

This is a preview - click here to buy the full publication



IEC 61970-301

Edition 7.0 2020-06

INTERNATIONAL STANDARD



**Energy management system application program interface (EMS-API) –
Part 301: Common information model (CIM) base**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.200

ISBN 978-2-8322-8502-2

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	35
INTRODUCTION.....	37
1 Scope.....	39
2 Normative references	39
3 Terms and definitions	40
4 CIM specification	40
4.1 Overview.....	40
4.2 CIM modelling notation	41
4.3 CIM packages.....	41
4.4 CIM classes and relationships.....	43
4.4.1 Classes	43
4.4.2 Generalization	44
4.4.3 Simple association.....	45
4.4.4 Aggregation.....	46
4.5 CIM model concepts and examples.....	46
4.5.1 Concepts	46
4.5.2 Containment, equipment hierarchies and naming.....	47
4.5.3 Names model	48
4.5.4 Connectivity model	49
4.5.5 Inheritance hierarchy	52
4.5.6 Transformer model	54
4.5.7 Transformer tap modelling	56
4.5.8 Phase wire modelling.....	69
4.5.9 Grounding devices modelling.....	71
4.5.10 Cuts, clamps and jumpers model	75
4.5.11 Measurements and controls.....	79
4.5.12 Regulating control models	84
4.5.13 DC model for CIM.....	85
4.5.14 Static Var Compensator Voltage Regulation	107
4.5.15 ICCP Configuration Model	108
4.5.16 Feeder Model	115
4.5.17 Control area modelling.....	115
4.6 Modelling guidelines	117
4.6.1 Modelling for change	117
4.6.2 Process for amendments to the CIM	117
4.6.3 Changes to the CIM UML model	118
4.6.4 Changes to the CIM standards documents.....	118
4.6.5 Deprecations	118
4.6.6 CIM profiles	118
4.7 Modelling tools.....	119
4.8 User implementation conventions.....	119
4.8.1 Conventions beyond UML.....	119
4.8.2 Number of terminals for ConductingEquipment objects	119
4.8.3 Nominal quantities	120
4.8.4 Datatypes	120
4.9 CIM modelling examples	120
5 Detailed model	120

5.1	Overview.....	120
5.2	Context.....	120
6	Package Base.....	122
6.1	General.....	122
6.2	Package Domain.....	122
6.2.1	General.....	122
6.2.2	ActivePower datatype.....	128
6.2.3	ActivePowerChangeRate datatype.....	129
6.2.4	ActivePowerPerCurrentFlow datatype.....	129
6.2.5	ActivePowerPerFrequency datatype.....	129
6.2.6	Admittance datatype.....	129
6.2.7	AngleDegrees datatype.....	130
6.2.8	AngleRadians datatype.....	130
6.2.9	ApparentPower datatype.....	130
6.2.10	Area datatype.....	130
6.2.11	Boolean primitive.....	131
6.2.12	Capacitance datatype.....	131
6.2.13	CapacitancePerLength datatype.....	131
6.2.14	Classification datatype.....	131
6.2.15	Conductance datatype.....	131
6.2.16	ConductancePerLength datatype.....	132
6.2.17	CostPerEnergyUnit datatype.....	132
6.2.18	CostPerHeatUnit datatype.....	132
6.2.19	CostPerVolume datatype.....	132
6.2.20	CostRate datatype.....	133
6.2.21	Currency enumeration.....	133
6.2.22	CurrentFlow datatype.....	137
6.2.23	Damping datatype.....	137
6.2.24	Date primitive.....	137
6.2.25	DateInterval compound.....	137
6.2.26	DateTime primitive.....	138
6.2.27	DateTimeInterval compound.....	138
6.2.28	Decimal primitive.....	138
6.2.29	DecimalQuantity compound.....	138
6.2.30	Displacement datatype.....	138
6.2.31	Duration primitive.....	139
6.2.32	Emission datatype.....	139
6.2.33	Float primitive.....	139
6.2.34	FloatQuantity compound.....	139
6.2.35	Frequency datatype.....	139
6.2.36	HeatRate datatype.....	140
6.2.37	Hours datatype.....	140
6.2.38	Impedance datatype.....	140
6.2.39	Inductance datatype.....	140
6.2.40	InductancePerLength datatype.....	141
6.2.41	Integer primitive.....	141
6.2.42	IntegerQuantity compound.....	141
6.2.43	KiloActivePower datatype.....	141
6.2.44	Length datatype.....	142

6.2.45	Mass datatype	142
6.2.46	Minutes datatype	142
6.2.47	Money datatype	142
6.2.48	MonthDay primitive	143
6.2.49	MonthDayInterval compound	143
6.2.50	PU datatype	143
6.2.51	PerCent datatype	143
6.2.52	Pressure datatype	143
6.2.53	Reactance datatype	144
6.2.54	ReactancePerLength datatype	144
6.2.55	ReactivePower datatype	144
6.2.56	RealEnergy datatype	144
6.2.57	Resistance datatype	145
6.2.58	ResistancePerLength datatype	145
6.2.59	RotationSpeed datatype	145
6.2.60	Seconds datatype	146
6.2.61	Speed datatype	146
6.2.62	String primitive	146
6.2.63	StringQuantity compound	146
6.2.64	Susceptance datatype	146
6.2.65	SusceptancePerLength datatype	147
6.2.66	Temperature datatype	147
6.2.67	Time primitive	147
6.2.68	TimeInterval compound	147
6.2.69	UnitMultiplier enumeration	148
6.2.70	UnitSymbol enumeration	149
6.2.71	Voltage datatype	154
6.2.72	VoltagePerReactivePower datatype	154
6.2.73	Volume datatype	154
6.2.74	VolumeFlowRate datatype	155
6.2.75	WaterLevel datatype	155
6.3	Package Core	155
6.3.1	General	155
6.3.2	ACDCTerminal	160
6.3.3	BaseFrequency	161
6.3.4	BasePower	162
6.3.5	BaseVoltage	162
6.3.6	BasicIntervalSchedule	163
6.3.7	Bay	163
6.3.8	BreakerConfiguration enumeration	164
6.3.9	BusbarConfiguration enumeration	165
6.3.10	ConductingEquipment	165
6.3.11	ConnectivityNode	166
6.3.12	ConnectivityNodeContainer	167
6.3.13	Curve	167
6.3.14	CurveData root class	168
6.3.15	CurveStyle enumeration	169
6.3.16	Equipment	169
6.3.17	EquipmentContainer	170

6.3.18	Feeder	171
6.3.19	GeographicalRegion	172
6.3.20	IdentifiedObject root class	173
6.3.21	IrregularIntervalSchedule.....	174
6.3.22	IrregularTimePoint root class	174
6.3.23	Name root class.....	175
6.3.24	NameType root class	175
6.3.25	NameTypeAuthority root class	176
6.3.26	OperatingParticipant	176
6.3.27	OperatingShare root class	177
6.3.28	PSRType	177
6.3.29	PhaseCode enumeration	178
6.3.30	PowerSystemResource.....	179
6.3.31	RegularIntervalSchedule.....	179
6.3.32	RegularTimePoint root class	180
6.3.33	ReportingGroup	181
6.3.34	ReportingSuperGroup	181
6.3.35	SubGeographicalRegion	182
6.3.36	Substation	183
6.3.37	Terminal	184
6.3.38	VoltageLevel.....	185
6.4	Package Wires.....	186
6.4.1	General	186
6.4.2	AsynchronousMachineKind enumeration.....	201
6.4.3	ACLineSegment.....	202
6.4.4	ACLineSegmentPhase	203
6.4.5	AsynchronousMachine	204
6.4.6	Breaker.....	206
6.4.7	BusbarSection	208
6.4.8	Clamp	209
6.4.9	CompositeSwitch	210
6.4.10	Conductor.....	211
6.4.11	Connector.....	212
6.4.12	CoolantType enumeration.....	213
6.4.13	Cut	213
6.4.14	Disconnecter	215
6.4.15	DisconnectingCircuitBreaker.....	216
6.4.16	EarthFaultCompensator	217
6.4.17	EnergyConnection	218
6.4.18	EnergyConsumer	219
6.4.19	EnergyConsumerPhase	221
6.4.20	EnergySchedulingType	222
6.4.21	EnergySource.....	222
6.4.22	EnergySourcePhase	224
6.4.23	ExternalNetworkInjection	225
6.4.24	FrequencyConverter	227
6.4.25	Fuse	228
6.4.26	Ground	229
6.4.27	GroundingImpedance	230

6.4.28	GroundDisconnector	231
6.4.29	Jumper	232
6.4.30	Junction	234
6.4.31	Line	234
6.4.32	LinearShuntCompensator	235
6.4.33	LinearShuntCompensatorPhase	237
6.4.34	LoadBreakSwitch	237
6.4.35	MutualCoupling	239
6.4.36	NonlinearShuntCompensator	240
6.4.37	NonlinearShuntCompensatorPhase	241
6.4.38	NonlinearShuntCompensatorPhasePoint root class	242
6.4.39	NonlinearShuntCompensatorPoint root class	243
6.4.40	PerLengthImpedance	243
6.4.41	PerLengthLineParameter	244
6.4.42	PerLengthPhaseImpedance	244
6.4.43	PerLengthSequenceImpedance	245
6.4.44	PetersenCoil	246
6.4.45	PetersenCoilModeKind enumeration	247
6.4.46	PhaseImpedanceData root class	247
6.4.47	PhaseShuntConnectionKind enumeration	248
6.4.48	PhaseTapChanger	249
6.4.49	PhaseTapChangerAsymmetrical	250
6.4.50	PhaseTapChangerLinear	251
6.4.51	PhaseTapChangerNonLinear	252
6.4.52	PhaseTapChangerSymmetrical	254
6.4.53	PhaseTapChangerTable	255
6.4.54	PhaseTapChangerTablePoint	255
6.4.55	PhaseTapChangerTabular	256
6.4.56	Plant	257
6.4.57	PowerElectronicsConnection	258
6.4.58	PowerElectronicsConnectionPhase	259
6.4.59	PowerTransformer	260
6.4.60	PowerTransformerEnd	262
6.4.61	ProtectedSwitch	264
6.4.62	RatioTapChanger	266
6.4.63	RatioTapChangerTable	267
6.4.64	RatioTapChangerTablePoint	267
6.4.65	ReactiveCapabilityCurve	268
6.4.66	Recloser	269
6.4.67	RegulatingCondEq	270
6.4.68	RegulatingControl	271
6.4.69	RegulatingControlModeKind enumeration	273
6.4.70	RegulationSchedule	273
6.4.71	RotatingMachine	274
6.4.72	Sectionalizer	276
6.4.73	SeriesCompensator	277
6.4.74	ShortCircuitRotorKind enumeration	278
6.4.75	ShuntCompensator	278
6.4.76	ShuntCompensatorPhase	280

6.4.77	SinglePhaseKind enumeration	281
6.4.78	StaticVarCompensator	282
6.4.79	SVCControlMode enumeration	283
6.4.80	Switch	283
6.4.81	SwitchPhase	285
6.4.82	SwitchSchedule	286
6.4.83	SynchronousMachine	287
6.4.84	SynchronousMachineOperatingMode enumeration	290
6.4.85	SynchronousMachineKind enumeration	290
6.4.86	TapChanger	290
6.4.87	TapChangerControl	292
6.4.88	TapChangerTablePoint root class	293
6.4.89	TapSchedule	294
6.4.90	TransformerControlMode enumeration	295
6.4.91	TransformerCoreAdmittance	295
6.4.92	TransformerEnd	296
6.4.93	TransformerMeshImpedance	297
6.4.94	TransformerStarImpedance	298
6.4.95	TransformerTank	299
6.4.96	TransformerTankEnd	299
6.4.97	VoltageControlZone	300
6.4.98	WireSegment	301
6.4.99	WireSegmentPhase	302
6.4.100	WindingConnection enumeration	303
6.5	Package LoadModel	303
6.5.1	General	303
6.5.2	ConformLoad	304
6.5.3	ConformLoadGroup	306
6.5.4	ConformLoadSchedule	306
6.5.5	DayType	307
6.5.6	EnergyArea	308
6.5.7	LoadArea	308
6.5.8	LoadGroup	309
6.5.9	LoadResponseCharacteristic	309
6.5.10	NonConformLoad	311
6.5.11	NonConformLoadGroup	312
6.5.12	NonConformLoadSchedule	313
6.5.13	PowerCutZone	314
6.5.14	Season	314
6.5.15	SeasonDayTypeSchedule	315
6.5.16	StationSupply	315
6.5.17	SubLoadArea	317
6.6	Package Generation	317
6.6.1	General	317
6.6.2	Package GenerationTrainingSimulation	318
6.6.3	Package Production	334
6.7	Package DC	386
6.7.1	General	386
6.7.2	ACDCConverter	390

6.7.3	ACDCConverterDCTerminal	393
6.7.4	CsConverter	394
6.7.5	DCTopologicalNode	396
6.7.6	CsOperatingModeKind enumeration.....	397
6.7.7	CsPpccControlKind enumeration	397
6.7.8	DCBaseTerminal	397
6.7.9	DCBreaker.....	398
6.7.10	DCBusbar	399
6.7.11	DCChopper.....	400
6.7.12	DCConductingEquipment.....	401
6.7.13	DCConverterOperatingModeKind enumeration.....	402
6.7.14	DCConverterUnit	402
6.7.15	DCDisconnecter.....	403
6.7.16	DCEquipmentContainer	404
6.7.17	DCGround	405
6.7.18	DCLine	406
6.7.19	DCLineSegment	407
6.7.20	DCNode.....	408
6.7.21	DCPolarityKind enumeration	409
6.7.22	DCSeriesDevice	409
6.7.23	DCShunt.....	410
6.7.24	DCSwitch.....	411
6.7.25	DCTerminal	412
6.7.26	DCTopologicalIsland.....	413
6.7.27	PerLengthDCLineParameter	413
6.7.28	VsCapabilityCurve	414
6.7.29	VsConverter	414
6.7.30	VsPpccControlKind enumeration.....	417
6.7.31	VsQpccControlKind enumeration	417
6.8	Package Equivalents.....	418
6.8.1	General	418
6.8.2	EquivalentBranch	419
6.8.3	EquivalentEquipment.....	422
6.8.4	EquivalentInjection	423
6.8.5	EquivalentNetwork.....	425
6.8.6	EquivalentShunt	426
6.9	Package AuxiliaryEquipment.....	427
6.9.1	General	427
6.9.2	AuxiliaryEquipment	428
6.9.3	CurrentTransformer	429
6.9.4	FaultIndicator	430
6.9.5	PostLineSensor	431
6.9.6	PotentialTransformer	432
6.9.7	PotentialTransformerKind enumeration	433
6.9.8	Sensor.....	434
6.9.9	SurgeArrester	435
6.9.10	WaveTrap.....	435
6.10	Package Meas	436
6.10.1	General	436

6.10.2	Accumulator	440
6.10.3	AccumulatorLimit	441
6.10.4	AccumulatorLimitSet	441
6.10.5	AccumulatorReset	442
6.10.6	AccumulatorValue	443
6.10.7	Analog	444
6.10.8	AnalogControl	444
6.10.9	AnalogLimit	445
6.10.10	AnalogLimitSet	446
6.10.11	AnalogValue	446
6.10.12	Command	447
6.10.13	Control	448
6.10.14	Discrete	449
6.10.15	DiscreteValue	450
6.10.16	IOPoint	451
6.10.17	Limit	452
6.10.18	LimitSet	452
6.10.19	Measurement	453
6.10.20	MeasurementValue	454
6.10.21	MeasurementValueQuality	455
6.10.22	MeasurementValueSource	456
6.10.23	Quality61850 root class	456
6.10.24	RaiseLowerCommand	457
6.10.25	SetPoint	458
6.10.26	StringMeasurement	459
6.10.27	StringMeasurementValue	460
6.10.28	Validity enumeration	460
6.10.29	ValueAliasSet	461
6.10.30	ValueToAlias	462
6.11	Package Topology	462
6.11.1	General	462
6.11.2	BusNameMarker	464
6.11.3	TopologicalIsland	464
6.11.4	TopologicalNode	465
6.12	Package DiagramLayout	466
6.12.1	General	466
6.12.2	Diagram	467
6.12.3	DiagramObject	468
6.12.4	DiagramObjectGluePoint root class	469
6.12.5	DiagramObjectPoint root class	470
6.12.6	DiagramObjectStyle	470
6.12.7	DiagramStyle	471
6.12.8	OrientationKind enumeration	471
6.12.9	TextDiagramObject	472
6.12.10	VisibilityLayer	473
6.13	Package OperationalLimits	473
6.13.1	General	473
6.13.2	ActivePowerLimit	475
6.13.3	ApparentPowerLimit	476

6.13.4	BranchGroup	476
6.13.5	BranchGroupTerminal root class	477
6.13.6	CurrentLimit	478
6.13.7	OperationalLimit	478
6.13.8	OperationalLimitDirectionKind enumeration	479
6.13.9	OperationalLimitSet	479
6.13.10	OperationalLimitType	480
6.13.11	VoltageLimit	481
6.14	Package ControlArea	481
6.14.1	General	481
6.14.2	AltGeneratingUnitMeas	483
6.14.3	AltTieMeas	484
6.14.4	ControlArea	485
6.14.5	ControlAreaGeneratingUnit	486
6.14.6	ControlAreaTypeKind enumeration	487
6.14.7	TieFlow	487
6.15	Package Contingency	488
6.15.1	General	488
6.15.2	Contingency	488
6.15.3	ContingencyElement	489
6.15.4	ContingencyEquipment	489
6.15.5	ContingencyEquipmentStatusKind enumeration	490
6.16	Package StateVariables	490
6.16.1	General	490
6.16.2	StateVariable root class	491
6.16.3	SvInjection	491
6.16.4	SvPowerFlow	492
6.16.5	SvShuntCompensatorSections	492
6.16.6	SvStatus	493
6.16.7	SvSwitch	493
6.16.8	SvTapStep	494
6.16.9	SvVoltage	494
6.17	Package Protection	495
6.17.1	General	495
6.17.2	CurrentRelay	496
6.17.3	ProtectionEquipment	497
6.17.4	RecloseSequence	498
6.17.5	SynchrocheckRelay	499
6.18	Package Faults	500
6.18.1	General	500
6.18.2	EquipmentFault	501
6.18.3	Fault	501
6.18.4	FaultCauseType	502
6.18.5	FaultImpedance compound	502
6.18.6	LineFault	503
6.18.7	PhaseConnectedFaultKind enumeration	503
6.19	Package SCADA	504
6.19.1	General	504
6.19.2	CommunicationLink	505

6.19.3	RemoteControl	506
6.19.4	RemotePoint.....	506
6.19.5	RemoteSource.....	507
6.19.6	RemoteUnit	508
6.19.7	RemoteUnitType enumeration.....	508
6.19.8	Source enumeration	509
6.20	Package ICCPConfiguration.....	509
6.20.1	General	509
6.20.2	ApplicationSecurityKind enumeration.....	511
6.20.3	BilateralExchangeActor	512
6.20.4	BilateralExchangeAgreement.....	512
6.20.5	ICCPAccessPrivilegeKind enumeration.....	513
6.20.6	ICCPInformationMessage	513
6.20.7	ICCPPointKind enumeration	514
6.20.8	ICCPProvidedPoint.....	514
6.20.9	ICCPQualityKind enumeration	515
6.20.10	ICCPScopeKind enumeration.....	516
6.20.11	ICCPVCC	516
6.20.12	ICCPVirtualControlCentre	517
6.20.13	IOPointSource	518
6.20.14	IPAccessPoint	519
6.20.15	IPAddressKind enumeration.....	520
6.20.16	ISOUpperLayer.....	520
6.20.17	ProvidedBilateralPoint	521
6.20.18	PublicX509Certificate root class	521
6.20.19	TASE2BilateralTable	522
6.20.20	TCPAccessPoint.....	523
Annex A (normative)	Custom extensions.....	525
A.1	Overview.....	525
A.2	European extensions	525
A.2.1	General	525
A.2.2	Package ExtEuCore.....	525
A.2.3	Package ExtEuOperationalLimits	528
A.2.4	Package ExtEuGeneration	531
Annex B (Informative)	Examples of PST transformer modelling.....	534
B.1	General.....	534
B.2	Detailed calculations and examples	534
B.2.1	Symmetrical phase shifters with two cores.....	534
B.2.2	Quadrature boosters.....	538
B.2.3	Asymmetrical phase shifter.....	542
Annex C (informative)	Use cases HVDC representation	549
C.1	Overview.....	549
C.2	Back-to-back installations	549
C.3	Monopole with ground return.....	550
C.4	Monopole with metallic return	551
C.5	Voltage source converter	552
Bibliography	554

Figure 1 – Defined dependencies between CIM packages and packages' versions information.....	42
Figure 2 – CIM IEC 61970-301 package diagram	43
Figure 3 – Example of generalization	45
Figure 4 – Example of simple association	46
Figure 5 – Example of aggregation	46
Figure 6 – Equipment containers.....	48
Figure 7 – Names	49
Figure 8 – Connectivity model.....	50
Figure 9 – Simple network example	51
Figure 10 – Simple network connectivity modelled with CIM Topology	52
Figure 11 – Equipment inheritance hierarchy	53
Figure 12 – Transformer and Tank model.....	54
Figure 13 – Transformer model.....	56
Figure 14 – Transformer tap model	57
Figure 15 – Phasor diagram and equations	60
Figure 16 – Symmetrical phase shifter impedance variation	61
Figure 17 – Core organization.....	62
Figure 18 – Phasor diagram and equations	62
Figure 19 – Core organization.....	63
Figure 20 – Phasor diagram and equations	64
Figure 21 – Core organization.....	65
Figure 22 – Phasor diagram and equations	65
Figure 23 – Phasor diagrams and equations	67
Figure 24 – Core organization.....	68
Figure 25 – Phase wire data model.....	70
Figure 26 – Phase connectivity	71
Figure 27 – Grounding device data model.....	73
Figure 28 – Station including Petersen coils drawing example	74
Figure 29 – Instance diagram objects with one terminal coil.....	75
Figure 30 – Cuts, clamps, and jumpers UML model	76
Figure 31 – Example before cuts and jumpers are applied	77
Figure 32 – Example after cuts and jumpers are applied	78
Figure 33 – Example of jumper without cut or clamp	79
Figure 34 – Navigating from PSR to MeasurementValue	81
Figure 35 – Measurement placement	84
Figure 36 – Regulating control models.....	85
Figure 37 – Simplified example of HVDC model representation.....	87
Figure 38 – Detailed example of HVDC model representation with fictitious HVDC substations	88
Figure 39 – Detailed example of HVDC model representation with no fictitious HVDC substations	89
Figure 40 – HVDC bi-polar link from IEC 60633	90
Figure 41 – A point-to-point VSC transmission scheme.....	90

Figure 42 – HVDC power flow model.....	91
Figure 43 – Detailed HVDC power flow model.....	92
Figure 44 – Current Source Converter power flow.....	92
Figure 45 – Voltage Source Converter power flow.....	93
Figure 46 – Power flow cases.....	94
Figure 47 – VSC transmission with a symmetrical monopole illustrated with capacitive earthing on the DC side (IEC 62747).....	95
Figure 48 – VSC P-Q capability curve.....	95
Figure 49 – Bipolar VSC transmission with earth return (IEC 62747).....	96
Figure 50 – Object instances for a bi-polar current source HVDC line.....	97
Figure 51 – Object instances for symmetric monopole VSC HVDC data model.....	98
Figure 52 – Containment structure for a bipolar HVDC line.....	99
Figure 53 – Containment structure for a bipolar back-to-back HVDC station.....	100
Figure 54 – The Basic topology in package Core.....	101
Figure 55 – DC and AC topology.....	102
Figure 56 – Equipment model.....	103
Figure 57 – HVDC line model.....	104
Figure 58 – Legend.....	105
Figure 59 – Simple monopole with measurements.....	105
Figure 60 – Simple bipolar.....	106
Figure 61 – Monopole one side with detailed model.....	106
Figure 62 – V-I Characteristic of SVC.....	107
Figure 63 – ICCP measurements and network models.....	109
Figure 64 – ICCP configuration and start up.....	109
Figure 65 – Measurement value provider and consumer example.....	110
Figure 66 – Generalized bilateral exchange agreement data model.....	112
Figure 67 – ICCP bilateral exchange agreement data model.....	114
Figure 68 – Feeder data model.....	115
Figure 69 – Orientation of the Terminal flow.....	116
Figure 70 – Several ways to describe control area ties.....	117
Figure 71 – CIM top level packages.....	121
Figure 72 – Class diagram Domain::CombinedElectricalDatatypes.....	123
Figure 73 – Class diagram Domain::BasicDatatypes.....	123
Figure 74 – Class diagram Domain::ElectricityDatatypes.....	124
Figure 75 – Class diagram Domain::EnumeratedUnitDatatypes.....	125
Figure 76 – Class diagram Domain::GeneralDatatypes.....	126
Figure 77 – Class diagram Domain::MonetaryDatatypes.....	127
Figure 78 – Class diagram Domain::TimeDatatypes.....	128
Figure 79 – Class diagram Core::Main.....	156
Figure 80 – Class diagram Core::Names.....	157
Figure 81 – Class diagram Core::CurveSchedule.....	157
Figure 82 – Class diagram Core::Datatypes.....	158
Figure 83 – Class diagram Core::FeederContainment.....	159

Figure 84 – Class diagram Core::Reporting	159
Figure 85 – Class diagram Core::OperatingShare	160
Figure 86 – Class diagram Wires::CutsAndJumpers	187
Figure 87 – Class diagram Wires::Datatypes	188
Figure 88 – Class diagram Wires::EarthFaultCompensator	189
Figure 89 – Class diagram Wires::InheritanceHierarchy	190
Figure 90 – Class diagram Wires::LineModel	191
Figure 91 – Class diagram Wires::MutualCoupling	192
Figure 92 – Class diagram Wires::NamingHierarchyPart1	193
Figure 93 – Class diagram Wires::NamingHierarchyPart2	194
Figure 94 – Class diagram Wires::RegulatingEquipment	195
Figure 95 – Class diagram Wires::Schedules	196
Figure 96 – Class diagram Wires::ShuntCompensator	196
Figure 97 – Class diagram Wires::SwitchingEquipment	197
Figure 98 – Class diagram Wires::TapChanger	198
Figure 99 – Class diagram Wires::VoltageControl	199
Figure 100 – Class diagram Wires::WiresPhaseModel	200
Figure 101 – Class diagram Wires::Transformer	201
Figure 102 – Class diagram LoadModel::Main	304
Figure 103 – Class diagram Generation::Main	318
Figure 104 – Class diagram GenerationTrainingSimulation::Main	318
Figure 105 – Class diagram GenerationTrainingSimulation::Datatypes	319
Figure 106 – Class diagram Production::PowerElectronics	334
Figure 107 – Class diagram Production::Nuclear	335
Figure 108 – Class diagram Production::Main	336
Figure 109 – Class diagram Production::Datatypes	337
Figure 110 – Class diagram Production::Hydro	338
Figure 111 – Class diagram Production::Thermal	339
Figure 112 – Class diagram DC::DCContainment	386
Figure 113 – Class diagram DC::DCEquipment	387
Figure 114 – Class diagram DC::DCLineModel	388
Figure 115 – Class diagram DC::ACDCConverter	389
Figure 116 – Class diagram DC::ACDCConnectivityModel	390
Figure 117 – Class diagram Equivalentents::Main	419
Figure 118 – Class diagram AuxiliaryEquipment::AuxiliaryEquipment	428
Figure 119 – Class diagram Meas::Control	437
Figure 120 – Class diagram Meas::Datatypes	437
Figure 121 – Class diagram Meas::Measurement	438
Figure 122 – Class diagram Meas::MeasurementInheritance	439
Figure 123 – Class diagram Meas::Quality	440
Figure 124 – Class diagram Topology::Main	463
Figure 125 – Class diagram Topology::TopologyReporting	463
Figure 126 – Class diagram DiagramLayout::DiagramLayout	467

Figure 127 – Class diagram OperationalLimits::OperationalLimits	474
Figure 128 – Class diagram OperationalLimits::BranchGroup	475
Figure 129 – Class diagram ControlArea::ControlArea	482
Figure 130 – Class diagram ControlArea::ControlAreaInheritance	483
Figure 131 – Class diagram ControlArea::Datatypes	483
Figure 132 – Class diagram Contingency::Contingency	488
Figure 133 – Class diagram StateVariables::StateVariables	491
Figure 134 – Class diagram Protection::Main	495
Figure 135 – Class diagram Faults::Faults	500
Figure 136 – Class diagram SCADA::Datatypes	504
Figure 137 – Class diagram SCADA::Main	505
Figure 138 – Class diagram ICCPConfiguration::GenericBilateralExchange	510
Figure 139 – Class diagram ICCPConfiguration::ICCP	511
Figure A.1 – Class diagram ExtEuBase::ExtEuBase	525
Figure A.2 – Class diagram ExtEuCore::ExtEuCore	526
Figure A.3 – Class diagram ExtEuOperationalLimits::ExtEuOperationalLimits	529
Figure A.4 – Class diagram ExtEuProduction::ExtEuProduction	531
Figure B.1 – Symmetrical phase shifters with two cores	534
Figure B.2 – Detailed three phase diagram	535
Figure B.3 – Detailed three phase diagram	538
Figure B.4 – Single phase diagram	539
Figure B.5 – Phasor diagram	540
Figure B.6 – Detailed three phase diagram	541
Figure B.7 – Phasor diagram	542
Figure B.8 – Asymmetrical phase shifter with two cores	542
Figure B.9 – Detailed three phase diagram	543
Figure B.10 – Phasor diagram	544
Figure B.11 – Asymmetrical phase shifter with a single core	545
Figure B.12 – Phasor diagram	546
Figure B.13 – Example of detailed three-phase diagram of voltage regulating auto-transformer and quadrature booster	547
Figure B.14 – Example of detailed winding diagram of voltage regulating auto-transformer and quadrature booster	548
Figure C.1 – Representation of a 12-p back-to-back installation	550
Figure C.2 – Representation of a 12-p monopole installation with ground return	551
Figure C.3 – Representation of a 12-p monopole installation with metallic return	552
Figure C.4 – Representation of a voltage source converter	553
Table 1 – Mapping of phase shift transformers to CIM classes	58
Table 2 – Mapping of symbols used in formulas to CIM attributes	59
Table 3 – Impedance variations in a phase shift transformer	59
Table 4 – Description of variables	60
Table 5 – Tap changer control options	69
Table 6 – measurementType naming conventions	82

Table 7 – MeasurementValueSource naming conventions.....	83
Table 8 – Attributes of Package1::Class1.....	121
Table 9 – Association ends of Package1::Class1 with other classes	122
Table 10 – Literals of Package1::Enumeration1	122
Table 11 – Attributes of Domain::ActivePower.....	128
Table 12 – Attributes of Domain::ActivePowerChangeRate	129
Table 13 – Attributes of Domain::ActivePowerPerCurrentFlow	129
Table 14 – Attributes of Domain::ActivePowerPerFrequency.....	129
Table 15 – Attributes of Domain::Admittance	129
Table 16 – Attributes of Domain::AngleDegrees	130
Table 17 – Attributes of Domain::AngleRadians	130
Table 18 – Attributes of Domain::ApparentPower	130
Table 19 – Attributes of Domain::Area	130
Table 20 – Attributes of Domain::Capacitance.....	131
Table 21 – Attributes of Domain::CapacitancePerLength.....	131
Table 22 – Attributes of Domain::Classification	131
Table 23 – Attributes of Domain::Conductance	132
Table 24 – Attributes of Domain::ConductancePerLength	132
Table 25 – Attributes of Domain::CostPerEnergyUnit	132
Table 26 – Attributes of Domain::CostPerHeatUnit.....	132
Table 27 – Attributes of Domain::CostPerVolume.....	133
Table 28 – Attributes of Domain::CostRate	133
Table 29 – Literals of Domain::Currency	133
Table 30 – Attributes of Domain::CurrentFlow.....	137
Table 31 – Attributes of Domain::Damping.....	137
Table 32 – Attributes of Domain::DateInterval.....	138
Table 33 – Attributes of Domain::DateTimeInterval	138
Table 34 – Attributes of Domain::DecimalQuantity	138
Table 35 – Attributes of Domain::Displacement.....	139
Table 36 – Attributes of Domain::Emission.....	139
Table 37 – Attributes of Domain::FloatQuantity	139
Table 38 – Attributes of Domain::Frequency	140
Table 39 – Attributes of Domain::HeatRate	140
Table 40 – Attributes of Domain::Hours.....	140
Table 41 – Attributes of Domain::Impedance.....	140
Table 42 – Attributes of Domain::Inductance.....	141
Table 43 – Attributes of Domain::InductancePerLength.....	141
Table 44 – Attributes of Domain::IntegerQuantity	141
Table 45 – Attributes of Domain::KiloActivePower.....	141
Table 46 – Attributes of Domain::Length	142
Table 47 – Attributes of Domain::Mass.....	142
Table 48 – Attributes of Domain::Minutes.....	142
Table 49 – Attributes of Domain::Money	142

Table 50 – Attributes of Domain::MonthDayInterval.....	143
Table 51 – Attributes of Domain::PU	143
Table 52 – Attributes of Domain::PerCent	143
Table 53 – Attributes of Domain::Pressure	144
Table 54 – Attributes of Domain::Reactance	144
Table 55 – Attributes of Domain::ReactancePerLength	144
Table 56 – Attributes of Domain::ReactivePower.....	144
Table 57 – Attributes of Domain::RealEnergy.....	145
Table 58 – Attributes of Domain::Resistance.....	145
Table 59 – Attributes of Domain::ResistancePerLength.....	145
Table 60 – Attributes of Domain::RotationSpeed	145
Table 61 – Attributes of Domain::Seconds	146
Table 62 – Attributes of Domain::Speed.....	146
Table 63 – Attributes of Domain::StringQuantity.....	146
Table 64 – Attributes of Domain::Susceptance.....	147
Table 65 – Attributes of Domain::SusceptancePerLength.....	147
Table 66 – Attributes of Domain::Temperature	147
Table 67 – Attributes of Domain::TimeInterval.....	147
Table 68 – Literals of Domain::UnitMultiplier.....	148
Table 69 – Literals of Domain::UnitSymbol.....	149
Table 70 – Attributes of Domain::Voltage	154
Table 71 – Attributes of Domain::VoltagePerReactivePower	154
Table 72 – Attributes of Domain::Volume	154
Table 73 – Attributes of Domain::VolumeFlowRate.....	155
Table 74 – Attributes of Domain::WaterLevel	155
Table 75 – Attributes of Core::ACDCTerminal.....	160
Table 76 – Association ends of Core::ACDCTerminal with other classes.....	161
Table 77 – Attributes of Core::BaseFrequency.....	161
Table 78 – Association ends of Core::BaseFrequency with other classes.....	162
Table 79 – Attributes of Core::BasePower.....	162
Table 80 – Association ends of Core::BasePower with other classes	162
Table 81 – Attributes of Core::BaseVoltage.....	162
Table 82 – Association ends of Core::BaseVoltage with other classes	163
Table 83 – Attributes of Core::BasicIntervalSchedule.....	163
Table 84 – Association ends of Core::BasicIntervalSchedule with other classes	163
Table 85 – Attributes of Core::Bay	164
Table 86 – Association ends of Core::Bay with other classes	164
Table 87 – Literals of Core::BreakerConfiguration.....	165
Table 88 – Literals of Core::BusbarConfiguration	165
Table 89 – Attributes of Core::ConductingEquipment	165
Table 90 – Association ends of Core::ConductingEquipment with other classes	166
Table 91 – Attributes of Core::ConnectivityNode	166
Table 92 – Association ends of Core::ConnectivityNode with other classes.....	167

Table 93 – Attributes of Core::ConnectivityNodeContainer	167
Table 94 – Association ends of Core::ConnectivityNodeContainer with other classes.....	167
Table 95 – Attributes of Core::Curve	168
Table 96 – Association ends of Core::Curve with other classes.....	168
Table 97 – Attributes of Core::CurveData.....	168
Table 98 – Association ends of Core::CurveData with other classes	169
Table 99 – Literals of Core::CurveStyle.....	169
Table 100 – Attributes of Core::Equipment.....	169
Table 101 – Association ends of Core::Equipment with other classes	170
Table 102 – Attributes of Core::EquipmentContainer.....	170
Table 103 – Association ends of Core::EquipmentContainer with other classes	171
Table 104 – Attributes of Core::Feeder	171
Table 105 – Association ends of Core::Feeder with other classes	172
Table 106 – Attributes of Core::GeographicalRegion.....	172
Table 107 – Association ends of Core::GeographicalRegion with other classes	173
Table 108 – Attributes of Core::IdentifiedObject.....	173
Table 109 – Association ends of Core::IdentifiedObject with other classes.....	173
Table 110 – Attributes of Core::IrregularIntervalSchedule	174
Table 111 – Association ends of Core::IrregularIntervalSchedule with other classes	174
Table 112 – Attributes of Core::IrregularTimePoint.....	174
Table 113 – Association ends of Core::IrregularTimePoint with other classes	175
Table 114 – Attributes of Core::Name	175
Table 115 – Association ends of Core::Name with other classes	175
Table 116 – Attributes of Core::NameType	175
Table 117 – Association ends of Core::NameType with other classes	176
Table 118 – Attributes of Core::NameTypeAuthority.....	176
Table 119 – Association ends of Core::NameTypeAuthority with other classes	176
Table 120 – Attributes of Core::OperatingParticipant	176
Table 121 – Association ends of Core::OperatingParticipant with other classes	177
Table 122 – Attributes of Core::OperatingShare.....	177
Table 123 – Association ends of Core::OperatingShare with other classes	177
Table 124 – Attributes of Core::PSRType.....	177
Table 125 – Association ends of Core::PSRType with other classes	178
Table 126 – Literals of Core::PhaseCode.....	178
Table 127 – Attributes of Core::PowerSystemResource	179
Table 128 – Association ends of Core::PowerSystemResource with other classes	179
Table 129 – Attributes of Core::RegularIntervalSchedule	180
Table 130 – Association ends of Core::RegularIntervalSchedule with other classes	180
Table 131 – Attributes of Core::RegularTimePoint	180
Table 132 – Association ends of Core::RegularTimePoint with other classes	181
Table 133 – Attributes of Core::ReportingGroup.....	181
Table 134 – Association ends of Core::ReportingGroup with other classes	181
Table 135 – Attributes of Core::ReportingSuperGroup	182

Table 136 – Association ends of Core::ReportingSuperGroup with other classes	182
Table 137 – Attributes of Core::SubGeographicalRegion.....	182
Table 138 – Association ends of Core::SubGeographicalRegion with other classes	182
Table 139 – Attributes of Core::Substation.....	183
Table 140 – Association ends of Core::Substation with other classes	183
Table 141 – Attributes of Core::Terminal.....	184
Table 142 – Association ends of Core::Terminal with other classes	184
Table 143 – Attributes of Core::VoltageLevel	185
Table 144 – Association ends of Core::VoltageLevel with other classes	186
Table 145 – Literals of Wires::AsynchronousMachineKind	202
Table 146 – Attributes of Wires::ACLineSegment.....	202
Table 147 – Association ends of Wires::ACLineSegment with other classes.....	203
Table 148 – Attributes of Wires::ACLineSegmentPhase	204
Table 149 – Association ends of Wires::ACLineSegmentPhase with other classes	204
Table 150 – Attributes of Wires::AsynchronousMachine	205
Table 151 – Association ends of Wires::AsynchronousMachine with other classes.....	206
Table 152 – Attributes of Wires::Breaker.....	207
Table 153 – Association ends of Wires::Breaker with other classes	207
Table 154 – Attributes of Wires::BusbarSection	208
Table 155 – Association ends of Wires::BusbarSection with other classes	208
Table 156 – Attributes of Wires::Clamp	209
Table 157 – Association ends of Wires::Clamp with other classes.....	210
Table 158 – Attributes of Wires::CompositeSwitch	210
Table 159 – Association ends of Wires::CompositeSwitch with other classes	211
Table 160 – Attributes of Wires::Conductor	211
Table 161 – Association ends of Wires::Conductor with other classes.....	212
Table 162 – Attributes of Wires::Connector	212
Table 163 – Association ends of Wires::Connector with other classes.....	213
Table 164 – Literals of Wires::CoolantType.....	213
Table 165 – Attributes of Wires::Cut	214
Table 166 – Association ends of Wires::Cut with other classes	214
Table 167 – Attributes of Wires::Disconnecter.....	215
Table 168 – Association ends of Wires::Disconnecter with other classes	215
Table 169 – Attributes of Wires::DisconnectingCircuitBreaker	216
Table 170 – Association ends of Wires::DisconnectingCircuitBreaker with other classes.....	217
Table 171 – Attributes of Wires::EarthFaultCompensator	217
Table 172 – Association ends of Wires::EarthFaultCompensator with other classes	218
Table 173 – Attributes of Wires::EnergyConnection	218
Table 174 – Association ends of Wires::EnergyConnection with other classes	219
Table 175 – Attributes of Wires::EnergyConsumer	219
Table 176 – Association ends of Wires::EnergyConsumer with other classes.....	220
Table 177 – Attributes of Wires::EnergyConsumerPhase	221
Table 178 – Association ends of Wires::EnergyConsumerPhase with other classes	222

Table 179 – Attributes of Wires::EnergySchedulingType	222
Table 180 – Association ends of Wires::EnergySchedulingType with other classes	222
Table 181 – Attributes of Wires::EnergySource	223
Table 182 – Association ends of Wires::EnergySource with other classes	224
Table 183 – Attributes of Wires::EnergySourcePhase	224
Table 184 – Association ends of Wires::EnergySourcePhase with other classes	225
Table 185 – Attributes of Wires::ExternalNetworkInjection	225
Table 186 – Association ends of Wires::ExternalNetworkInjection with other classes	226
Table 187 – Attributes of Wires::FrequencyConverter	227
Table 188 – Association ends of Wires::FrequencyConverter with other classes	228
Table 189 – Attributes of Wires::Fuse	228
Table 190 – Association ends of Wires::Fuse with other classes	229
Table 191 – Attributes of Wires::Ground	229
Table 192 – Association ends of Wires::Ground with other classes	230
Table 193 – Attributes of Wires::GroundingImpedance	230
Table 194 – Association ends of Wires::GroundingImpedance with other classes	231
Table 195 – Attributes of Wires::GroundDisconnecter	231
Table 196 – Association ends of Wires::GroundDisconnecter with other classes	232
Table 197 – Attributes of Wires::Jumper	233
Table 198 – Association ends of Wires::Jumper with other classes	233
Table 199 – Attributes of Wires::Junction	234
Table 200 – Association ends of Wires::Junction with other classes	234
Table 201 – Attributes of Wires::Line	235
Table 202 – Association ends of Wires::Line with other classes	235
Table 203 – Attributes of Wires::LinearShuntCompensator	235
Table 204 – Association ends of Wires::LinearShuntCompensator with other classes	236
Table 205 – Attributes of Wires::LinearShuntCompensatorPhase	237
Table 206 – Association ends of Wires::LinearShuntCompensatorPhase with other classes	237
Table 207 – Attributes of Wires::LoadBreakSwitch	238
Table 208 – Association ends of Wires::LoadBreakSwitch with other classes	238
Table 209 – Attributes of Wires::MutualCoupling	239
Table 210 – Association ends of Wires::MutualCoupling with other classes	240
Table 211 – Attributes of Wires::NonlinearShuntCompensator	240
Table 212 – Association ends of Wires::NonlinearShuntCompensator with other classes	241
Table 213 – Attributes of Wires::NonlinearShuntCompensatorPhase	241
Table 214 – Association ends of Wires::NonlinearShuntCompensatorPhase with other classes	242
Table 215 – Attributes of Wires::NonlinearShuntCompensatorPhasePoint	242
Table 216 – Association ends of Wires::NonlinearShuntCompensatorPhasePoint with other classes	242
Table 217 – Attributes of Wires::NonlinearShuntCompensatorPoint	243
Table 218 – Association ends of Wires::NonlinearShuntCompensatorPoint with other classes	243

Table 219 – Attributes of Wires::PerLengthImpedance	243
Table 220 – Association ends of Wires::PerLengthImpedance with other classes.....	244
Table 221 – Attributes of Wires::PerLengthLineParameter	244
Table 222 – Association ends of Wires::PerLengthLineParameter with other classes	244
Table 223 – Attributes of Wires::PerLengthPhaseImpedance	244
Table 224 – Association ends of Wires::PerLengthPhaseImpedance with other classes	245
Table 225 – Attributes of Wires::PerLengthSequenceImpedance	245
Table 226 – Association ends of Wires::PerLengthSequenceImpedance with other classes	246
Table 227 – Attributes of Wires::PetersenCoil.....	246
Table 228 – Association ends of Wires::PetersenCoil with other classes.....	247
Table 229 – Literals of Wires::PetersenCoilModeKind	247
Table 230 – Attributes of Wires::PhaseImpedanceData.....	248
Table 231 – Association ends of Wires::PhaseImpedanceData with other classes.....	248
Table 232 – Literals of Wires::PhaseShuntConnectionKind	248
Table 233 – Attributes of Wires::PhaseTapChanger	249
Table 234 – Association ends of Wires::PhaseTapChanger with other classes.....	249
Table 235 – Attributes of Wires::PhaseTapChangerAsymmetrical	250
Table 236 – Association ends of Wires::PhaseTapChangerAsymmetrical with other classes	251
Table 237 – Attributes of Wires::PhaseTapChangerLinear	251
Table 238 – Association ends of Wires::PhaseTapChangerLinear with other classes	252
Table 239 – Attributes of Wires::PhaseTapChangerNonLinear	253
Table 240 – Association ends of Wires::PhaseTapChangerNonLinear with other classes	253
Table 241 – Attributes of Wires::PhaseTapChangerSymmetrical	254
Table 242 – Association ends of Wires::PhaseTapChangerSymmetrical with other classes	255
Table 243 – Attributes of Wires::PhaseTapChangerTable	255
Table 244 – Association ends of Wires::PhaseTapChangerTable with other classes	255
Table 245 – Attributes of Wires::PhaseTapChangerTablePoint	256
Table 246 – Association ends of Wires::PhaseTapChangerTablePoint with other classes	256
Table 247 – Attributes of Wires::PhaseTapChangerTabular	256
Table 248 – Association ends of Wires::PhaseTapChangerTabular with other classes	257
Table 249 – Attributes of Wires::Plant.....	257
Table 250 – Association ends of Wires::Plant with other classes.....	257
Table 251 – Attributes of Wires::PowerElectronicsConnection	258
Table 252 – Association ends of Wires::PowerElectronicsConnection with other classes	259
Table 253 – Attributes of Wires::PowerElectronicsConnectionPhase.....	260
Table 254 – Association ends of Wires::PowerElectronicsConnectionPhase with other classes	260
Table 255 – Attributes of Wires::PowerTransformer	261
Table 256 – Association ends of Wires::PowerTransformer with other classes	262

Table 257 – Attributes of Wires::PowerTransformerEnd	263
Table 258 – Association ends of Wires::PowerTransformerEnd with other classes	264
Table 259 – Attributes of Wires::ProtectedSwitch	265
Table 260 – Association ends of Wires::ProtectedSwitch with other classes	265
Table 261 – Attributes of Wires::RatioTapChanger	266
Table 262 – Association ends of Wires::RatioTapChanger with other classes	267
Table 263 – Attributes of Wires::RatioTapChangerTable	267
Table 264 – Association ends of Wires::RatioTapChangerTable with other classes	267
Table 265 – Attributes of Wires::RatioTapChangerTablePoint	268
Table 266 – Association ends of Wires::RatioTapChangerTablePoint with other classes	268
Table 267 – Attributes of Wires::ReactiveCapabilityCurve	268
Table 268 – Association ends of Wires::ReactiveCapabilityCurve with other classes	269
Table 269 – Attributes of Wires::Recloser	269
Table 270 – Association ends of Wires::Recloser with other classes	270
Table 271 – Attributes of Wires::RegulatingCondEq	270
Table 272 – Association ends of Wires::RegulatingCondEq with other classes	271
Table 273 – Attributes of Wires::RegulatingControl	272
Table 274 – Association ends of Wires::RegulatingControl with other classes	273
Table 275 – Literals of Wires::RegulatingControlModeKind	273
Table 276 – Attributes of Wires::RegulationSchedule	274
Table 277 – Association ends of Wires::RegulationSchedule with other classes	274
Table 278 – Attributes of Wires::RotatingMachine	274
Table 279 – Association ends of Wires::RotatingMachine with other classes	275
Table 280 – Attributes of Wires::Sectionaliser	276
Table 281 – Association ends of Wires::Sectionaliser with other classes	276
Table 282 – Attributes of Wires::SeriesCompensator	277
Table 283 – Association ends of Wires::SeriesCompensator with other classes	278
Table 284 – Literals of Wires::ShortCircuitRotorKind	278
Table 285 – Attributes of Wires::ShuntCompensator	279
Table 286 – Association ends of Wires::ShuntCompensator with other classes	280
Table 287 – Attributes of Wires::ShuntCompensatorPhase	280
Table 288 – Association ends of Wires::ShuntCompensatorPhase with other classes	281
Table 289 – Literals of Wires::SinglePhaseKind	282
Table 290 – Attributes of Wires::StaticVarCompensator	282
Table 291 – Association ends of Wires::StaticVarCompensator with other classes	283
Table 292 – Literals of Wires::SVCControlMode	283
Table 293 – Attributes of Wires::Switch	284
Table 294 – Association ends of Wires::Switch with other classes	285
Table 295 – Attributes of Wires::SwitchPhase	285
Table 296 – Association ends of Wires::SwitchPhase with other classes	286
Table 297 – Attributes of Wires::SwitchSchedule	286
Table 298 – Association ends of Wires::SwitchSchedule with other classes	287
Table 299 – Attributes of Wires::SynchronousMachine	287

Table 300 – Association ends of Wires::SynchronousMachine with other classes	289
Table 301 – Literals of Wires::SynchronousMachineOperatingMode	290
Table 302 – Literals of Wires::SynchronousMachineKind	290
Table 303 – Attributes of Wires::TapChanger.....	291
Table 304 – Association ends of Wires::TapChanger with other classes	292
Table 305 – Attributes of Wires::TapChangerControl	292
Table 306 – Association ends of Wires::TapChangerControl with other classes	293
Table 307 – Attributes of Wires::TapChangerTablePoint	293
Table 308 – Attributes of Wires::TapSchedule.....	294
Table 309 – Association ends of Wires::TapSchedule with other classes	295
Table 310 – Literals of Wires::TransformerControlMode.....	295
Table 311 – Attributes of Wires::TransformerCoreAdmittance	295
Table 312 – Association ends of Wires::TransformerCoreAdmittance with other classes	296
Table 313 – Attributes of Wires::TransformerEnd	296
Table 314 – Association ends of Wires::TransformerEnd with other classes.....	297
Table 315 – Attributes of Wires::TransformerMeshImpedance.....	297
Table 316 – Association ends of Wires::TransformerMeshImpedance with other classes	298
Table 317 – Attributes of Wires::TransformerStarImpedance.....	298
Table 318 – Association ends of Wires::TransformerStarImpedance with other classes	298
Table 319 – Attributes of Wires::TransformerTank	299
Table 320 – Association ends of Wires::TransformerTank with other classes	299
Table 321 – Attributes of Wires::TransformerTankEnd	300
Table 322 – Association ends of Wires::TransformerTankEnd with other classes	300
Table 323 – Attributes of Wires::VoltageControlZone	301
Table 324 – Association ends of Wires::VoltageControlZone with other classes.....	301
Table 325 – Attributes of Wires::WireSegment	301
Table 326 – Association ends of Wires::WireSegment with other classes.....	302
Table 327 – Attributes of Wires::WireSegmentPhase	302
Table 328 – Association ends of Wires::WireSegmentPhase with other classes	303
Table 329 – Literals of Wires::WindingConnection	303
Table 330 – Attributes of LoadModel::ConformLoad.....	305
Table 331 – Association ends of LoadModel::ConformLoad with other classes.....	305
Table 332 – Attributes of LoadModel::ConformLoadGroup	306
Table 333 – Association ends of LoadModel::ConformLoadGroup with other classes	306
Table 334 – Attributes of LoadModel::ConformLoadSchedule	307
Table 335 – Association ends of LoadModel::ConformLoadSchedule with other classes	307
Table 336 – Attributes of LoadModel::DayType	307
Table 337 – Association ends of LoadModel::DayType with other classes.....	308
Table 338 – Attributes of LoadModel::EnergyArea	308
Table 339 – Association ends of LoadModel::EnergyArea with other classes	308
Table 340 – Attributes of LoadModel::LoadArea.....	308
Table 341 – Association ends of LoadModel::LoadArea with other classes	309
Table 342 – Attributes of LoadModel::LoadGroup	309

Table 343 – Association ends of LoadModel::LoadGroup with other classes	309
Table 344 – Attributes of LoadModel::LoadResponseCharacteristic	310
Table 345 – Association ends of LoadModel::LoadResponseCharacteristic with other classes	311
Table 346 – Attributes of LoadModel::NonConformLoad.....	311
Table 347 – Association ends of LoadModel::NonConformLoad with other classes	312
Table 348 – Attributes of LoadModel::NonConformLoadGroup	312
Table 349 – Association ends of LoadModel::NonConformLoadGroup with other classes	313
Table 350 – Attributes of LoadModel::NonConformLoadSchedule	313
Table 351 – Association ends of LoadModel::NonConformLoadSchedule with other classes	313
Table 352 – Attributes of LoadModel::PowerCutZone.....	314
Table 353 – Association ends of LoadModel::PowerCutZone with other classes	314
Table 354 – Attributes of LoadModel::Season	314
Table 355 – Association ends of LoadModel::Season with other classes.....	315
Table 356 – Attributes of LoadModel::SeasonDayTypeSchedule	315
Table 357 – Association ends of LoadModel::SeasonDayTypeSchedule with other classes	315
Table 358 – Attributes of LoadModel::StationSupply	316
Table 359 – Association ends of LoadModel::StationSupply with other classes	316
Table 360 – Attributes of LoadModel::SubLoadArea.....	317
Table 361 – Association ends of LoadModel::SubLoadArea with other classes	317
Table 362 – Attributes of GenerationTrainingSimulation::BWRSteamSupply	319
Table 363 – Association ends of GenerationTrainingSimulation::BWRSteamSupply with other classes	320
Table 364 – Literals of GenerationTrainingSimulation::BoilerControlMode	320
Table 365 – Attributes of GenerationTrainingSimulation::CTTempActivePowerCurve	321
Table 366 – Association ends of GenerationTrainingSimulation::CTTempActivePowerCurve with other classes	321
Table 367 – Attributes of GenerationTrainingSimulation::CombustionTurbine	321
Table 368 – Association ends of GenerationTrainingSimulation::CombustionTurbine with other classes	322
Table 369 – Attributes of GenerationTrainingSimulation::DrumBoiler	323
Table 370 – Association ends of GenerationTrainingSimulation::DrumBoiler with other classes	324
Table 371 – Attributes of GenerationTrainingSimulation::FossilSteamSupply	324
Table 372 – Association ends of GenerationTrainingSimulation::FossilSteamSupply with other classes	325
Table 373 – Attributes of GenerationTrainingSimulation::HeatRecoveryBoiler	325
Table 374 – Association ends of GenerationTrainingSimulation::HeatRecoveryBoiler with other classes	326
Table 375 – Attributes of GenerationTrainingSimulation::HydroTurbine.....	327
Table 376 – Association ends of GenerationTrainingSimulation::HydroTurbine with other classes	327
Table 377 – Attributes of GenerationTrainingSimulation::PWRSteamSupply	328

Table 378 – Association ends of GenerationTrainingSimulation::PWRSteamSupply with other classes	328
Table 379 – Attributes of GenerationTrainingSimulation::PrimeMover	329
Table 380 – Association ends of GenerationTrainingSimulation::PrimeMover with other classes	329
Table 381 – Attributes of GenerationTrainingSimulation::SteamSupply	329
Table 382 – Association ends of GenerationTrainingSimulation::SteamSupply with other classes	330
Table 383 – Attributes of GenerationTrainingSimulation::SteamTurbine	330
Table 384 – Association ends of GenerationTrainingSimulation::SteamTurbine with other classes	331
Table 385 – Attributes of GenerationTrainingSimulation::Subcritical	331
Table 386 – Association ends of GenerationTrainingSimulation::Subcritical with other classes	332
Table 387 – Attributes of GenerationTrainingSimulation::Supercritical	332
Table 388 – Association ends of GenerationTrainingSimulation::Supercritical with other classes	333
Table 389 – Literals of GenerationTrainingSimulation::HydroTurbineKind	334
Table 390 – Attributes of Production::AirCompressor	339
Table 391 – Association ends of Production::AirCompressor with other classes	340
Table 392 – Literals of Production::BatteryStateKind	340
Table 393 – Attributes of Production::BatteryUnit	340
Table 394 – Association ends of Production::BatteryUnit with other classes	341
Table 395 – Attributes of Production::CAESPlant	341
Table 396 – Association ends of Production::CAESPlant with other classes	342
Table 397 – Attributes of Production::CogenerationPlant	342
Table 398 – Association ends of Production::CogenerationPlant with other classes	343
Table 399 – Attributes of Production::CombinedCyclePlant	343
Table 400 – Association ends of Production::CombinedCyclePlant with other classes	343
Table 401 – Attributes of Production::EmissionAccount	344
Table 402 – Association ends of Production::EmissionAccount with other classes	344
Table 403 – Attributes of Production::EmissionCurve	345
Table 404 – Association ends of Production::EmissionCurve with other classes	345
Table 405 – Literals of Production::EmissionType	346
Table 406 – Literals of Production::WindGenUnitKind	346
Table 407 – Literals of Production::EmissionValueSource	346
Table 408 – Attributes of Production::FossilFuel	347
Table 409 – Association ends of Production::FossilFuel with other classes	347
Table 410 – Attributes of Production::FuelAllocationSchedule	348
Table 411 – Association ends of Production::FuelAllocationSchedule with other classes	348
Table 412 – Literals of Production::FuelType	349
Table 413 – Attributes of Production::GenUnitOpCostCurve	349
Table 414 – Association ends of Production::GenUnitOpCostCurve with other classes	350
Table 415 – Attributes of Production::GenUnitOpSchedule	350
Table 416 – Association ends of Production::GenUnitOpSchedule with other classes	350

Table 417 – Attributes of Production::GeneratingUnit.....	351
Table 418 – Association ends of Production::GeneratingUnit with other classes	353
Table 419 – Literals of Production::GeneratorControlMode	354
Table 420 – Literals of Production::GeneratorControlSource.....	354
Table 421 – Attributes of Production::GrossToNetActivePowerCurve	354
Table 422 – Association ends of Production::GrossToNetActivePowerCurve with other classes	355
Table 423 – Attributes of Production::HeatInputCurve.....	355
Table 424 – Association ends of Production::HeatInputCurve with other classes.....	356
Table 425 – Attributes of Production::HeatRateCurve	356
Table 426 – Association ends of Production::HeatRateCurve with other classes	356
Table 427 – Literals of Production::HydroEnergyConversionKind	357
Table 428 – Attributes of Production::HydroGeneratingEfficiencyCurve	357
Table 429 – Association ends of Production::HydroGeneratingEfficiencyCurve with other classes	358
Table 430 – Attributes of Production::HydroGeneratingUnit	358
Table 431 – Association ends of Production::HydroGeneratingUnit with other classes	359
Table 432 – Literals of Production::HydroPlantStorageKind	360
Table 433 – Attributes of Production::HydroPowerPlant	360
Table 434 – Association ends of Production::HydroPowerPlant with other classes	361
Table 435 – Attributes of Production::HydroPump	362
Table 436 – Association ends of Production::HydroPump with other classes.....	362
Table 437 – Attributes of Production::HydroPumpOpSchedule	363
Table 438 – Association ends of Production::HydroPumpOpSchedule with other classes	363
Table 439 – Attributes of Production::IncrementalHeatRateCurve	364
Table 440 – Association ends of Production::IncrementalHeatRateCurve with other classes	364
Table 441 – Attributes of Production::InflowForecast	364
Table 442 – Association ends of Production::InflowForecast with other classes	365
Table 443 – Attributes of Production::LevelVsVolumeCurve	365
Table 444 – Association ends of Production::LevelVsVolumeCurve with other classes.....	366
Table 445 – Attributes of Production::NuclearGeneratingUnit.....	366
Table 446 – Association ends of Production::NuclearGeneratingUnit with other classes	367
Table 447 – Attributes of Production::PenstockLossCurve	368
Table 448 – Association ends of Production::PenstockLossCurve with other classes	368
Table 449 – Attributes of Production::PhotoVoltaicUnit	369
Table 450 – Association ends of Production::PhotoVoltaicUnit with other classes	369
Table 451 – Attributes of Production::PowerElectronicsUnit	370
Table 452 – Association ends of Production::PowerElectronicsUnit with other classes.....	370
Table 453 – Attributes of Production::PowerElectronicsWindUnit	371
Table 454 – Association ends of Production::PowerElectronicsWindUnit with other classes	371
Table 455 – Attributes of Production::Reservoir	372
Table 456 – Association ends of Production::Reservoir with other classes	372

Table 457 – Attributes of Production::ShutdownCurve.....	373
Table 458 – Association ends of Production::ShutdownCurve with other classes	373
Table 459 – Attributes of Production::SolarGeneratingUnit.....	374
Table 460 – Association ends of Production::SolarGeneratingUnit with other classes	375
Table 461 – Attributes of Production::StartIgnFuelCurve.....	376
Table 462 – Association ends of Production::StartIgnFuelCurve with other classes.....	376
Table 463 – Attributes of Production::StartMainFuelCurve	376
Table 464 – Association ends of Production::StartMainFuelCurve with other classes	377
Table 465 – Attributes of Production::StartRampCurve	377
Table 466 – Association ends of Production::StartRampCurve with other classes	378
Table 467 – Attributes of Production::StartupModel	378
Table 468 – Association ends of Production::StartupModel with other classes	379
Table 469 – Attributes of Production::SteamSendoutSchedule	379
Table 470 – Association ends of Production::SteamSendoutSchedule with other classes	379
Table 471 – Attributes of Production::TailbayLossCurve	380
Table 472 – Association ends of Production::TailbayLossCurve with other classes	380
Table 473 – Attributes of Production::TargetLevelSchedule	381
Table 474 – Association ends of Production::TargetLevelSchedule with other classes	381
Table 475 – Attributes of Production::ThermalGeneratingUnit	382
Table 476 – Association ends of Production::ThermalGeneratingUnit with other classes.....	383
Table 477 – Attributes of Production::WindGeneratingUnit.....	384
Table 478 – Association ends of Production::WindGeneratingUnit with other classes.....	385
Table 479 – Attributes of DC::ACDCCConverter	391
Table 480 – Association ends of DC::ACDCCConverter with other classes.....	392
Table 481 – Attributes of DC::ACDCCConverterDCTerminal.....	393
Table 482 – Association ends of DC::ACDCCConverterDCTerminal with other classes	393
Table 483 – Attributes of DC::CsConverter	394
Table 484 – Association ends of DC::CsConverter with other classes	396
Table 485 – Attributes of DC::DCTopologicalNode	396
Table 486 – Association ends of DC::DCTopologicalNode with other classes.....	397
Table 487 – Literals of DC::CsOperatingModeKind	397
Table 488 – Literals of DC::CsPpccControlKind	397
Table 489 – Attributes of DC::DCBaseTerminal.....	398
Table 490 – Association ends of DC::DCBaseTerminal with other classes	398
Table 491 – Attributes of DC::DCBreaker.....	398
Table 492 – Association ends of DC::DCBreaker with other classes	399
Table 493 – Attributes of DC::DCBusbar	399
Table 494 – Association ends of DC::DCBusbar with other classes.....	400
Table 495 – Attributes of DC::DCChopper.....	400
Table 496 – Association ends of DC::DCChopper with other classes	401
Table 497 – Attributes of DC::DCConductingEquipment.....	401
Table 498 – Association ends of DC::DCConductingEquipment with other classes.....	402

Table 499 – Literals of DC::DCConverterOperatingModeKind	402
Table 500 – Attributes of DC::DCConverterUnit	402
Table 501 – Association ends of DC::DCConverterUnit with other classes	403
Table 502 – Attributes of DC::DCDisconnecter.....	403
Table 503 – Association ends of DC::DCDisconnecter with other classes	404
Table 504 – Attributes of DC::DCEquipmentContainer	404
Table 505 – Association ends of DC::DCEquipmentContainer with other classes	405
Table 506 – Attributes of DC::DCGround	405
Table 507 – Association ends of DC::DCGround with other classes	406
Table 508 – Attributes of DC::DCLine	406
Table 509 – Association ends of DC::DCLine with other classes	406
Table 510 – Attributes of DC::DCLineSegment.....	407
Table 511 – Association ends of DC::DCLineSegment with other classes	408
Table 512 – Attributes of DC::DCNode.....	408
Table 513 – Association ends of DC::DCNode with other classes	409
Table 514 – Literals of DC::DCPolarityKind.....	409
Table 515 – Attributes of DC::DCSeriesDevice	409
Table 516 – Association ends of DC::DCSeriesDevice with other classes	410
Table 517 – Attributes of DC::DCShunt.....	410
Table 518 – Association ends of DC::DCShunt with other classes.....	411
Table 519 – Attributes of DC::DCSwitch.....	411
Table 520 – Association ends of DC::DCSwitch with other classes	412
Table 521 – Attributes of DC::DCTerminal	412
Table 522 – Association ends of DC::DCTerminal with other classes	412
Table 523 – Attributes of DC::DCTopologicalIsland.....	413
Table 524 – Association ends of DC::DCTopologicalIsland with other classes	413
Table 525 – Attributes of DC::PerLengthDCLineParameter	413
Table 526 – Association ends of DC::PerLengthDCLineParameter with other classes	414
Table 527 – Attributes of DC::VsCapabilityCurve	414
Table 528 – Association ends of DC::VsCapabilityCurve with other classes	414
Table 529 – Attributes of DC::VsConverter.....	415
Table 530 – Association ends of DC::VsConverter with other classes	416
Table 531 – Literals of DC::VsPpccControlKind	417
Table 532 – Literals of DC::VsQpccControlKind	418
Table 533 – Attributes of Equivalents::EquivalentBranch	420
Table 534 – Association ends of Equivalents::EquivalentBranch with other classes	422
Table 535 – Attributes of Equivalents::EquivalentEquipment.....	422
Table 536 – Association ends of Equivalents::EquivalentEquipment with other classes.....	423
Table 537 – Attributes of Equivalents::EquivalentInjection	423
Table 538 – Association ends of Equivalents::EquivalentInjection with other classes	425
Table 539 – Attributes of Equivalents::EquivalentNetwork.....	425
Table 540 – Association ends of Equivalents::EquivalentNetwork with other classes	426
Table 541 – Attributes of Equivalents::EquivalentShunt	426

Table 542 – Association ends of EquivalentShunt with other classes	427
Table 543 – Attributes of AuxiliaryEquipment	429
Table 544 – Association ends of AuxiliaryEquipment with other classes	429
Table 545 – Attributes of AuxiliaryEquipment::CurrentTransformer	430
Table 546 – Association ends of AuxiliaryEquipment::CurrentTransformer with other classes	430
Table 547 – Attributes of AuxiliaryEquipment::FaultIndicator	431
Table 548 – Association ends of AuxiliaryEquipment::FaultIndicator with other classes	431
Table 549 – Attributes of AuxiliaryEquipment::PostLineSensor	432
Table 550 – Association ends of AuxiliaryEquipment::PostLineSensor with other classes	432
Table 551 – Attributes of AuxiliaryEquipment::PotentialTransformer	433
Table 552 – Association ends of AuxiliaryEquipment::PotentialTransformer with other classes	433
Table 553 – Literals of AuxiliaryEquipment::PotentialTransformerKind	434
Table 554 – Attributes of AuxiliaryEquipment::Sensor	434
Table 555 – Association ends of AuxiliaryEquipment::Sensor with other classes	434
Table 556 – Attributes of AuxiliaryEquipment::SurgeArrester	435
Table 557 – Association ends of AuxiliaryEquipment::SurgeArrester with other classes	435
Table 558 – Attributes of AuxiliaryEquipment::WaveTrap	436
Table 559 – Association ends of AuxiliaryEquipment::WaveTrap with other classes	436
Table 560 – Attributes of Meas::Accumulator	440
Table 561 – Association ends of Meas::Accumulator with other classes	441
Table 562 – Attributes of Meas::AccumulatorLimit	441
Table 563 – Association ends of Meas::AccumulatorLimit with other classes	441
Table 564 – Attributes of Meas::AccumulatorLimitSet	442
Table 565 – Association ends of Meas::AccumulatorLimitSet with other classes	442
Table 566 – Attributes of Meas::AccumulatorReset	442
Table 567 – Association ends of Meas::AccumulatorReset with other classes	443
Table 568 – Attributes of Meas::AccumulatorValue	443
Table 569 – Association ends of Meas::AccumulatorValue with other classes	443
Table 570 – Attributes of Meas::Analog	444
Table 571 – Association ends of Meas::Analog with other classes	444
Table 572 – Attributes of Meas::AnalogControl	445
Table 573 – Association ends of Meas::AnalogControl with other classes	445
Table 574 – Attributes of Meas::AnalogLimit	445
Table 575 – Association ends of Meas::AnalogLimit with other classes	446
Table 576 – Attributes of Meas::AnalogLimitSet	446
Table 577 – Association ends of Meas::AnalogLimitSet with other classes	446
Table 578 – Attributes of Meas::AnalogValue	447
Table 579 – Association ends of Meas::AnalogValue with other classes	447
Table 580 – Attributes of Meas::Command	448
Table 581 – Association ends of Meas::Command with other classes	448

Table 582 – Attributes of Meas::Control	449
Table 583 – Association ends of Meas::Control with other classes	449
Table 584 – Attributes of Meas::Discrete	450
Table 585 – Association ends of Meas::Discrete with other classes	450
Table 586 – Attributes of Meas::DiscreteValue	450
Table 587 – Association ends of Meas::DiscreteValue with other classes	451
Table 588 – Attributes of Meas::IOPoint	451
Table 589 – Association ends of Meas::IOPoint with other classes	451
Table 590 – Attributes of Meas::Limit	452
Table 591 – Association ends of Meas::Limit with other classes	452
Table 592 – Attributes of Meas::LimitSet	452
Table 593 – Association ends of Meas::LimitSet with other classes	453
Table 594 – Attributes of Meas::Measurement	453
Table 595 – Association ends of Meas::Measurement with other classes	454
Table 596 – Attributes of Meas::MeasurementValue	454
Table 597 – Association ends of Meas::MeasurementValue with other classes	455
Table 598 – Attributes of Meas::MeasurementValueQuality	455
Table 599 – Association ends of Meas::MeasurementValueQuality with other classes	456
Table 600 – Attributes of Meas::MeasurementValueSource	456
Table 601 – Association ends of Meas::MeasurementValueSource with other classes	456
Table 602 – Attributes of Meas::Quality61850	457
Table 603 – Attributes of Meas::RaiseLowerCommand	458
Table 604 – Association ends of Meas::RaiseLowerCommand with other classes	458
Table 605 – Attributes of Meas::SetPoint	458
Table 606 – Association ends of Meas::SetPoint with other classes	459
Table 607 – Attributes of Meas::StringMeasurement	459
Table 608 – Association ends of Meas::StringMeasurement with other classes	460
Table 609 – Attributes of Meas::StringMeasurementValue	460
Table 610 – Association ends of Meas::StringMeasurementValue with other classes	460
Table 611 – Literals of Meas::Validity	461
Table 612 – Attributes of Meas::ValueAliasSet	461
Table 613 – Association ends of Meas::ValueAliasSet with other classes	461
Table 614 – Attributes of Meas::ValueToAlias	462
Table 615 – Association ends of Meas::ValueToAlias with other classes	462
Table 616 – Attributes of Topology::BusNameMarker	464
Table 617 – Association ends of Topology::BusNameMarker with other classes	464
Table 618 – Attributes of Topology::TopologicalIsland	465
Table 619 – Association ends of Topology::TopologicalIsland with other classes	465
Table 620 – Attributes of Topology::TopologicalNode	465
Table 621 – Association ends of Topology::TopologicalNode with other classes	466
Table 622 – Attributes of DiagramLayout::Diagram	467
Table 623 – Association ends of DiagramLayout::Diagram with other classes	468
Table 624 – Attributes of DiagramLayout::DiagramObject	468

Table 625 – Association ends of DiagramLayout::DiagramObject with other classes	469
Table 626 – Association ends of DiagramLayout::DiagramObjectGluePoint with other classes	470
Table 627 – Attributes of DiagramLayout::DiagramObjectPoint	470
Table 628 – Association ends of DiagramLayout::DiagramObjectPoint with other classes	470
Table 629 – Attributes of DiagramLayout::DiagramObjectStyle	471
Table 630 – Association ends of DiagramLayout::DiagramObjectStyle with other classes	471
Table 631 – Attributes of DiagramLayout::DiagramStyle	471
Table 632 – Association ends of DiagramLayout::DiagramStyle with other classes	471
Table 633 – Literals of DiagramLayout::OrientationKind	472
Table 634 – Attributes of DiagramLayout::TextDiagramObject	472
Table 635 – Association ends of DiagramLayout::TextDiagramObject with other classes	472
Table 636 – Attributes of DiagramLayout::VisibilityLayer	473
Table 637 – Association ends of DiagramLayout::VisibilityLayer with other classes	473
Table 638 – Attributes of OperationalLimits::ActivePowerLimit	475
Table 639 – Association ends of OperationalLimits::ActivePowerLimit with other classes	476
Table 640 – Attributes of OperationalLimits::ApparentPowerLimit	476
Table 641 – Association ends of OperationalLimits::ApparentPowerLimit with other classes	476
Table 642 – Attributes of OperationalLimits::BranchGroup	477
Table 643 – Association ends of OperationalLimits::BranchGroup with other classes	477
Table 644 – Attributes of OperationalLimits::BranchGroupTerminal	477
Table 645 – Association ends of OperationalLimits::BranchGroupTerminal with other classes	477
Table 646 – Attributes of OperationalLimits::CurrentLimit	478
Table 647 – Association ends of OperationalLimits::CurrentLimit with other classes	478
Table 648 – Attributes of OperationalLimits::OperationalLimit	478
Table 649 – Association ends of OperationalLimits::OperationalLimit with other classes	479
Table 650 – Literals of OperationalLimits::OperationalLimitDirectionKind	479
Table 651 – Attributes of OperationalLimits::OperationalLimitSet	479
Table 652 – Association ends of OperationalLimits::OperationalLimitSet with other classes	480
Table 653 – Attributes of OperationalLimits::OperationalLimitType	480
Table 654 – Association ends of OperationalLimits::OperationalLimitType with other classes	480
Table 655 – Attributes of OperationalLimits::VoltageLimit	481
Table 656 – Association ends of OperationalLimits::VoltageLimit with other classes	481
Table 657 – Attributes of ControlArea::AltGeneratingUnitMeas	484
Table 658 – Association ends of ControlArea::AltGeneratingUnitMeas with other classes	484
Table 659 – Attributes of ControlArea::AltTieMeas	484
Table 660 – Association ends of ControlArea::AltTieMeas with other classes	485

Table 661 – Attributes of ControlArea::ControlArea.....	485
Table 662 – Association ends of ControlArea::ControlArea with other classes	486
Table 663 – Attributes of ControlArea::ControlAreaGeneratingUnit	486
Table 664 – Association ends of ControlArea::ControlAreaGeneratingUnit with other classes	487
Table 665 – Literals of ControlArea::ControlAreaTypeKind.....	487
Table 666 – Attributes of ControlArea::TieFlow	487
Table 667 – Association ends of ControlArea::TieFlow with other classes.....	488
Table 668 – Attributes of Contingency::Contingency	489
Table 669 – Association ends of Contingency::Contingency with other classes	489
Table 670 – Attributes of Contingency::ContingencyElement.....	489
Table 671 – Association ends of Contingency::ContingencyElement with other classes	489
Table 672 – Attributes of Contingency::ContingencyEquipment.....	490
Table 673 – Association ends of Contingency::ContingencyEquipment with other classes	490
Table 674 – Literals of Contingency::ContingencyEquipmentStatusKind	490
Table 675 – Attributes of StateVariables::SvInjection	492
Table 676 – Association ends of StateVariables::SvInjection with other classes.....	492
Table 677 – Attributes of StateVariables::SvPowerFlow	492
Table 678 – Association ends of StateVariables::SvPowerFlow with other classes.....	492
Table 679 – Attributes of StateVariables::SvShuntCompensatorSections	493
Table 680 – Association ends of StateVariables::SvShuntCompensatorSections with other classes	493
Table 681 – Attributes of StateVariables::SvStatus	493
Table 682 – Association ends of StateVariables::SvStatus with other classes	493
Table 683 – Attributes of StateVariables::SvSwitch.....	494
Table 684 – Association ends of StateVariables::SvSwitch with other classes	494
Table 685 – Attributes of StateVariables::SvTapStep	494
Table 686 – Association ends of StateVariables::SvTapStep with other classes.....	494
Table 687 – Attributes of StateVariables::SvVoltage	495
Table 688 – Association ends of StateVariables::SvVoltage with other classes	495
Table 689 – Attributes of Protection::CurrentRelay.....	496
Table 690 – Association ends of Protection::CurrentRelay with other classes	497
Table 691 – Attributes of Protection::ProtectionEquipment.....	497
Table 692 – Association ends of Protection::ProtectionEquipment with other classes	498
Table 693 – Attributes of Protection::RecloseSequence	498
Table 694 – Association ends of Protection::RecloseSequence with other classes.....	499
Table 695 – Attributes of Protection::SynchrocheckRelay	499
Table 696 – Association ends of Protection::SynchrocheckRelay with other classes	500
Table 697 – Attributes of Faults::EquipmentFault.....	501
Table 698 – Association ends of Faults::EquipmentFault with other classes.....	501
Table 699 – Attributes of Faults::Fault	501
Table 700 – Association ends of Faults::Fault with other classes	502
Table 701 – Attributes of Faults::FaultCauseType	502

Table 702 – Association ends of Faults::FaultCauseType with other classes.....	502
Table 703 – Attributes of Faults::FaultImpedance	503
Table 704 – Attributes of Faults::LineFault.....	503
Table 705 – Association ends of Faults::LineFault with other classes.....	503
Table 706 – Literals of Faults::PhaseConnectedFaultKind.....	504
Table 707 – Attributes of SCADA::CommunicationLink.....	505
Table 708 – Association ends of SCADA::CommunicationLink with other classes	506
Table 709 – Attributes of SCADA::RemoteControl.....	506
Table 710 – Association ends of SCADA::RemoteControl with other classes	506
Table 711 – Attributes of SCADA::RemotePoint	507
Table 712 – Association ends of SCADA::RemotePoint with other classes.....	507
Table 713 – Attributes of SCADA::RemoteSource	507
Table 714 – Association ends of SCADA::RemoteSource with other classes.....	508
Table 715 – Attributes of SCADA::RemoteUnit.....	508
Table 716 – Association ends of SCADA::RemoteUnit with other classes	508
Table 717 – Literals of SCADA::RemoteUnitType.....	509
Table 718 – Literals of SCADA::Source	509
Table 719 – Literals of ICCPConfiguration::ApplicationSecurityKind.....	512
Table 720 – Attributes of ICCPConfiguration::BilateralExchangeActor.....	512
Table 721 – Association ends of ICCPConfiguration::BilateralExchangeActor with other classes	512
Table 722 – Attributes of ICCPConfiguration::BilateralExchangeAgreement.....	513
Table 723 – Association ends of ICCPConfiguration::BilateralExchangeAgreement with other classes	513
Table 724 – Literals of ICCPConfiguration::ICCPAccessPrivilegeKind.....	513
Table 725 – Attributes of ICCPConfiguration::ICCPInformationMessage	514
Table 726 – Association ends of ICCPConfiguration::ICCPInformationMessage with other classes	514
Table 727 – Literals of ICCPConfiguration::ICCPPointKind	514
Table 728 – Attributes of ICCPConfiguration::ICCPProvidedPoint.....	515
Table 729 – Association ends of ICCPConfiguration::ICCPProvidedPoint with other classes	515
Table 730 – Literals of ICCPConfiguration::ICCPQualityKind	516
Table 731 – Literals of ICCPConfiguration::ICCPScopeKind	516
Table 732 – Attributes of ICCPConfiguration::ICCPVCC	516
Table 733 – Association ends of ICCPConfiguration::ICCPVCC with other classes	517
Table 734 – Attributes of ICCPConfiguration::ICCPVirtualControlCentre	517
Table 735 – Association ends of ICCPConfiguration::ICCPVirtualControlCentre with other classes	518
Table 736 – Attributes of ICCPConfiguration::IOPointSource	518
Table 737 – Association ends of ICCPConfiguration::IOPointSource with other classes	519
Table 738 – Attributes of ICCPConfiguration::IPAccessPoint	519
Table 739 – Association ends of ICCPConfiguration::IPAccessPoint with other classes	519
Table 740 – Literals of ICCPConfiguration::IPAddressKind	520
Table 741 – Attributes of ICCPConfiguration::ISUpperLayer.....	520

Table 742 – Association ends of ICCPConfiguration::ISOUpperLayer with other classes.....	521
Table 743 – Attributes of ICCPConfiguration::ProvidedBilateralPoint	521
Table 744 – Association ends of ICCPConfiguration::ProvidedBilateralPoint with other classes	521
Table 745 – Attributes of ICCPConfiguration::PublicX509Certificate	522
Table 746 – Association ends of ICCPConfiguration::PublicX509Certificate with other classes	522
Table 747 – Attributes of ICCPConfiguration::TASE2BilateralTable.....	522
Table 748 – Association ends of ICCPConfiguration::TASE2BilateralTable with other classes	523
Table 749 – Attributes of ICCPConfiguration::TCPAccessPoint.....	523
Table 750 – Association ends of ICCPConfiguration::TCPAccessPoint with other classes	524
Table A.1 – Attributes of ExtEuCore::BoundaryPoint.....	527
Table A.2 – Association ends of ExtEuCore::BoundaryPoint with other classes.....	528
Table A.3 – Attributes of ExtEuCore::ExtEulIdentifiedObject	528
Table A.4 – Attributes of ExtEuOperationalLimits::ExtEuOperationalLimitType.....	529
Table A.5 – Literals of ExtEuOperationalLimits::LimitKind	530
Table A.6 – Attributes of ExtEuProduction::SolarPowerPlant.....	532
Table A.7 – Association ends of ExtEuProduction::SolarPowerPlant with other classes	532
Table A.8 – Attributes of ExtEuProduction::WindPowerPlant	533
Table A.9 – Association ends of ExtEuProduction::WindPowerPlant with other classes.....	533

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ENERGY MANAGEMENT SYSTEM APPLICATION PROGRAM INTERFACE (EMS-API) –

Part 301: Common information model (CIM) base

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61970-301 has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

This seventh edition cancels and replaces the sixth edition, published in 2016. This edition constitutes a technical revision.

This edition reflects the model content version ‘IEC61970CIM17v38’, dated ‘2020-01-21’, and includes the following significant technical changes with respect to the previous edition:

- a) Added Feeder modelling;
- b) Added ICCP configuration modelling;
- c) Correction of issues found in interoperability testing or use of the standard;
- d) Improved documentation;
- e) Updated Annex A with custom extensions;
- f) Added Annex B Examples of PST transformer modelling;

g) Added Annex C HVDC use cases.

The text of this standard is based on the following documents:

FDIS	Report on voting
57/2210/FDIS	57/2224/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61970 series, under the general title: *Energy management system application program interface (EMS-API)*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document is part of the IEC 61970 series which define an application program interface (API) for an energy management system (EMS). IEC 61970 was originally based upon the work of the EPRI Control Center API (CCAPI) research project (RP-3654-1). The principle objectives of the EPRI CCAPI project were to:

- reduce the cost and time needed to add new applications to an EMS;
- protect the investment of existing applications or systems that are working effectively with an EMS.

The principal objective of the IEC 61970 series is to produce documents which facilitate the integration of EMS applications developed independently by different vendors, between entire EMS systems developed independently, or between an EMS system and other systems concerned with different aspects of power system operations, such as generation or distribution management systems (DMS). This is accomplished by defining application program interfaces to enable these applications or systems access to public data and exchange information independent of how such information is represented internally.

The Common Information Model (CIM) specifies the semantics for this API. The Component Interface Specifications (CIS), which are contained in other parts of the IEC 61970 series, specify the content of the messages exchanged.

The CIM is an abstract model that represents all the major objects in an electric utility enterprise typically needed to model the operational aspects of a utility. This model includes public classes and attributes for these objects, as well as the relationships between them.

This document defines the CIM Base set of packages which provide a logical view of the functional aspects of an Energy Management System including Supervisory Control and Data Acquisition (SCADA). Other functional areas are standardized in separate IEC documents that augment and reference this document. For example, IEC 61968-11 addresses distribution models and references this document. While there are multiple IEC standards dealing with different parts of the CIM, there is a single, unified information model comprising the CIM behind all these individual standards documents.

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent concerning a computer-based implementation of an object-oriented power system model in a relational database. As such, it does not conflict with the development of any logical power system model including the Common Information Model (CIM), where implementation of the model is not defined.

The IEC takes no position concerning the evidence, validity and scope of this patent right.

The holder of this patent right has assured the IEC that he/she is willing to negotiate licences either free of charge or under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with IEC. Information may be obtained from:

ICL
Wenlock Way
West Gorton
Manchester
M12 5DR
United Kingdom

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those identified above. IEC shall not be held responsible for identifying any or all such patent rights.

ISO (www.iso.org/patents) and IEC (http://www.iec.ch/tctools/patent_decl.htm) maintain on-line data bases of patents relevant to their standards. Users are encouraged to consult the data bases for the most up to date information concerning patents.

ENERGY MANAGEMENT SYSTEM APPLICATION PROGRAM INTERFACE (EMS-API) –

Part 301: Common information model (CIM) base

1 Scope

The common information model (CIM) is an abstract model that represents all the major objects in an electric utility enterprise typically involved in utility operations. By providing a standard way of representing power system resources as object classes and attributes, along with their relationships, the CIM facilitates the integration and interoperability of network applications developed independently by different vendors, between entire systems running network applications developed independently, or between a system running network applications and other systems concerned with different aspects of power system operations, such as generation or distribution management. SCADA is modelled to the extent necessary to support power system simulation and inter-control centre communication. The CIM facilitates integration by defining a common language (i.e. semantics) based on the CIM to enable these applications or systems to access public data and exchange information independent of how such information is represented internally.

The object classes represented in the CIM are abstract in nature and can be used in a wide variety of applications. The use of the CIM goes far beyond its application in an EMS. This document should be understood as a tool to enable integration in any domain where a common power system model is needed to facilitate interoperability and plug compatibility between applications and systems independent of any particular implementation.

Due to the size of the complete CIM, the object classes contained in the CIM are grouped into several logical Packages, each of which represents a certain part of the overall power system being modelled. Collections of these Packages are progressed as separate International Standards. This document specifies a Base set of packages which provide a logical view of the functional aspects of Energy Management System (EMS) and power system modelling information within the electric utility enterprise that is shared between all applications. Other standards specify more specific parts of the model that are needed by only certain applications. Subclause 4.3 of this document provides the current grouping of packages into standards documents.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61850 (all parts), *Communication networks and systems for power utility automation*

IEC 61850-7-4:2010, *Communication networks and systems for power utility automation – Part 7-4: Basic communication structure – Compatible logical node classes and data object classes*

IEC 61968 (all parts), *Application integration at electric utilities – System interfaces for distribution management*

IEC TS 61970-2, *Energy management system application program interface (EMS-API) – Part 2: Glossary*

Object Management Group: *UML 2.0 Specification* – <http://www.omg.org>