMode.condenser

Else

SynchronousMachine.type = SynchronousMachineType.generator
SynchronousMachine.operatingMode =
SynchronousMachineOperatingMode.generator

SynchronousMachineType.generator_or_condenser type is not used.

GeneratingUnit and SynchronousMachine must be associated with the l'EquipmentContainer VoltageLevel of the ConnectivityNode.

When a SynchronousMachine is created, it must be associated with an MVArCapabilityCurve with the following attributes:

- CurveSchedule.curveStyle = straightLineYValues
- CurveSchedule.xUnit = MW
- CurveSchedule.y1Unit = MVAr
- CurveSchedule.y2Unit = MVAr

and two CurveSchedData are associated with the MVArCapabilityCurve:

- CurveSchedData 1
    - CurveSchedData.xvalue = – PMIN if PMIN is defined, else 0
    - CurveSchedData.y1value = SynchronousMachine.minimumMVAr
    - CurveSchedData.y2value = SynchronousMachine.maximumMVAr
- CurveSchedData 2
    - CurveSchedData.xvalue = – PMAX si PMAX is defined, else – PG
    - CurveSchedData.y1value = SynchronousMachine.minimumMVAr
    - CurveSchedData.y2value = SynchronousMachine.maximumMVAr

2.6.3.1. Data analysis

Slack node	PG								QG							
25	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
2			-	4	6	4	8	b					3	3	8	b
0					0	.	0	b					0	.	0	b
0		-	2	0	0	.	0	b			-	3	7	.	0	b

PMIN							
66	67	68	69	70	71	72	73
●[1]							b
							b
			-	1	5	0	b

PMAX

[1] End of record

74	75	76	77	78	79	80	81
							b
							b
			-	2	5	0	b

QMIN								QMAX						
82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
							b							
						0	b							0
				1	4	4	b					-	8	4

Case 1: SLNOD = 2 (Slack Node = PV node). PG = –4648, QG = 338

therefore

GeneratingUnit.initialMW = 4648
SynchronousMachine.baseMVAr = –338
PMIN, PMAX, QMIN, QMAX not defined

Case 2: SLNOD = 0, and PG, QG are zero, PMIN, PMAX, QMIN, QMAX not defined: do nothing

Case 3: SLNOD = 0, PG = –200, QG = –37, PMIN = –150, PMAX = –250, QMIN = 144, QMAX =–84

therefore

GeneratingUnit.initialMW = 200
GeneratingUnit.minimumOperatingMW = 150
GeneratingUnit.maximumOperatingMW = 250
SynchronousMachine.minimumMVAr = –144
SynchronousMachine.maximumMVAr = 84

2.6.4. PV type node

If SLNOD = 2, the node type is PV type. A voltage regulation will be created and the voltage setpoint VOLTSP = *Voltage (reference value) (kV)* will be indicated. Refer to the « Preliminaries » chapter:

- The equipment is the SynchronousMachine already connected to the node.
- The setpoint is VOLTSP
- The Analog is associated with the SynchronousMachine Terminal and is MemberOf_PSR of the SynchronousMachine.

2.6.4.1. Data analysis:

Slack node
25
2

VOLTSP					
27	28	29	30	31	32
	4	0	2	.	8

The SynchronousMachine does the regulation.

The following are associated with this equipment:

- An Analog, itself associated with the LineToLineVoltage MeasurementType and the Unit kV;
- A RegulationSchedule, with the following attributes:
  - BasicIntervalSchedule.startTime = 00:00:00
  - BasicIntervalSchedule.value1Unit = kV
  - RegularIntervalSchedule.timeStep = 0
  - RegularIntervalSchedule.endTime = 00:00:00

A RegularTimePoint is associated with the RegulationSchedule with the following attributes:

- RegularTimePoint.sequenceNumber = 1
- RegularTimePoint.value1 = 402.8
- RegularTimePoint.value2 = not defined

The Analog must be associated with the SynchronousMachine Terminal to indicate the location at which the voltage is regulated. It must also be a MemberOf_PSR of the SynchronousMachine.

Detailed analysis of the IEEE 14-node network:

Node	SlackNode	VOLTSP
FNOD0111	2	402.8 kV
FNOD0311	2	383.8 kV
FNOD0621	2	235.4 kV
FNOD0871	2	29.43 kV

2.6.5. Slack type node

If SLNOD = 3, the node is a slack type node.

The CPSM profile Appendix A page 40 specifies that the concept of a slack node does not exist (« The traditional concept of a System Swing Generator identifier is not required for the initial implementation related to State Estimation nor is a mechanism currently available in the standard CIM to designate it. »). This data will be indicated when the load flow is started, if necessary.

The following option is selected:

For the voltage part, the procedure is the same as for a PV node.

For the angle part, a second Analog will be created:

Analog2 of type MeasurementType (Angle) and with Unit (Degree). The attribute is:

Analog.normalValue = TETASP (TETASP is not described in the UCTE file. It is used to keep the Eurostag name, and in this case we will use TETASP = 0. This second Analog is used to keep the summary node information)

The Analog2 is associated with the same Terminal as the voltage regulation Analog.

It is a MemberOf_PSR of the BusbarSection corresponding to the UCTE slack node.

2.6.5.1. Data analysis:

```
FNOD0211                0 3  397.1     434     254    -800    -848●
```

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
F	N	O	D	0	2	1	1	b													b	0	b	3	b	

28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
3	9	7	.	1	b					4	3	4	b					2	5	4	b			

53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
-	8	0	0	b				-	8	4	8	b	●[2]							b				

Analysis of 14-node IEEE data

Node	SlackNode	Processing
FNOD0211	3	VOLTSP = 397.1 TETASP = 0

[2] end of record

2.7. Example of Line data

```
##L
FNOD0111 FNOD0211 1 0 1.3993 4.2721 731.3018   9999
FNOD0111 FNOD0511 1 0 3.9010 16.104 681.4404   9999
FNOD0511 FNOD0512 1 2 0.0000 0.0000 0.000000   9999
```

NODE 1									NODE 2									OrderCode		Status	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
F	N	O	D	0	1	1	1		F	N	O	D	0	2	1	1		1		0	

Resistance R					
23	24	25	26	27	28
1	.	3	9	9	3

	Reactance X							Susceptance B									Current Limit						
29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
	4	.	2	7	2	1		7	3	1	.	3	0	1	8				9	9	9	9	●

Element Name[3]									
53	54	55	56	57	58	59	60	61	62

The order of nodes describing a line is unimportant, nor is the order of lines in the file. As we will see later, the order of nodes for transformers is not indifferent because the tap changer (when there is one) is assumed to be on the same side as node 2.

[3] optional

2.8. Coupling (BUSBAR COUPLER)

These are lines in the ##L block for which the *Status* is equal to 2 or 7.

A coupling becomes an LoadBreakSwitch (it is different from the Disconnector in that it allows to specify a current limit, and this data is available in UCTE).

A LoadBreakSwitch inherits from PowerSystemResource/Equipment/ConductingEquipment/Switch.

Specify:

its state in normalOpen (open (true) if *Status* = 7, closed (false) if *Status* = 2)

its current limit in ampRating = *Current limit I (A)*

Create two Terminals to connect to the two ConnectivityNodes.

The LoadBreakSwitch must be associated with the EquipmentContainer VoltageLevel of ConnectivityNodes (in principle, it must be the same).

2.8.1. Data analysis

```
FNOD0511 FNOD0512 1 2 0.0000 0.0000 0.000000   9999
```

with NormalOpen = false (because Status = 2), ampRating = 9999 A.

The LoadBreakSwitch `FNOD0511-FNOD0512-1` will actually be associated with VoltageLevel `FNOD0511`

2.9. Lines (LINE)

These are lines in block ##L with a *Status* equal to 0, 1, 8 or 9.

A UCTE line leads to creation of

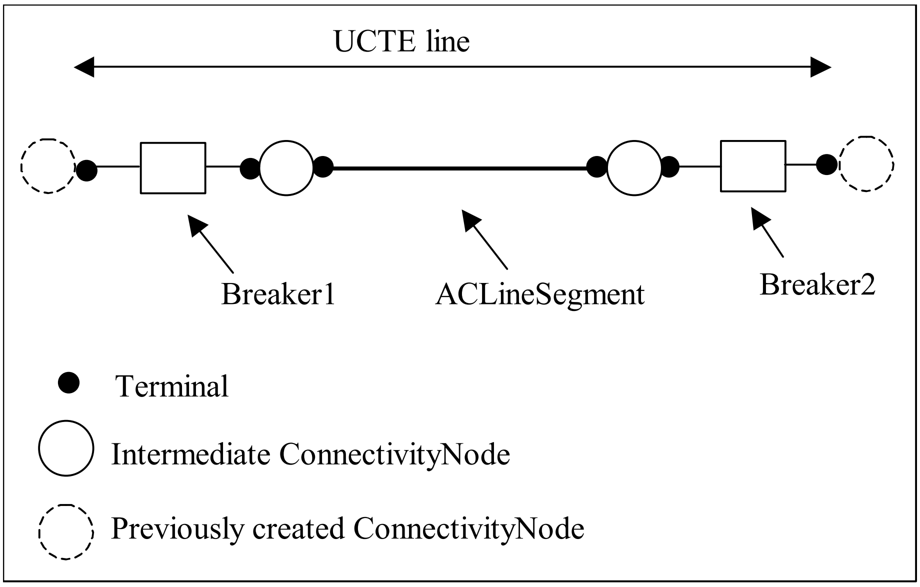
- an ACLineSegment surrounded by two Breakers
- a line aggregating the ACLineSegment
- an Analog to store the maximum allowable transit

Create an ACLineSegment.

ACLineSegment inherits from PowerSystemResource/Equipment/ConductingEquipment/Conductor.

Create 2 Terminals to connect to ConnectivityNodes.

The UCTE *Status* attribute leads to creation of two Breakers with intermediate ConnectivityNodes and Terminals



Define the attributes of ACLineSegment:

ACLineSegment.r = *Resistance R (Ω)*

ACLineSegment.x = *Reactance X (Ω)*

ACLineSegment.bch = 10^{-6} * *Susceptance B (μS)* (bch is in Siemens)

Starting from CPSM3, Line becomes an EquipmentContainer. But CPSM3 considerably reduces this role, because Line can only contain ACLineSegments, and moreover **only one** ACLineSegment.

Therefore,

create a Line,
create the MemberOf_EquipmentContainer association of ACLineSegment to the Line
create the association of the Line with the SubGeographicalRegion of Node 1

The ACLineSegment does not have an ampRating attribute that would have been capable of storing the *Current limit I* value *(A)*. An Analog will be used with an AnalogLimitSet and an AnalogLimit.

Therefore, an Analog will be created for which the MeasurementType is LineCurrent and the Unit is Amperes.

The Analog is MemberOf_PSR of ACLineSegment.

Note: In the CIM model, there is no Measurement association between ACLineSegment and Analog, unlike the case for RegulatingCondEqs.

An AnalogLimitSet is then associated with the Analog (set the LimitSet.isPercentageLimits to the value false).

An AnalogLimit is finally associated with the AnalogLimitSet. The name of the AnalogLimit is imposed by CPSM: it should be « Normal ». AnalogLimit.value is equal to the value of the UCTE *Current Limit I (A)* field:

IdentifiedObject.name = Normal
AnalogLimit.value = *Current Limit I (A)*

If *Current Limit I (A)* is not defined, there is no need for this treatment.

Define the attributes of the two Breakers:

Status	Breaker1.normalOpen	Breaker2.normalOpen
0 or 1	closed (false)	closed (false)
8 or 9	open (true)	open (true)

Finally, instantiate the association of ACLineSegment with BaseVoltage (value of voltage = Voltage(C7) of one of the adjacent nodes).

2.9.1. Data analysis:

```
FNOD1321 FNOD1421 1 0 4.1365  8.422 0.000000   9999
FNOD1221 FNOD1421 1 8 3.7496  4.228 0.000000   9999
```

NODE 1									NODE 2									Order Code		Status	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
F	N	O	D	1	3	2	1		F	N	O	D	1	4	2	1		1		8	

Resistance R					
23	24	25	26	27	28
3	.	7	4	9	6

	Reactance X							Susceptance B									Current Limit I						
29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
		4	.	2	2	8		0	.	0	0	0	0	0	0				9	9	9	9	●

Element Name[4]									
53	54	55	56	57	58	59	60	61	62

ACLineSegment.r = *3.7496* (Ω)

ACLineSegment.x = *4.228* (Ω)

ACLineSegment.bch = 0(μS)

2 Breakers created associated with nodes FNOD1321 and FNOD1421.

```
FNOD1321                0 0            270      116       0       0
FNOD1421                0 0            298      100       0       0
```

Since C7 is equal to 2 in both cases, the BaseVoltage is 220 kV.

[4] optional

2.10. Transformers

The UCTE file only contains transformers with two windings.

The transformers are described in the ##T block.

When the tap changers exist, they are necessarily described in the ##R block. By convention the tap changer is put on winding 2 (which is connected to node *Node 2*).

Some tap changers may be described in more detail, tap by tap, in the optional block ##TT.

In unusual cases, the two tap change modes are described in the ##R block. In this case, two TapChangers are created on winding 2. This is possible, depending on the cardinal numbers of the relation in CIM. But the load flows undoubtedly use only one of the two tap changers (CPSM3 only accepts one).

The transformers with two windings requires the creation of:

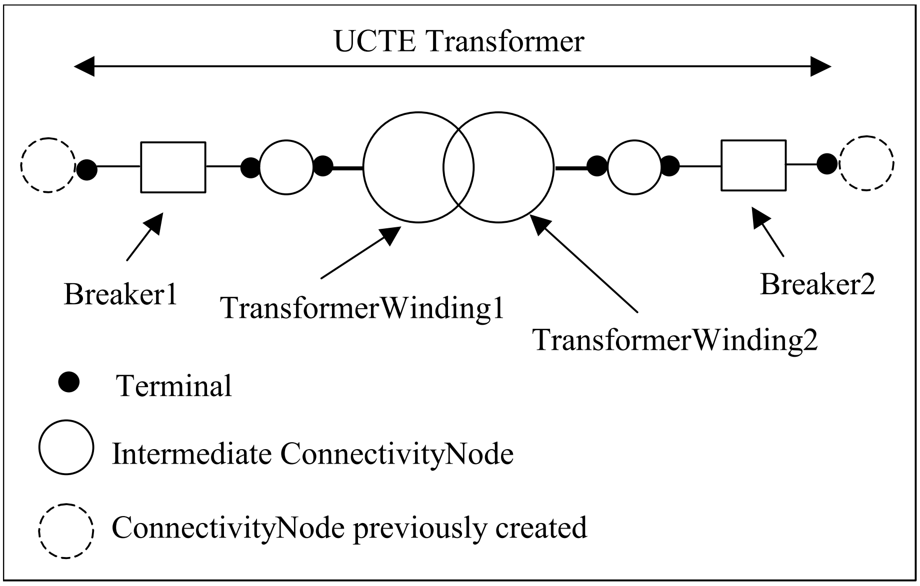
- a PowerTransformer (inheriting from PowerSystemResource/Equipment)
- two TransformerWindings (inheriting from PowerSystemResource/Equipment/ConductingEquipment) and aggregated in the PowerTransformer
- possibly a TapChanger (inheriting from PowerSystemResource) and aggregated in the corresponding TransformerWinding (very rarely 2)

Each TransformerWinding has 1 Terminal connected to the corresponding ConnectivityNode.

The PowerTransformer must be associated with the EquipmentContainer Substation of the ConnectivityNodes (in principle, it must be the same).

Instantiate the association of each TransformerWinding with the corresponding BaseVoltage (value of voltage = Voltage(C7) of the node to which it is connected).

The same processing needs to be done as in the case of lines for Breakers.



Impedances and admittances are shared between the two windings (they are divided by 2).

Let U_{1N} (C23-C27) = *Rated voltage 1 (kV)*

U_{2N} (C29-C33) = *Rated voltage 2 (kV)*

RATE (C35-C39) = *Nominal power(MVA)*

For the other attributes R (C41-C46), X (C48-C53), B (C55-C62), G (C64-C69) and I (C71-C76), the notation in the UCTE file is used.

If the I (*Current limit*) and *Nominal power* attributes are both defined, then I is ignored.

If *Nominal power* is not defined, then it is calculated from I:

$$\text{NominalPower} = \sqrt{3}\ U_{1N}\ I / 1000$$

2.10.1.1. Data analysis:

```
##T
FNOD0411 FNOD0711 1 0 380.0 380.0       0.0000 15.098 0.000000 0.0000   9999
FNOD0411 FNOD0921 1 0 380.0 220.0       0.0000 40.156 0.000000 0.0000   9999
FNOD0511 FNOD0621 1 0 380.0 220.0       0.0000 18.195 0.000000 0.0000   9999
FNOD0711 FNOD0871 1 0 380.0 27.00       0.0000 12.718 0.000000 0.0000   9999
FNOD0711 FNOD0921 1 0 380.0 220.0       0.0000 7.9425 0.000000 0.0000   9999
FNOD0411 FNOD0211 1 0 380.0 380.0       4.1956 12.730 470.9140 0.0000   9999
```

NODE1									NODE2									OperCode		Status	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
F	N	O	D	0	4	1	1	b	F	N	O	D	0	7	1	1		1		0	

Rated Voltage 1				
23	24	25	26	27
3	8	0	.	0

	Rated Voltage 2						Nominal Power NP						Resistance R						
28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
	3	8	0	.	0								0	.	0	0	0	0	

Reactance X					
48	49	50	51	52	53
1	5	.	0	9	8

	Susceptance B									Conductance G							Current Limit I						
54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
	0	.	0	0	0	0	0	0		0	.	0	0	0	0				9	9	9	9	●

Element Name[5]											
78	79	80	81	82	83	84	85	86	87	88	89
			b								b

[5] optional

2.10.2. PowerTransformer data:

<u>In PowerTransformer</u>:

If the transformer is not present in ##R

transformerType = fix

If the transformer is present in ##R, the table gives the value to be assigned to transformerType:

		« Phase regulation » zone defined (C21-C38)	
		No	**yes**
«Angle / quadrature regulation» zone defined (C40-C63)	**no**	fix	voltageControl
	yes	phaseControl	voltageAndPhaseControl

2.10.2.1.Data analysis:

```
##R
FNOD0411 FNOD0711 1 2.200  1  -1
FNOD0411 FNOD0921 1 3.100  1  -1
FNOD0511 FNOD0621 1 6.800  1  -1
FNOD0711 FNOD0871 1
FNOD0711 FNOD0921 1
FNOD0411 FNOD0211 1                    1.32 90.00  9   5
```

All transformers are present.

In the example 1 below: the angle/ quadrature regulation field is not defined, and the phase-regulation field is defined => voltageControl

In the second example below, the angle/ quadrature regulation field is defined, and the phase-regulation field is not defined => phaseControl

Node 1									Node 2									Order code		Var U%					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
F	N	O	D	0	4	1	1	b	F	N	O	D	0	7	1	1		1		2	.	2	0	0	
F	N	O	D	0	4	1	1	b	F	N	O	D	0	2	1	1		1							

N			N’				U [6]						Var U %						TETA					
27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
1			-	1	●																			
														1	.	3	2		9	0	.	0	0	

N			N’				P [7]				
52	53	54	55	56	57	58	59	60	61	62	63
	9		5								

The detailed analysis of the data shows that:

Data of #R

			Phase regulation			Angle/quadrature regulation					REG Type
N1	**N2**	**OC**	**ΔU**	**N**	**N’ U**	**ΔU**	**Teta**	**N**	**N’**	**P**	
FNOD0411	FNOD0711	1	2.200	1	-1						voltageControl
FNOD0411	FNOD0921	1	3.100	1	-1						voltageControl
FNOD0511	FNOD0621	1	6.800	1	-1						voltageControl
FNOD0711	FNOD0871	1									fix
FNOD0711	FNOD0921	1									fix
FNOD0411	FNOD0211	1				1.32	90.00	9	5		phaseControl

2.10.3.TransformerWindings data

In TransformerWinding 1:

$$r = \frac{R}{2}$$

$$x = \frac{X}{2}$$

$$g = 10^{-6} * \frac{G}{2}$$

$$b = 10^{-6} * \frac{B}{2}$$ (B is negative in UCTE files)

$$\text{ratedKV} = U_{1N}$$

[6] optional

[7] optional

$$\text{ratedMVA} = \text{RATE}$$

windingType = « primary »

(note: g does not appear in CPSM)

In TransformerWinding 2:

$$r = \frac{R}{2} * \frac{U_{2N}{}^2}{U_{1N}{}^2}$$

$$x = \frac{X}{2} * \frac{U_{2N}{}^2}{U_{1N}{}^2}$$

$$g = 10^{-6} * \frac{G}{2} * \frac{U_{1N}{}^2}{U_{2N}{}^2}$$

$$b = 10^{-6} * \frac{B}{2} * \frac{U_{1N}{}^2}{U_{2N}{}^2}$$

$$\text{ratedKV} = U_{2N}$$

$$\text{ratedMVA} = \text{RATE}$$

windingType = « secondary »

(note: g does not appear in CPSM)

2.10.3.1.Data analysis

```
##T
FNOD0411 FNOD0711 1 0 380.0 380.0       0.0000 15.098 0.000000 0.0000   9999

##R
FNOD0411 FNOD0711 1 2.200  1  -1
```

TransformerWinding 1:

$$r = \frac{R}{2} = 0$$

$$x = \frac{X}{2} = 15.098/2$$

$$g = 10^{-6} * \frac{G}{2} = 0$$

$$b = 10^{-6} * \frac{B}{2} = 0$$

U_{1N} (C23-C27) = *380 (kV)*

U_{2N} (C29-C33) = *380 (kV)*

$\text{RATE (C34-C39)} = \sqrt{3}\, U_{1N}\, I/1000 = 6581\ \text{MVA}$

$$\text{ratedKV} = U_{1N} = 380\ \text{kV}$$

$$\text{ratedMVA} = \text{RATE} = 6581\ \text{MVA}$$

windingType = « primary »

TransformerWinding 2:

$$r = \frac{R}{2} * \frac{U_{2N}{}^2}{U_{1N}{}^2} = 0$$

$$x = \frac{X}{2} * \frac{U_{2N}{}^2}{U_{1N}{}^2} = 7.549$$

$$g = 10^{-6} * \frac{G}{2} * \frac{U_{1N}{}^2}{U_{2N}{}^2} = 0$$

$$b = 10^{-6} * \frac{B}{2} * \frac{U_{1N}{}^2}{U_{2N}{}^2} = 0$$

$$\text{ratedKV} = U_{2N} = 380\ \text{kV}$$

$$\text{ratedMVA} = \text{RATE} = 6581\ \text{MVA}$$

windingType = « secondary »

2.10.4.TapChanger data

If the transformer is described in ##R, a TapChanger has to be created on the TransformerWinding 2. In the unusual case in which the two regulations are described, two TapChangers are created (a simplifying option would consist of only processing one of the two regulations, for example the first one. According to the CNES, the two regulations should not occur at the same time).

Number of taps:

Four taps are necessary, namely minimum, maximum, nominal and initial

minimum:	in the UCTE file, this is tap – n
maximum:	in the UCTE file, this is tap + n
nominal:	in the UCTE file, this is tap 0
initial:	in the UCTE file, this is tap n'

Taps in the UCTE file are numbered symmetrically around 0. In the CIM, it must start at 1. Therefore, the numbers in the -n, +n interval must be translated to the 1, 2n+1 interval. Therefore, the numbers are translated by n + 1.

Therefore we have highStep = 2n + 1

lowStep = 1

neutralStep = n + 1

normalStep = n' + n + 1

Tap data

neutralKV = ratedKV of TransformerWinding2

2.10.4.1.Data analysis:

There is only one TapChanger, because only one of the two regulations exists each time.

Transformer data:

NODE1									NODE2									OperCode		Status	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
F	N	O	D	0	4	1	1	b	F	N	O	D	0	7	1	1		1		0	

Rated Voltage 1				
23	24	25	26	27
3	8	0	.	0

	Rated Voltage 2						Nominal Power						Resistance R						
28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
	3	8	0	.	0								0	.	0	0	0	0	

Reactance X					
48	49	50	51	52	53
1	5	.	0	9	8

	Susceptance B								Conductance G							Current Limit I					
54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
	0	.	0	0	0	0	0	0		0	.	0	0	0	0				9	9	9	9	●

Element Name[8]											
78	79	80	81	82	83	84	85	86	87	88	89
			b								b

neutralKV = ratedKV = 380 kV.

Regulation data:

Node 1									Node 2									Order code		Var U % voltage change per tap					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
F	N	O	D	0	4	1	1	b	F	N	O	D	0	7	1	1		1		2	.	2	0	0	

N number of tap			N' used tap				U [9] voltage reference value						Var U % voltage change per tap						TETA phase regulation displacement					
27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
1			-	1	●																			

N			N'				P [10] load flow reference value				
52	53	54	55	56	57	58	59	60	61	62	63

Therefore we have: highStep = 2n + 1 = 3

lowStep = 1

neutralStep = n + 1 = 2

normalStep = n' + n + 1 = 1

[8] optional

[9] optional

[10] optional

2.10.4.2.« Phase regulation » case

$\text{stepVoltageIncrement} = \Delta U\ (kV)$ (C21-C25)

stepPhaseShiftIncrement = 0

tculControlMode = Volt

Setpoint:

If *U (kV)* is defined:

A voltage regulation is created to indicate the voltage setpoint as indicated in the « Preliminaries» chapter:

- The equipment is the TapChanger.
- The setpoint is *U (kV)*
- The Analog is associated with the Terminal of TransformerWinding 2 and is MemberOf_PSR of the TapChanger.

2.10.4.2.1.Data analysis

```
##T
FNOD0411 FNOD0711 1 0 380.0 380.0       0.0000 15.098 0.000000 0.0000   9999

##R
FNOD0411 FNOD0711 1 2.200  1  -1
```

$\text{stepVoltageIncrement} = \Delta U\ (kV)$ = 2.2 kV, U is not defined and therefore no setpoint is created.

Node 1									Node 2									Order code		Var U % voltage change per tap					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
F	N	O	D	0	4	1	1	b	F	N	O	D	0	7	1	1		1		2	.	2	0	0	

N number of tap			N' used tap				U[11] voltage reference value						Var U % voltage change per tap						TETA phase regulation displacement					
27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51

[11] optional

1			-	1	●																			

N			N’				P[12] load flow reference value				
52	53	54	55	56	57	58	59	60	61	62	63

Analysis of 14-node IEEE data:

Data of #T

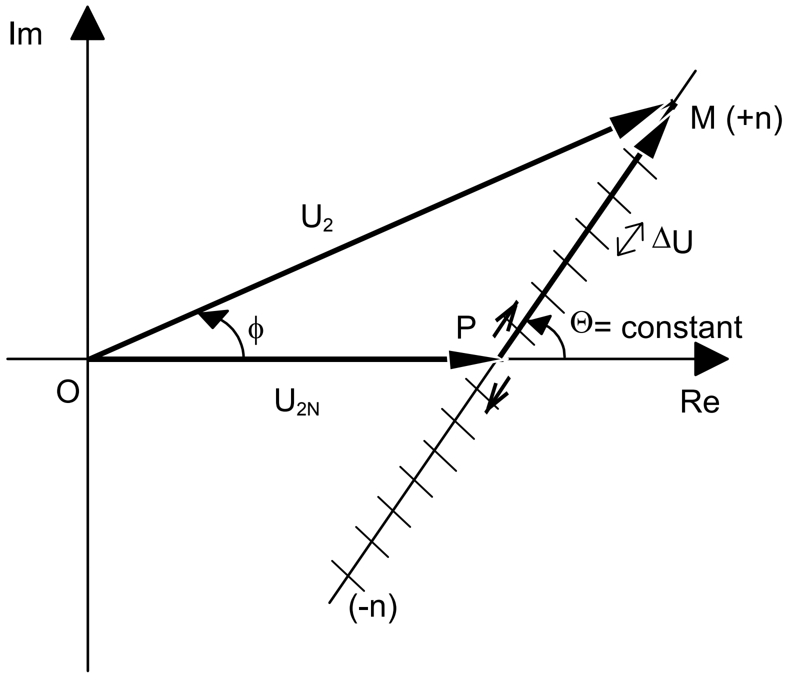
N1	N2	OC	S	RV1	RV2	NP	R	X	B	G	I
FNOD0711	FNOD0871	1	0	380.0	27.00		0.0000	12.718	0.000000	0.0000	9999
FNOD0711	FNOD0921	1	0	380.0	220.0		0.0000	7.9425	0.000000	0.0000	9999
FNOD0411	FNOD0211	1	0	380.0	380.0		4.1956	12.730	470.9140	0.0000	9999

Data of #R

			Phase regulation				Angle/quadrature regulation					REG Type
N1	N2	OC	ΔU	N	N’	U	ΔU	Teta	N	N’	P	
FNOD0411	FNOD0711	1	2.200	1	-1							voltageControl
FNOD0411	FNOD0921	1	3.100	1	-1							voltageControl
FNOD0511	FNOD0621	1	6.800	1	-1							voltageControl

12 optional

2.10.4.3.« Angle / Quadrature regulation » case



On the last tap:

$$\mathrm{Re}(\mathrm{U}_2) = \mathrm{U}_{2\mathrm{N}}\left(1 + \mathrm{n}\frac{\Delta\mathrm{U}}{100}\cos\Theta\right)$$

$$\mathrm{Im}(\mathrm{U}_2) = \mathrm{U}_{2\mathrm{N}}\ \mathrm{n}\frac{\Delta\mathrm{U}}{100}\sin\Theta$$

The phase shift introduced by the tap changer on the last tap is $\phi = arctg\,\frac{IM(U_2)}{RE(U_2)}$

The average phase shift per tap is $\frac{\phi}{n}$, namely

$$\text{stepPhaseShiftIncrement} = arctg\,\frac{\frac{\Delta\mathrm{U}}{100}\sin\Theta}{1 + \mathrm{n}\frac{\Delta\mathrm{U}}{100}\cos\Theta}$$ to be expressed in degrees

The modulus of U_2 is $\sqrt{(\mathrm{Re}(\mathrm{U}_2))^2 + (\mathrm{Im}(\mathrm{U}_2))^2}$

The average voltage increment per tap in % of U_{2N} is $\frac{|U_2|-|U_{2N}|}{|U_{2N}|}*\frac{100}{n}$, namely:

$$\text{stepVoltageIncrement} = \frac{100}{n}\left(\sqrt{1+\left(n\frac{\Delta U}{100}\right)^2 + 2n\frac{\Delta U}{100}\cos\Theta} - 1\right)$$

tculControlMode = MW

The average value put into stepvoltageIncrement is approximate, because in fact this value is not constant. In particular, depending on the values of Θ and ΔU, the increment may firstly rise and then fall, or vice versa. In this case, the stepvoltageIncrement is not very meaningful. Therefore, a warning message will be printed when:

$$n\,\Delta U > U_{2N}\cos\Theta$$

Setpoint:

If *P (MW)* (C59-C63) is defined:

An active transit regulation will be created on the same model as the voltage regulation described in the « Preliminaries » chapter:

- The equipment is the TapChanger.
- The set value is *P (MW)*
- The Analog is associated with the TransformerWinding Terminal 2. and MemberOf_PSR of the TapChanger.

The differences are as follows:

- the Analog is associated with the MeasurementType ThreePhaseActivePower and the Unit MW,
- the Analog.positiveFlowIn attribute = true

2.10.4.3.1.Data analysis

```
##T
FNOD0411 FNOD0211 1 0 380.0 380.0       4.1956 12.730 470.9140 0.0000   9999


##R
FNOD0411 FNOD0211 1                     1.32 90.00  9   5
```

P is not defined, therefore no active transit regulation is created.

Node 1									Node 2									Order code		Var U % voltage change per tap						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
F	N	O	D	0	4	1	1	b	F	N	O	D	0	2	1	1		1							

N number of taps			N' used tap				U [13] Voltage Reference value						Var U % voltage change per tap						TETA phase regulation displacement					
27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
														1	.	3	2		9	0	.	0	0	

N number of taps			N' used tap				P [14] load flow ref value				
52	53	54	55	56	57	58	59	60	61	62	63
	9		5								

Analysis of IEEE 14-node data

Data in #T

N1	**N2**	**OC**	**S**	**RV1**	**RV2**	**NP**	**R**	**X**	**B**	**G**	**I**
FNOD0711	FNOD0871	1	0	380.0	27.00		0.0000	12.718	0.000000	0.0000	9999
FNOD0711	FNOD0921	1	0	380.0	220.0		0.0000	7.9425	0.000000	0.0000	9999
FNOD0411	FNOD0211	1	0	380.0	380.0		4.1956	12.730	470.9140	0.0000	9999

Data in #R

			Phase regulation				**Angle/quadrature regulation**					**REG type**
N1	**N2**	**OC**	**ΔU**	**N**	**N'**	**U**	**ΔU**	**Teta**	**N**	**N'**	**P**	
FNOD0711	FNOD0871	1										fix
FNOD0711	FNOD0921	1										fix
FNOD0411	FNOD0211	1					1.32	90.00	9	5		phaseControl

2.10.4.4. Improvement of the data accuracy

If the transformer is in the ##TT block, more precise data are available for each tap. But the CIM does not have this detail level. Therefore, this block will not be used (in any case it is rarely defined).

The analyzed files do not have a record of this type.

[13] optional

[14] optional

2.11. Exchanges (EXCHANGE POWERS)

This ##E block is optional and is not used for a load flow calculation. It indicates programmed active power exchanges between zones.

Such information does not appear in the CPSM profile.

3. Returning from CIM to UCTE

The UCTE file has to be built with its ##N blocks (NODES), ##L blocks (LINES), ##T blocks (2 WINDING TRANSFORMERS), ##R blocks (2 WINDING TRANSFORMER REGULATIONS).

Nodes in the ##N block are sorted by zone. Each zone is introduced by ##Zxx, where xx is the zone name.

A comment block will be introduced at the beginning of the file by ##C, followed by the date in the form dd/mm/yyyy; followed by a line: file in the UCTE format generated by the CIM-UCTE converter. For example:

> ##C 30/05/2006
> FILE IN THE UCTE FORMAT GENERATED BY THE CIM-UCTE CONVERTER

3.1. Naming of objects

No more objects than there were originally are created in the CIM to UCTE direction. Therefore, names of CIM objects can be reused. The difficulty is due to the fact that CIM names can be longer than UCTE names (node names are limited to 8 characters, and zone names to 2 characters) and the names of UCTE nodes must respect some conventions.

Node names in the UCTE format are limited to 8 characters:

- charact 1: country code
- charact 2 to 6: free name (for example substation name)
- charact 7: voltage level
- charact 8: differentiation character (0, .., 9, A, .., Z)

If the CIM file to be transformed was built from a UCTE file by the UCTE → CIM converter, the names of nodes respecting this rule are automatically recovered when returning to a UCTE file.

Therefore, do the following processing.

Starting from the node name deduced from the CIM:

- truncate to 8 characters
- overwrite the first character with the « country code node »
- overwrite the 7th character with « voltage level »
- if the name already exists, modify the 8th character, taking it from the list (0, .., 9, A, .., Z), to obtain a name that has not yet been used.
- If all names have already been used, attempt to change the 6th character in the same way, then possibly the 5th, etc., down to the 2nd.

<u>How to determine the VoltageLevel?</u>

ConnectivityNode → VoltageLevel → BaseVoltage.baseVoltage path is used to determine the voltage (denoted bV below) of one of the ConnectivityNode forming the UCTE node.

baseVoltage ConnectivityNode Cim (kV)	voltage level UCTE node
bV <= 45	7
45 < bV <= 85	6
85 < bV <= 115	5
115 < bV <= 135	4
135 < bV <= 180	3
180 < bV <= 270	2
270 < bV <= 350	8
350 < bV <= 500	1
500 < bV	0

This is derived from the table on page 3 of the document on the UCTE-DEF format.

<u>How to determine the « country code nodes »?</u>

Let us denote the first two characters of the name of the GeographicalRegion of the ConnectivityNode, as GRN.

Use the table on page 4 of the document on the UCTE-DEF format.

GRN should be searched for in the « country code ISO » column. For example if GRN = « AT », the nodes country code is « O ».

If GRN is blank, the nodes country code is « X ».

If GRN is not found in the ISO country code column, then the nodes Country code will be the first character of GRN.

Note: If the CIM file to be transformed was built from a UCTE file using the UCTE → CIM converter, the proposed method should be sufficient to find the original names.

The field names are truncated to 2 characters, avoiding duplicates.

<u>UCTE nodes - CIM ConnectivityNodes correspondence file</u>

Since names are shortened and modified, the correspondence between UCTE names and CIM names has to be found. An associated file can contain an indication of the ConnectivityNode name from which each UCTE node was created (name and unique identifier of ConnectivityNodes)

3.2. Topology - creation of UCTE nodes

The purpose is to convert from the detailed topology of the CPSM profile to the nodal topology of the UCTE format.

Firstly, breakers directly adjacent to branches (ACLineSegment, PowerTransformer (+TransformerWindings) and SeriesCompensator) are integrated into these branches. A breaker is directly adjacent to a branch if it and nothing else is connected to the ConnectivityNode at the end of the branch (Connectors, in other words Junctions and BusbarSections, should not be included in the search for elements connected to the ConnectivityNode). Breaking devices may be Breakers, Disconnectors or LoadBreakSwitches (they will be called Switches in the remainder of this description).

Integrating devices into the branch means that the devices disappear and that all that is kept is the open/closed information that is transferred into the Status attribute for the branch (if at least one of the two devices is open, then the branch is « out of operation », namely Status = 8, otherwise it is « in operation », namely Status = 0). If one end has no adjacent device, then the procedure adopted is the same as if it were a closed device.

Secondly, the remaining ConnectivityNodes connected to each other only through closed Switches are brought together. Each group (ConnectivityNodes + Switches) forms a node in the UCTE file. The UCTE node is named by using the name of a grouped ConnectivityNode, choosing it as follows:

- first criterion: the ConnectivityNode is associated with a BusbarSection
- second criterion: use the ConnectivityNode with the shortest name that satisfies with the first criterion
- if no ConnectvityNode satisfies the first criterion, use the ConnectivityNode with the shortest name

The correspondence file previously mentioned mentions, for each node that is finally kept, which ConnectivityNodes have already been grouped with it.

List of nodes

The list of UCTE nodes in the ##N block will be created during the study of the topology.

They have to be sorted by zone. Zones are the SubGeographicalRegions of the CIM. Each zone is introduced by ##Zxx. xx is built up from IdentifiedObject.name of the SubGeographicalRegion.

The fields are initialized as follows:

Node (code): as mentioned above

Node (geographical name): take IdentifiedObject.aliasName of the ConnectivityNode if it is defined, otherwise, use IdentifiedObject.name of the corresponding BusbarSection, if there is one.

Status: 0

Slack Node: initialize to 0. This field will be modified later for PV and slack nodes.

Voltage: defined later

Active load, Reactive load, Active power generation, Reactive power generation: initialize to 0. These fields are incremented as the processing is carried out.

Minimum permissible generation (MW), Maximum permissible generation (MW), Minimum permissible generation (MVar), Maximum permissible generation (MVar): ditto

Other fields: do not define them

3.3. ACLineSegment

Create a LINE.

Node1, Node2: derived from the topology study

Order code: used to distinguish lines in parallel. Put 1. If a line already exists with 1, put 2, etc. Possible values are 1..9, A…Z

Status: derived from the topology study (0 or 8)

Resistance R (Ω) = ACLineSegment.r

Reactance X (Ω) = ACLineSegment.x

Susceptance B (μS) = 10^6 ACLineSegment.bch

Current limit I:

- Search for a LineCurrent or ThreePhasePower type Analog associated with ACLineSegment.
- Search for AnalogLimitSet associated with Analog.
- Search among AnalogLimits associated with the AnalogLimitSet for the one with the name « Normal ».

If nothing is found during this search, then stop and do not define *Current limit*.

In UCTE, *Current limit* is equal to Amperes. If the Analog type is LineCurrent, the correspondence is direct, namely K=1. If the Analog type is ThreePhasePower, then convert from MVAs to Amperes. A search must be made for BaseVoltage.nominalVoltage using ACLineSegment to BaseVoltage link, then calculate $\mathrm{K} = \frac{1000}{\sqrt{3}\,\mathrm{nominalVoltage}}$

Finally, set *Current limit* = K * AnalogLimit.value

3.4. ShuntCompensator

The *Reactive load* field of the UCTE node in which this ShuntCompensator is connected will be modified.

Search for nominalVoltage with the ConnectivityNode->VoltageLevel->BaseVoltage link

Calculate $\Delta \mathrm{ReacLoad} = -\mathrm{normalSections} * \mathrm{mVArPerSection} * \frac{\mathrm{nominalVoltage}^2}{\mathrm{nominalkV}^2}$

Modify *Reactive Load*:

Reactive Load = *Reactive Load* + ∆ReacLoad

3.5. SeriesCompensator

It becomes a LINE in the UCTE file.

The same method is used as for an ACLineSegment.

Resistance R and *Reactance X* are calculated from r and x.

Susceptance B is set to 0.

The maximum transit is calculated in the same way from an Analog if there is one.

3.6. EnergyConsumer

Same principle as for a ShuntCompensator, in other words two fields (*Active Load* and *Reactive Load*) of the UCTE node are modified.

Active Load = *Active Load* + pfixed

Reactive Load = *Reactive Load* + qfixed

3.7. StaticVarCompensator

This relates to equipment that can vary the injected reactive power continuously as a function of a voltage setpoint. It might behave like an inductance or like a capacitor, depending on needs.

There is no equivalent in the UCTE format. But its capacities to produce or consume reactive power can be taken into account in node fields related to reactive power production limits.

Two fields of the UCTE node *Node*: *Minimum permissible generation (Mvar)* denoted QMIN and *Maximum permissible generation (Mvar*) denoted QMAX are modified.

QMIN = QMIN + inductiveRating

QMAX = QMAX - capacitiveRating

If a voltage regulation is present, it will be used to fix the *Voltage* field of a node

- Search for a RegulationSchedule associated with the StaticVarCompensator.
- Search for the associated RegularTimePoint: the value1 attribute gives the value of *Voltage*
- Search for a LineToLineVoltage type Analog associated with StaticVarCompensator.

- This Analog must be associated with a Terminal itself associated with a ConnectivityNode: if the UCTE node (denoted ND) that contains this ConnectivityNode is node *Node*, then the *Voltage* field of node *Node* is modified by setting the value RegularTimePoint.value1.

If nothing is found during this search, or if ND ≠ *Node*, the procedure stops and *Voltage* is not defined (print a message: StaticVarCompensator xxxxxx: no voltage setpoint.)

3.8. GeneratingUnits and SynchronousMachines

GeneratingUnit is used to draw the active production (initialMW); the reactive production (baseMVAr) and/or reactive production limits (minimumMVAr and maximumMVAr) are drawn from SynchronousMachine.

It is possible that an MVArCapacityCurve is associated with the SynchronousMachine. In this case, this is the diagram that gives reactive production limits as a function of the active production. Since the corresponding active production is not known (because there may be several SynchronousMachines for one GeneratingUnit), we will use:

- for minimumMVAr: the value of CurveShedData.y1value, for the largest value xvalue
- for maximumMVAr: the value of CurveShedData.y2value for the largest value xvalue

```
if baseMVAr is not defined
        if maximumMVAr = minimumMVAr
                do baseMVAr = minimumMVAr
        else
                do baseMVAr = 0
```

Two fields of the UCTE node *Node*: *Active power generation (MW)* denoted PG and *Reactive power generation (Mvar)* denoted QG are modified.

PG = PG - initialMW

QG = QG - baseMVAr

Two fields of the UCTE node *Node*: *Minimum permissible generation (Mvar)* denoted QMIN and *Maximum permissible generation (Mvar)* denoted QMAX are modified

QMIN = QMIN - minimumMVAr

QMAX = QMAX - maximumMVAr

Two fields of the UCTE node *Node*: *Minimum permissible generation (MW)* denoted PMIN and *Maximum permissible generation (MW)* denoted PMAX are modified using GeneratingUnit attributes that are not necessarily defined.

If minimumOperatingMW is defined

PMIN = PMIN - minimumOperatingMW

else nothing.

If maximumOperatingMW is defined

PMAX = PMAX - maximumOperatingMW

else, if ratedNetMaxMW is defined

PMAX = PMAX - ratedNetMaxMW

else nothing.

If a voltage regulation is present, it will be used to set the *Voltage* field of a node:

- Search for a RegulationSchedule associated with SynchronousMachine.
- Search for the associated RegularTimePoint: the attribute value 1 provides the *Voltage* value
- Search for a LineToLineVoltage type Analog associated with the SynchronousMachine.
- This Analog must be associated with a Terminal, itself associated with a ConnectivityNode: if the UCTE node (denoted ND) that contains this ConnectivityNode is node *Node*, then the *Voltage* field of node *Node* will be modified using the value of RegularTimePoint.value1.

If nothing is found during this search, or if ND ≠ *Node*, the procedure is stopped and *Voltage* is not defined (print the message: SynchronousMachine xxxxxx: no voltage setpoint.)

If the *Voltage* field has been defined, the node is PV. Therefore, the *Slack Node* field is set to the value 2. But the value 3 should be used if the node is also slack. It will be noted that the node is slack if an Angle type Analog is connected to the same terminal as the LineToLineVoltage type Analog.

3.9. BusbarSection

They are not used, except in the topology study to determine the name of UCTE nodes.

3.10. Breaker, Disconnector, LoadBreakSwitch

Those which were not eliminated during the topology study become busbar coupler type LINEs, in other words with Status set to 2 or 7 depending on whether the device is closed or open.

Node1, Node2: derived from the topology study

Order code: used to distinguish lines in parallel. Set to 1. If there is already a line equal to 1, use 2, etc. Possible values are 1..9, A…Z

Status: derived from the topology study (2 or 7)

Resistance R, Reactance X, Susceptance B: set 0.0.

Current limit I:

For the LoadBreakSwitch only, do *Current limit* = ampRating if this attribute is defined.

Note: in principle, considering the topology processing, all that need to be generated here are open busbar couplers (Status = 7).

3.11. Transformers

This deals with the PowerTransformer, TransformerWinding and TapChanger assembly.

3.11.1.Considerations about the number of TapChangers.

Cardinalities of associations in the CIM make it possible to have several TapChangers on the same TransformerWinding. If such cases arise, a warning message is printed and a non-regulated transformer will be generated (in other words the procedure will be the same as if there were no TapChanger).

It is also possible to have a TapChanger on each TransformerWinding. This arises frequently in CIM-rdf files from outside. This case is only acceptable if one of the TapChangers is not regulating (TapChanger.tculControlMode = off) and the other is regulating (TapChanger.tculControlMode = volt). In this case, the characteristics of TransformerWinding that has the non-regulating TapChanger are modified, and this case becomes equivalent to the normal case with a single TapChanger.

The following table summarizes the different cases:

Processing to be applied as a function of the layout of TapChangers		TapChanger on TransformerWinding 1			
		0	1 non-regulating	1 regulating	more than 1
TapChanger on Transformer Winding 2	0	normal	normal	normal	message + normal ignoring TapChangers
	1 non-regulating	normal	message + normal ignoring TapChangers	modification Transformer Winding 2 + normal	message + normal ignoring TapChangers
	1 regulating	normal	modification Transformer Winding 1 + normal	message + normal ignoring TapChangers	message + normal ignoring TapChangers
	more than 1	message + normal ignoring TapChangers	message + normal ignoring TapChangers	message + normal ignoring TapChangers	message + normal ignoring TapChangers

3.11.2.General considerations

The PowerTransformer + two TransformerWinding (primary and secondary) + one possible non-regulating TapChanger (when there is also a regulating TapChanger on the other TransformerWinding) produces a « 2 WINDING TRANSFORMER » record in the ##T block of the UCTE file.

The remaining TapChanger produces a record « 2 WINDING TRANSFORMER REGULATION » in the ##R block of the UCTE file.

If there is no TapChanger, nothing will be created in the ##R block.

In the following, winding 1 (or TransformerWinding1) will be the winding for which the winding type is equal to « primary »; winding 2 will be the winding for which the winding type is equal to « secondary ».

3.11.3.Preprocessing in the case of a non-regulating TapChanger and a regulating TapChanger.

The side used is the side of the non-regulating TapChanger (TapChanger.tculControlMode = off).

Attributes of the TapChanger and attributes of the TransformerWinding are used.

The voltage corresponding to the tap used (normalStep) is calculated.

$$\mathrm{Un} = \mathrm{neutralKV} + (\mathrm{normalStep} - \mathrm{neutralStep}) * \mathrm{stepVoltageIncrement} * \frac{\mathrm{ratedKV}}{100}$$

then the new values to be used

$$r_{new} = r * \frac{\mathrm{Un}}{\mathrm{ratedKV}}$$

$$x_{new} = x * \frac{\mathrm{Un}}{\mathrm{ratedKV}}$$

$$g_{new} = g * \frac{\mathrm{ratedKV}}{\mathrm{Un}}$$

$$b_{new} = b * \frac{\mathrm{ratedKV}}{\mathrm{Un}}$$

$$\mathrm{ratedKV}_{new} = \mathrm{Un}$$

This preprocessing provides **values to be used in the following instead of** r_1, x_1, g_1, b_1, $\mathrm{ratedKV}_1$ if the non-regulating TapChanger is side 1, or instead of r_2, x_2, g_2, b_2, $\mathrm{ratedKV}_2$, if the non-regulating TapChanger is side 2.

3.11.4.Fields in the « 2 WINDING TRANSFORMER » record

Node1, Node2: derived from the topology study (*Node1* TransformerWinding1 side, *Node2* TransformerWinding2 side)

Order code: used to distinguish transformers in parallel. Put 1. If there is already a transformer with 1, put 2, etc. Possible values are 1..9, A…Z

Status: derived from the topology study (0 or 8)

Rated voltage 1: ratedKV of winding 1, denoted U_{1N} in the following

Rated voltage 2: ratedKV of winding 2, denoted U_{2N} in the following

Nominal power

The two windings have the same nominal apparent ratedMVA power. If this is not the case, then the lowest of the two will be chosen and will be denoted S_{NTFO}.

We will set:

$$\textit{Nominal power} = S_{NTFO}$$

Resistance R

The resistance and the following attributes X, G and B are calculated at the winding 1 voltage

If the resistances of the two windings are denoted r_1 and r_2, we have:

$$R = r_1 + r_2 \frac{U_{1N}^2}{U_{2N}^2}$$

Reactance X

If the reactances of the two windings are denoted x_1 and x_2 we have:

$$X = x_1 + x_2 \frac{U_{1N}^2}{U_{2N}^2}$$

Conductance G

If the conductances of the two windings are denoted g_1 and g_2, we have:

$$G = 10^6 \left(g_1 + g_2 \frac{U_{2N}^2}{U_{1N}^2} \right)$$

Susceptance B

If the susceptances of the two windings are denoted b_1 and b_2, we have:

$$B = 10^6 \left(b_1 + b_2 \frac{U_{2N}^2}{U_{1N}^2} \right)$$

3.11.5. Fields in the « 2 WINDING TRANSFORMER REGULATION » record

Node 1, *Node 2* and *Order code*: identical to the « 2 WINDING TRANSFORMER » record

If stepPhaseShiftIncrement = 0 or not defined, then the « Phase regulation » of the record part is defined.

If stepPhaseShiftIncrement is not equal to zero, then the « Angle/quadrature regulation » part of the record is defined

In the UCTE file, the regulated winding is always winding 2, in other words the TapChanger in the CIM should be associated with TransformerWinding2. The first step is to make all calculations in this case, and then the modifications will be indicated if the TapChanger is associated with TransformerWinding1.

3.11.5.1. TapChanger associated with winding 2

If TapChanger.neutralKV is not defined, it is replaced by TransformerWinding.ratedKV.

Calculation of taps

$$n = \frac{\text{highStep} - \text{lowStep}}{2}$$

$$n' = -n + \text{normalStep} - \text{lowStep}$$

Case in which stepPhaseShiftIncrement = 0 or is not defined

ΔU = stepVoltageIncrement

The voltage regulation will be used to set the optional field *U (kV)*

- Search for a RegulationSchedule associated with the TapChanger.
- Search for the associated RegularTimePoint: the value1 attribute supplies the value of *U (kV)*, but it must not be defined immediately
- Search for a LineToLineVoltage type Analog associated with the TapChanger.
- This Analog must be associated with a Terminal, itself associated with a ConnectivityNode: if the UCTE node (denoted ND) that contains this connectivity node is node *Node2*, then *U(kV)* is defined to be equal to the value RegularTimePoint.value1

If nothing is found during this search, or if ND ≠ *Node2*, the procedure is stopped and *U(kV)* is not defined (display a message: PowerTransformer xxxxxx: no voltage setpoint.)

Case in which stepPhaseShiftIncrement is not equal to 0

The calculation is more complicated.

The maximum voltage U_2 is given by

$$U_2 = \text{neutralKV}\left(1 + (\text{highStep} - \text{neutralStep})\frac{\text{stepVoltageIncrement}}{100}\right)$$

The minimum voltage u_2 is given by

$$u_2 = \text{neutralKV}\left(1 + (\text{lowStep} - \text{neutralStep})\frac{\text{stepVoltageIncrement}}{100}\right)$$

The average tap voltage is equal to $U_{2N} = (U_2 + u_2) / 2$

Refer to the figure in section 1.10.4.3 « Angle / Quadrature regulation » Case, and we get

$$\Phi = n * \text{stepPhaseShiftIncrement}$$

$$n\frac{\Delta U}{100}U_{2N} = PM = \sqrt{U_2^2 - 2U_2U_{2N}\cos\Phi + U_{2N}^2}$$

namely $$\Delta U = \sqrt{U_2^2 - 2U_2U_{2N}\cos\Phi + U_{2N}^2} * \frac{100}{n\,U_{2N}}$$

$$tg\Theta = \frac{U_2 \sin\Phi}{U_2\cos\Phi - U_{2N}}$$

namely $$\Theta = arctg\frac{U_2 \sin\Phi}{U_2\cos\Phi - U_{2N}}$$

If sign(Θ) ≠ sign(stepPhaseShiftIncrement), set sign(Θ) = sign(stepPhaseShiftIncrement). The purpose of this is to process the case of a 90° angle that could equally well be 89.9° or -89.9°.

3.11.5.2.TapChanger associated with winding 1

If the TapChanger is associated with TransformerWinding1, then the same calculations are done as in the previous case, and then the following steps are done:

$$\Delta U = -\Delta U$$

$$\Theta = -\Theta$$

$$U(kV) = U(kV)\frac{Rated\ Voltage\,2}{Rated\ Voltage\,1}$$

Note: Even in this case (Tapchanger associated with winding 1), it is tested if ND = *Node2*, because the regulated winding in the UCTE file can only be winding 2.

3.12. Conclusion

This study is released as a public document because we believe that standards harmonization could benefits the electrical community.

Deriving a profile needs to be done consistently. It can be done consistently and with a better reliability if there is an information model.

Bibliography

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[2] CPSM Document Version 3:
Draft IEC 61970: Energy Management System - Application Program Interface (EMS-API)
Part 452: CIM Network Applications Model Exchange Specification
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[3] UCTE Subgroup « Network models and forecast tools »: UCTE data exchange format for load flow and three phase short circuit studies (UCTE-DEF) Version 01 (coming into force: 2003.09.01)

[4] Business objects discovery process (Core Components) starting from the message contents model (HR-48/04/032/A)

4. APPENDIX A

CIM object naming rules

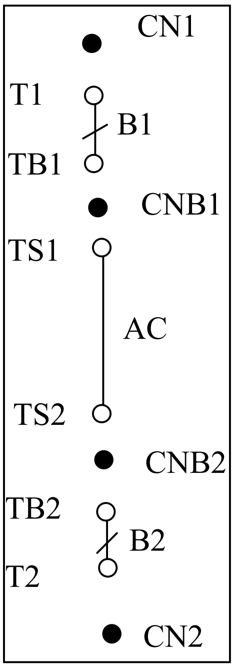
UCTE -> CIM: Objects and relations to be created + naming

Each node is assigned to a Substation and a VoltageLevel in the Substation (see spec)
The Substation is named according to the name of the first node assigned to it
The VoltageLevel is named according to the name of the first node assigned to it
The « naming » column indicates the content of the IdentifiedObject.Name attribute

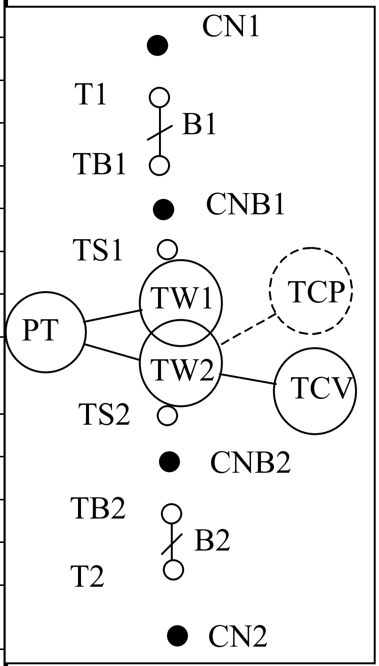
UCTE object	CIM object to be created	Associated with	Name
	MeasurementType (voltage)		"LineToLineVoltage"
	Unit (kV)		"kV"
	MeasurementType (angle)		"Angle"
	Unit (degree)		"Degrees"
	MeasurementType (active power)		"ThreePhaseActivePower"
	Unit (MW)		"MW"
	MeasurementType (current)		"LineCurrent"
	Unit (A)		"Amperes"
	BasePower		"BasePower" (object out of CPSM3)
Area (Zxx)	GeographicalRegion		xx
	SubGeographicalRegion	GeographicalRegion	xx
Node	BaseVoltage (if it does not already exist)		No name
	Substation (if it does not already exist)	SubGeographicalRegion (aggregation)	*Node*
	VoltageLevel (if it does not already exist)	Substation (aggregation)	*Node*
		BaseVoltage	
	ConnectivityNode	VoltageLevel (aggregation)	*Node*

(busbar)	BusbarSection	VoltageLevel (aggregation)	*Node*_BS
	Terminal	BusbarSection	*Node*_BS_T
		ConnectivityNode	
(load)	EnergyConsumer	VoltageLevel (aggregation)	*Node*_LO
	Terminal	EnergyConsumer	*Node*_LO_T
		ConnectivityNode	
(production)	SynchronousMachine	VoltageLevel (aggregation)	*Node*_SM
	Terminal	SynchronousMachine	*Node* _SM_T
		ConnectivityNode	
	GeneratingUnit	SynchronousMachine (aggregation)	*Node* _GU
		VoltageLevel (aggregation)	
	MVArCapabilityCurve	SynchronousMachine	*Nœud*_SM_MCC
	CurveSchedData1	MVArCapabilityCurve	No name
	CurveSchedData2	MVArCapabilityCurve	No name
(PV node)	Analog	MeasurementType (voltage)	*Node* _SM_MS
		Unit (kV)	
		SynchronousMachine (aggregation)	
		SynchronousMachine	
		Terminal (of the SynchronousMachine)	
	RegulationSchedule	SynchronousMachine	*Node* _SM_RS
	RegularTimePoint	RegulationSchedule	No name
(slack node)	Same as for PV Node,		
	but with a 2nd Analog:		
	Analog 2	MeasurementType (angle)	*Node* _MS
		Unit (degree)	
		BusbarSection (aggregation)	
		SynchronousMachine	
		Terminal (of the SynchronousMachine)	

Coupling device (=Line with status 2 or 7)	LoadBreakSwitch	VoltageLevel (aggregation)	*Node1-Node2-Xpp*
	Terminal 1	LoadBreakSwitch	*Node1-Node2-Xpp*_T1
		ConnectivityNode 1	
	Terminal 2	LoadBreakSwitch	*Node1-Node2-Xpp*_T2
		ConnectivityNode 2	
Line	Line		*Node1-Node2-Xpp*
	ACLineSegment	BaseVoltage	*Node1-Node2-Xpp*
		Line	
	Breaker 1	VoltageLevel (aggregation)	*Node1-Node2-Xpp*_B1
	ConnectivityNode b1	VoltageLevel (aggregation)	*Node1-Node2-Xpp*_CNB1
	Breaker 2	VoltageLevel (aggregation)	*Node1-Node2-Xpp*_B2
	ConnectivityNode b2	VoltageLevel (aggregation)	*Node1-Node2-Xpp*_CNB2
	Terminal 1	Breaker 1	*Node1-Node2-Xpp*_T1
		ConnectivityNode 1	
	Terminal b1	Breaker 1	*Node1-Node2-Xpp*_B1
		ConnectivityNode b1	
	Terminal s1	ACLineSegment	*Node1-Node2-Xpp*_TS1
		ConnectivityNode b1	
	Terminal s2	ACLineSegment	*Node1-Node2-Xpp*_TS2
		ConnectivityNode b2	
	Terminal b2	Breaker 2	*Node1-Node2-Xpp*_TB2
		ConnectivityNode b2	
	Terminal 2	Breaker 2	*Node1-Node2-Xpp*_T2
		ConnectivityNode 2	
(current limit)	Analog	MeasurementType (current)	*Node1-Node2-Xpp*_MS
		Unit (A)	
		ACLineSegment (aggregation)	
	AnalogLimitSet	Analog	*Node1-Node2-Xpp*_MS_LS
	AnalogLimit	AnalogLimitSet	Normal



Transformer	PowerTransformer	Substation	*Node1-Node2-Xpp*
	TransformerWinding1	PowerTransformer	*Node1-Node2-Xpp*_TW1
		BaseVoltage	
	TransformerWinding2	PowerTransformer	*Node1-Node2-Xpp*_TW2
		BaseVoltage	
	TapChangerV	TransformerWinding2	*Node1-Node2-Xpp*_TCV
or / and	TapChangerP	TransformerWinding2	*Node1-Node2-Xpp*_TCP
	then as line starting from breaker 1 except		
	Terminal s1	**TransformerWinding1**	*Node1-Node2-Xpp*_TS1
	Terminal s2	**TransformerWinding2**	*Node1-Node2-Xpp*_TS2
	If TapChanger		
	Analog	MeasurementType (voltage)	*Node1-Node2-Xpp*_TCV_MS
		Unit (kV)	
		TapchangerV	
		Terminal (of TransformerWinding2)	
	RegulationSchedule	TapChangerV	*Node1-Node2-Xpp*_TCV_RS
	RegularTimePoint	RegulationSchedule	*Node1-Node2-Xpp*_TCV_CSD
	or / and		
	Analog	MeasurementType (active power)	*Node1-Node2-Xpp*_TCP_MS
		Unit (MW)	
		TapchangerP	
		Terminal (of TransformerWinding2)	
	RegulationSchedule	TapChangerP	*Node1-Node2-Xpp*_TCP_RS
	RegularTimePoint	RegulationSchedule	*Node1-Node2-Xpp*_TCP_CSD



5. APPENDIX B

Graphic representation of the IEEE 14-node file

The figure shows a simplified view of the IEEE 14-node network in the UCTE format. The data associated with regulation, and the data on transformers are not shown.

Simplified view of the
IEEE 14-node network in the UCTE format