Advanced Architectures and Control Concepts for More Microgrids

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1. Introduction

The main objective of this report is to review commercial and technical standards applicable to Low Voltage (LV) distributed generation technologies and provide a critical review of current grid code requirements. This twofold target should pave the way to allow the easy installation of micro sources with plug and play capabilities into exiting power networks, with particular focus on µGrids as alternative and/or complementary network design.

The progressive penetration of distributed energy resources (DER), some of them renewable based into medium voltage (MV) networks introduces the concept of active distribution networks increasing the need of digital technologies supporting data exchanges and network automation.

The standardisation of interfaces between the micro generator and the distribution network, protocols for negotiating sales and purchasing electrical energy and ancillary services, network access, monitoring and control data for normal and abnormal conditions are key issues to enable an effective deployment of these new technologies. µGrid technology penetration in the electrical sector will strongly depend on the ability to overcome current technical and commercial barriers. EU standardisation at several levels is paramount in this process to fully realise the µGrid benefits and to avoid negative impacts on system reliability and safety.

This document is structured into three different parts covering technical standards, commercial standards and grid code requirements respectively.

2. Technical Standards

Standards are aimed towards providing a stable framework to industry and users enabling common goals at design phase, products interoperability and efficiency by removing technical barriers and leading to open competition and economic growth.

The effective standardization process of any given business process or data exchange model is linked to the availability of normalized conformance testing procedures ensuring interoperability as well as public acceptance and support.

Under normal circumstances standards come from two main sources, new born and de-facto. The first type includes those standards appearing after the identification of one current or future need by some entity promoting a standardization body work; the second type comes when an initially proprietary solution receives increased interest by third parties and, after it is widely supported, it is formally transformed into an standard (Internet protocols is a good example).

It is interesting to notice that standards produced by public or private bodies do not have any guarantee that the proposition would become in use in the future if such a reference is not supported by major manufacturers or it is considered as a pre-requisite for competitive products. In fact, the observation of Information and Communication Technologies experience demonstrate that concurrent supposed-to-be standards fail to succeed outside their influence area and sometimes, gateways and interfacing applications are developed to translate from model to model, from communication protocol to communication protocol to enable the interoperability between platforms but none of them are abandon in favour of the competence proposal.

The analysed technical standards cover the full range of possibilities, from the IEC 61970 and 61968 appearing to satisfy the integration of applications from different purveyors and with deep involvement of large companies, to the IEC 61400-25 appearing after a significant amount of wind power plants are in place, control systems developed and in production for many years and the standard attempting to be introduced into them.

The standardization of technical protocols and data models for Distributed Energy Resources faces an intermediate situation. The producers of those systems do have proprietary solutions but, so far, there has been no need to integrate them into the power system management applications, only measurements were needed and most of the times for billing purposes. One advisable advantage is that the only available DER standard is constructed after a recognised IEC 61850, no many installations are in place nowadays but main players do actively support it. The need of integrating DER installations into power system operation is attracting a growing interest and it could be possible to reach a point in time in which there is a requirement while the standard to fulfil it is already there leading to its public acceptance and general use.

2.1. IEC TC57

The International Electrotechnical Commission (IEC) is an international organization preparing and publishing international standards for all electrical, electronic and related technologies;

The IEC is organized by means of Technical Committees (TC) and Sub-Committees (SC) that include some 700 project & maintenance teams -termed as Working Groups (WGs)- carrying out the standards elaboration. WGs are composed of experts all around the world coming from industry, commerce, government, laboratories, research institutions, universities, etc.

Technical documents produced by the respective working groups are submitted to the full member National Committees for voting. The process, at IEC, ends with the publication of international standards reviewed on as-needed basis and source of the corresponding national standards.

2.1.1. Summary

2.1.1.1. Description

IEC TC57 is devoted to prepare international standards related to high voltage power systems control equipment and systems: power systems management comprises control within control centres, substations and some primary equipment. The scope covers from Energy Management Systems (EMS) to Distribution Automation, including Supervisory Control And Data Acquisition (SCADA), information exchange for both real-time and non-real-time, but also information exchanges for planning, operation and maintenance.

2.1.1.2. Status

The status of the current WGs within TC57 is summarized in Table 2-I with disbanded projects left out.

Table 2-I: IEC – Technical Committee TC57

WG	Name	Standard[1]
3	Telecontrol protocols	60870
10	Power system IED communication and associated data models	61850
13	Energy management system application program interface (EMS - API)	61970

[1] IEC Stage Codes, see http://www.iec.ch/ or Annex A: IEC Stage Codes

WG	Name	Standard[1]
14	System interfaces for distribution management (SIDM)	61968
15	Data and communication security	62210
16	Deregulated energy market communications	62325
17	Communications Systems for Distributed Energy Resources (DER)	62350 61850-7-420
18	Hydroelectric power plants - Communication for monitoring and control	62344
19	Interoperability within TC 57 in the long term	62357
20	Planning of (single-sideband) power line carrier systems	60495 60663

Figure 2-1 shows diagrammatically the distinct WGs involved in the work (January 2005). Notice that since that date AHWG07 has became WG19 and WG16 has gained links to other organisations.

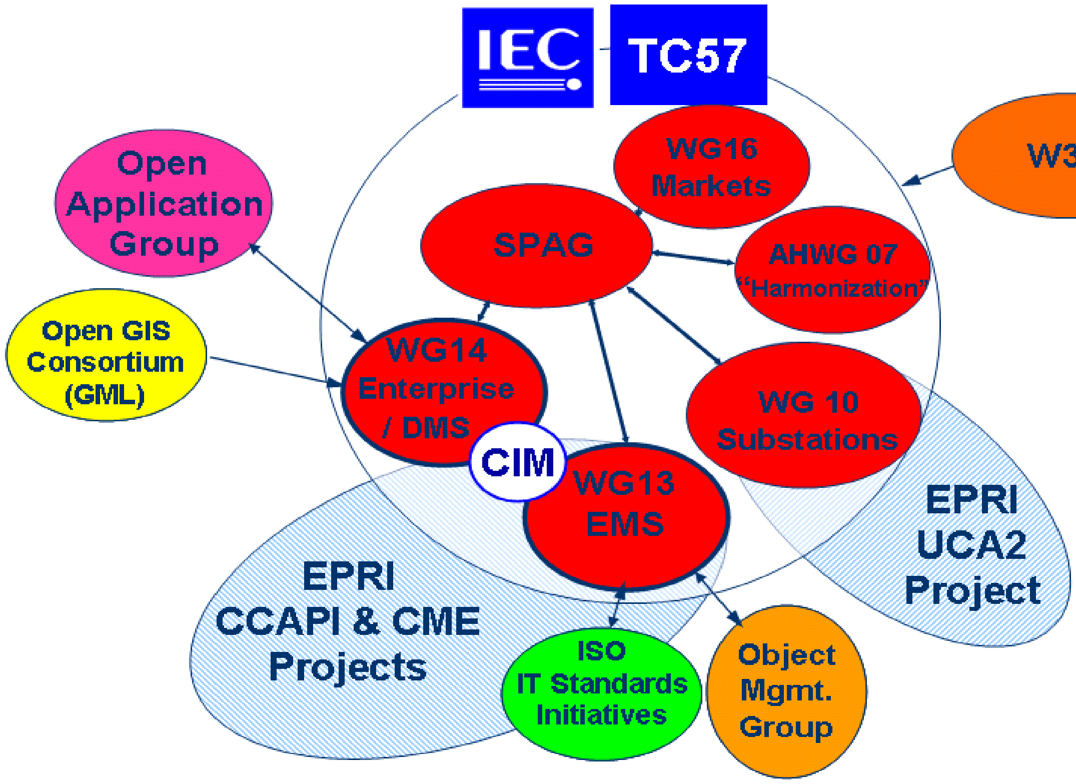


Figure 2-1: TC57 development collaboration

2.1.2. Overview

The different WGs work and standards are described in more detail with this document, nevertheless it is important to note the WG19 activities.

WG19 is aimed to provide the ‘glue’ between the different WGs sharing a common view in terms of data modelling, vocabulary, architecture and quality. The reference architecture in use so far is shown at Figure 2-2, the different standards produced from the TC57 activities match the overall power system management activities.

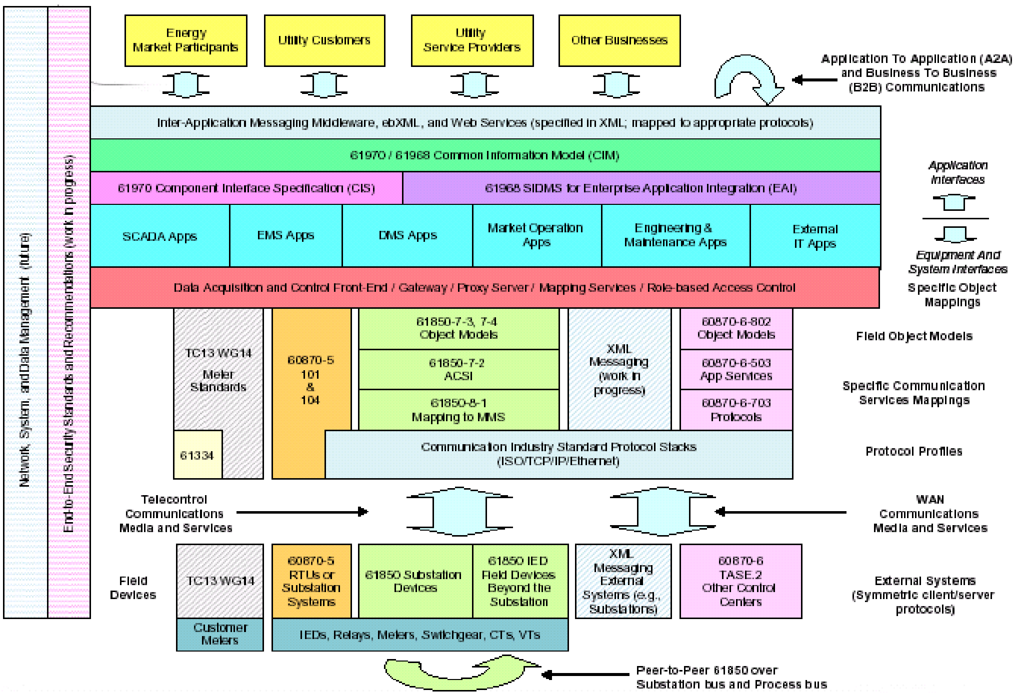


Figure 2-2: TC57 Reference Architecture (current)

The other standards (some from Internet world), appearing needs and trends have transformed this reference architecture into the new one (see Figure 2-3) leaving room for the integration of object oriented technologies (Java Beans, Web Services), business exchange frameworks (ebXML), etc. implemented by model extensions and mappings to specific communications means.

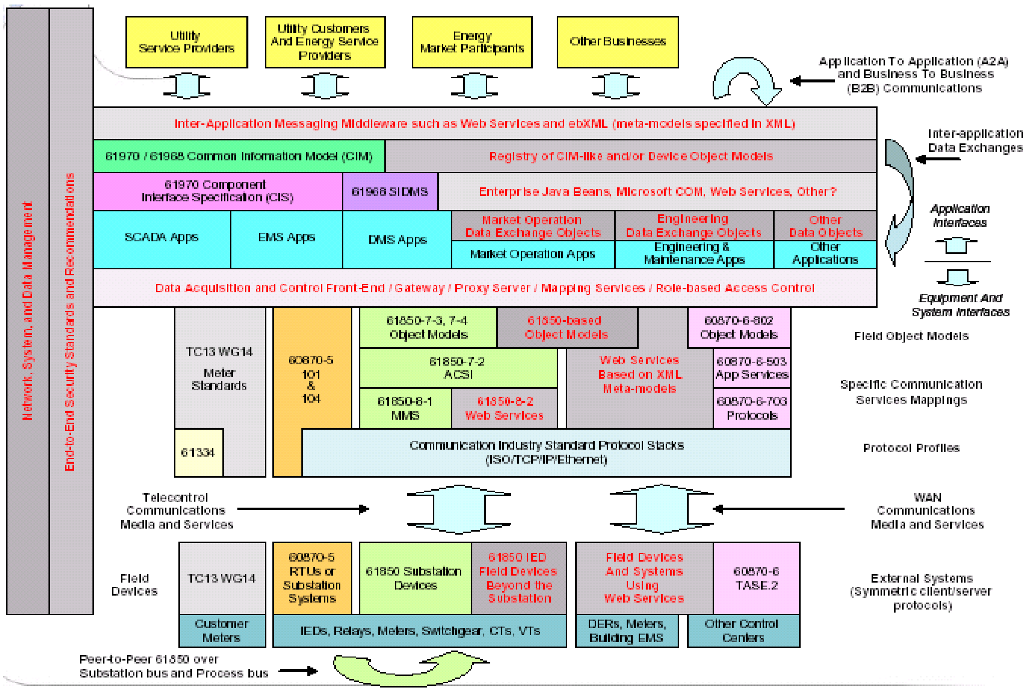


Figure 2-3: TC57 Reference Architecture (future)

This convergence has also internal effects due to the required harmonization between standards that extend its influence area outside its original aim and coordination efforts with other standardisation bodies and user groups.

2.2. IEC 61970

2.2.1. Summary

2.2.1.1. Description

The IEC 61970 series of standards define the set of technologies required to enable the integration of control centre applications.

IEC 61970 is based on a previous work done by EPRI Control Center API (CCAPI) research project (RP-3654-1).

The CCAPI project was aimed to enable the easy integration of applications in EMS environments and improve data exchange features, both internal and external. The proposed solution should cover architecture, data model and be completely independent from the underlying technology.

The specification resulting from IEC 61970 shares the same objectives:

- Enable the integration of multi-vendor applications.
- Allow the exchange of information to systems outside the control centre.

It is worth mention that the scope is not limited to transmission systems; it also includes distribution and generation systems exchanging real time data.

2.2.1.2. Status

Table 2-II: IEC - Search > Publications & Work in progress > Reference IEC61970

Part	Date	Description	Status[2]
-1	2005-12	Guidelines and general requirements	IS
-2	2004-07	Glossary	TS
-301	2005-03	Common Information Model (CIM) base	IS
-401	2005-09	Component interface specification (CIS) framework	TS
-501	2006-03	Common Information Model Resource Description Framework (CIM RDF) schema	IS
-302		Common information model (CIM) financial, energy scheduling and reservations	PWI
-402		Component interface specification (CIS) - Common services	CCDV
-403		Component Interface Specification (CIS) - Generic data access	CCDV
-404		Component Interface Specification (CIS) - High speed data access	CCDV
-405		Component Interface Specification (CIS) - Generic eventing and subscription	CCDV
-407		Component Interface Specification (CIS) - Time series data access	CCDV
-453		CIM based graphics exchange	1CD

[2] IEC Stage Codes, see http://www.iec.ch/ or Annex A: IEC Stage Codes

2.2.1.3. Support

Although the IEC 61970 series of standards is far from being complete the CIM is receiving a significant growing support from leading manufacturers. The InterOp group is formed by mayor vendors such as Siemens, Areva, ABB, …, utilities like EdF and other actors already running interoperability tests between their respective CIM implementations and using distinct power system models.

The results of this coordination activities is two fold, on one side EMS/DMS/SCADA manufacturers come into effective use of the standards paving the way to followers while on the other side standard gaps, pending issues and errors are identified and solved.

The successive InterOp group meetings have produced new versions of the Common Power System Model (CPSM). This CPSM provides a shared interpretation and modelling guideline where the standard fails to deliver.

A second source of support is envisioned at the Large Scale Power Grid Operators (LSVPGO) association formed by Transmission System Operators (TSO). This association created in 2004 a working group to produce the vision of the next generation EMS/MMS architecture, widely supported by the industry and based on de facto standards.

The identified issues regarding control systems are summarized in:

- In use control systems are designed as a whole proprietary solution. Application modularity and interoperability between vendors is not considered as a key target.
- Real time performance leads to highly integrated solutions with scarce chances to software modules reutilization or expansion.
- Standard data models are not so standards due to the differences among distinct implementations and internal assumptions on how interpret data.
- The lack of a common vision of the control system results on particular user interfaces for each module/application/function.

2.2.2. Data Model Overview

The IEC 61970 Common Information Model (CIM) is an abstract model supported as a Unified Model Language (UML[3]) source file using Rational Rose® (.mdl and .cat extension files).

This model is completely independent of the implementation language because it establishes the data classes, attributes, relationships and dependencies without being restricted to any object oriented language. As consequence it should serve as a tool anywhere when a power system model is required enabling the integration and plug compatibility.

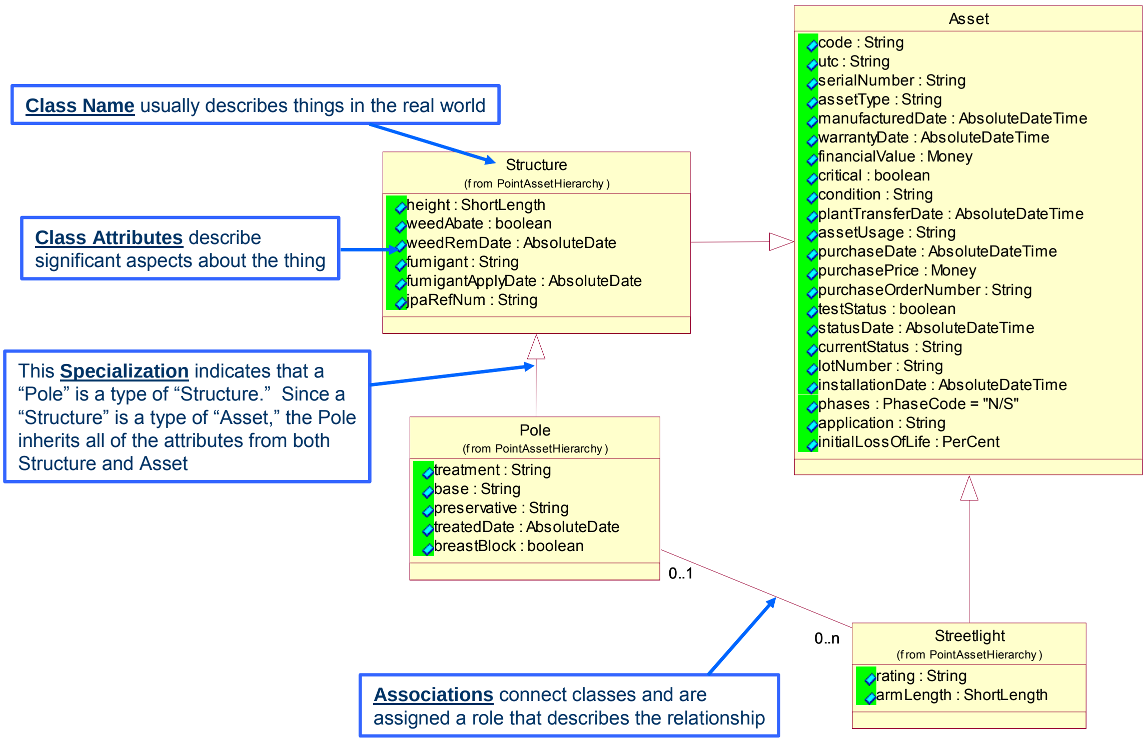


Figure 2-4: UML Notation basics

The CIM-API is intended to define the Application Programming Interface (API) enabling transmission, distribution and generation management systems to access to public data and information exchange without being linked to the underlying implementation details.

[3] For more information on UML notation (a standard), refer to Martin Fowler's book "UML Distilled," Addison-Wesley

The CIM details the semantics that is the domain ontology, while the Component Interface Specification (CIS) specify the contents of the exchanged information.

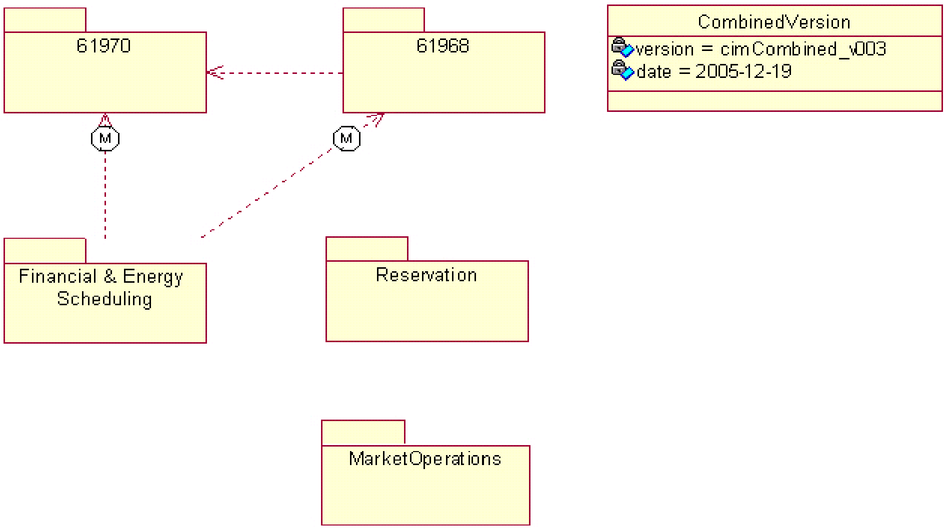


Figure 2-5: CIM v10r7 Logical view

For data exchange purposes, the IEC 61970-501 standard defines a Resource Description Framework (RDF) and eXtensible Markup Language (XML).

The CIM is structured in several packages. A package has no other meaning than grouping object classes logically and represents as certain part of the overall power system model for convenience (maintenance, revision, etc.). Collections of packages are defined and linked to the distinct standards, as seen in Figure 2-5 and handled in one single document. This grouping is resumed at Table 2-III

Table 2-III: Standard parts and included packages

Standard	Packages
61970-301	Core Domain Generation Generation Dynamics LoadModel Measu Outage Production Protection Topology Wires
61970-302	Energy Scheduling Financial Reservation
61970-303	SCADA
61968	Assets

Standard	Packages
	Consumer Core2 Distribution Documentation

It is worth mentioning that the package classification is not intended to define any boundaries, each application would use object classes merging them as needed.

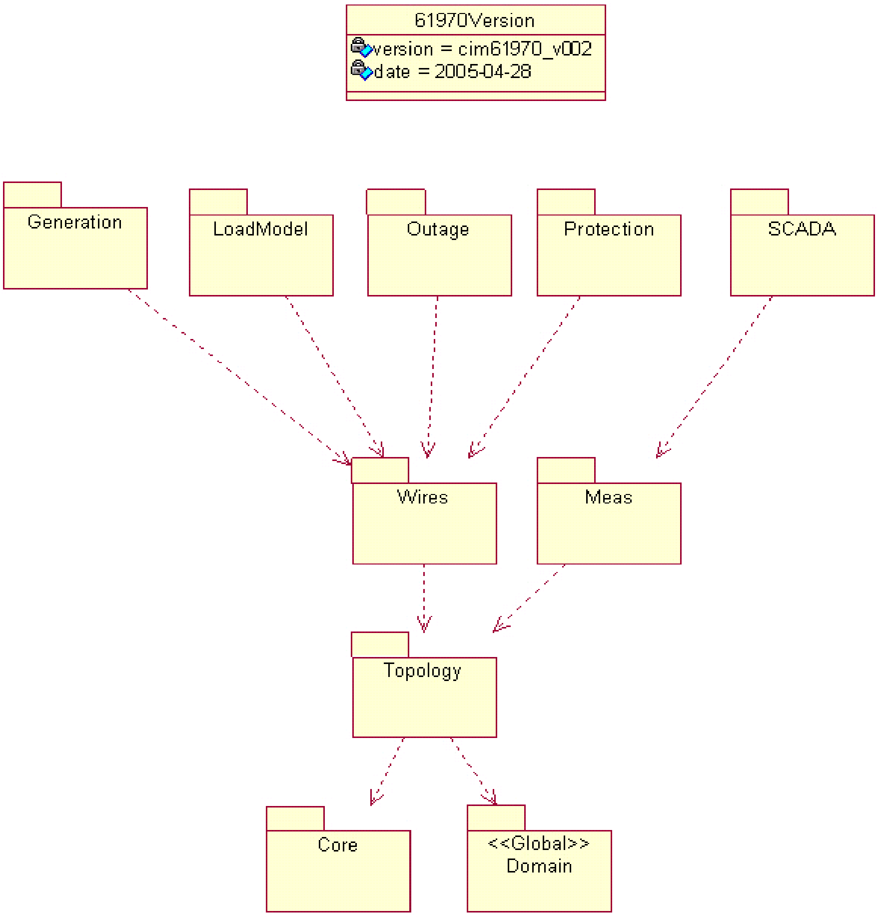


Figure 2-6: IEC 61970-301 Logical View

2.2.2.1. Package: Core

Core package contains Naming, PowerSystemResource, EquipmentContainer and ConductingEquipment classes that are shared by all applications as well as other entities. Although not every application may use Core package object classes all other entities depend on them.

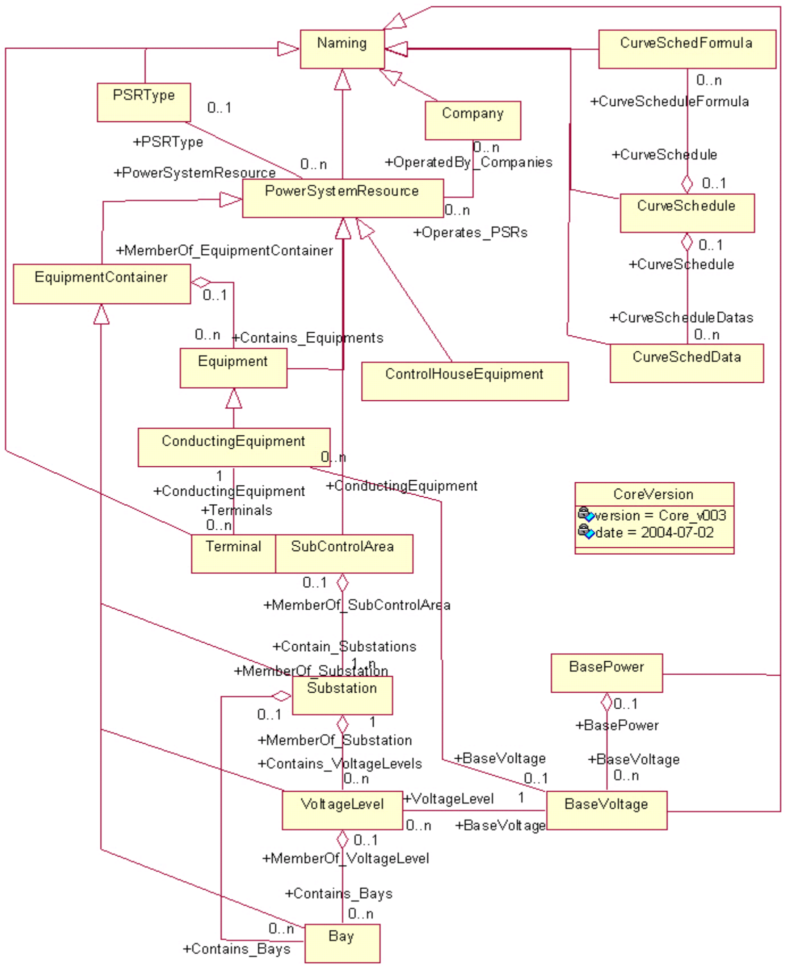


Figure 2-7: IEC 61970-301: Core package object classes' diagram

Core package does not depend on any other but all others have dependency relationships to it.

Table 2-IV: IEC 61970-301 Core package classes

Classes	Bay	Company	ConductingEquipment
ControlHouseEquipment	PowerSystemResource	Substation	Terminal
SubControlArea	CurveSchedule	CurveSchedData	CurveSchedFormula
BaseVoltage	BasePower	VoltageLevel	Naming
Equipment	Unit	EquipmentContainer	PSRType
CoreVersion			

2.2.2.2. Package: Domain

Domain package is a data dictionary of quantities and units defining data types for any other class object properties.

Table 2-V: IEC 61970-301 Domain package classes

Classes	AbsoluteDateTime	ActivePower	ApparentPower
BoilerControlMode	Classification	ControlMode	CostPerEnergyUnit
…	…	…	…
Admittance	Impedance	Conductance	Susceptance
…	…	…	…
CompositeSwitchType	GeneratorControlSource	TimeStamp	DomainVersion
Integer	Octet	String	VoltagePerReactivePower
AreaControlMode			

2.2.2.3. Package: (Generation) Generation Dynamics

Generation Dynamics package contains data models for those simulations where prime movers affect the system response (for instance, transient stability). Within the logical package view it is a sub-package of Generation package (used for mere grouping purposes).

Table 2-VI: IEC 61970-301 (Generation) Generation Dynamics package classes

Classes	Supercritical	Subcritical	SteamTurbine
SteamSupply	PWRSteamSupply	PrimeMover	HeatRecoveryBoiler
HydroTurbine	FossilSteamSupply	DrumBoiler	CombustionTurbine
BWRSteamSupply	CTTempMWCurve		

2.2.2.4. Package: (Generation) Production

Production package holds object classes describing generation types, production costs for unit commitment & generation scheduling and reserves. This package is also under the general Generation package.

Table 2-VII: IEC 61970-301 (Generation) Production package classes

Classes	ThermalGeneratingUnit	TargetLevelSchedule	TailbayLossCurve
SteamSendoutSchedule	StartupModel	StartRampCurve	StartMainFuelCurve
StartIgnFuelCurve	ShutdownCurve	Reservoir	PenstockLossCurve
LevelVsVolumeCurve	InflowForecast	IncrementalHeatRateCurve	HydroPumpOpSchedule
HydroPump	HydroPowerPlant	HydroGeneratingUnit	HydroGeneratingEfficiencyCurve
HeatRateCurve	HeatInputCurve	GrossToNetMWCurve	GenUnitOpSchedule
GenUnitOpCostCurve	GeneratingUnit	FuelAllocationSchedule	FossilFuel
EmissionCurve	CombinedCyclePlant	CogenerationPlant	CAESPlant
AirCompressor	EmissionAccount	AccountBalance	

2.2.2.5. Package: Load Model

Load Model package covers energy consumer models and classes for load profiling. It is intended to load forecasting and load management activities.

Table 2-VIII: IEC 61970-301 Load Model package classes

Classes	AreaLoadCurve	AreaLossCurve	CustomerMeter

DayType	EquivalentLoad	InductionMotorLoad	LoadArea
LoadDemandModel	NonConformLoadSchedule	Season	StationSupply
PowerCutZone	LoadModelVersion		

2.2.2.6. Package: Meas

Meas package is devoted to handle entities related to dynamic measurement data.

Table 2-IX: IEC 61970-301 Meas package classes

Classes	Measurement	MeasurementValueQuality	MeasurementValue
ValueAliasSet	ValueToAlias	LimitSet	Limit
Control	MeasurementValueSource	MeasurementType	ControlType
Quality61850	MeasVersion	Accumulator	Analog
Discrete	AnalogValue	DiscreteValue	AccumulatorValue

2.2.2.7. Package: Protection

Protection package is devoted built from Core and Wires package to model protection equipment generalities.

Table 2-X: IEC 61970-301 Protection package classes

Classes	CurrentRelay	ProtectionEquipment	RecloseSequence
SynchrocheckRelay	ProtectionVersion		

The view offered from the Protection package is quite general (see Figure 2-8) and limited, the current standard states that this package is intended for training simulators and distribution network fault location applications.

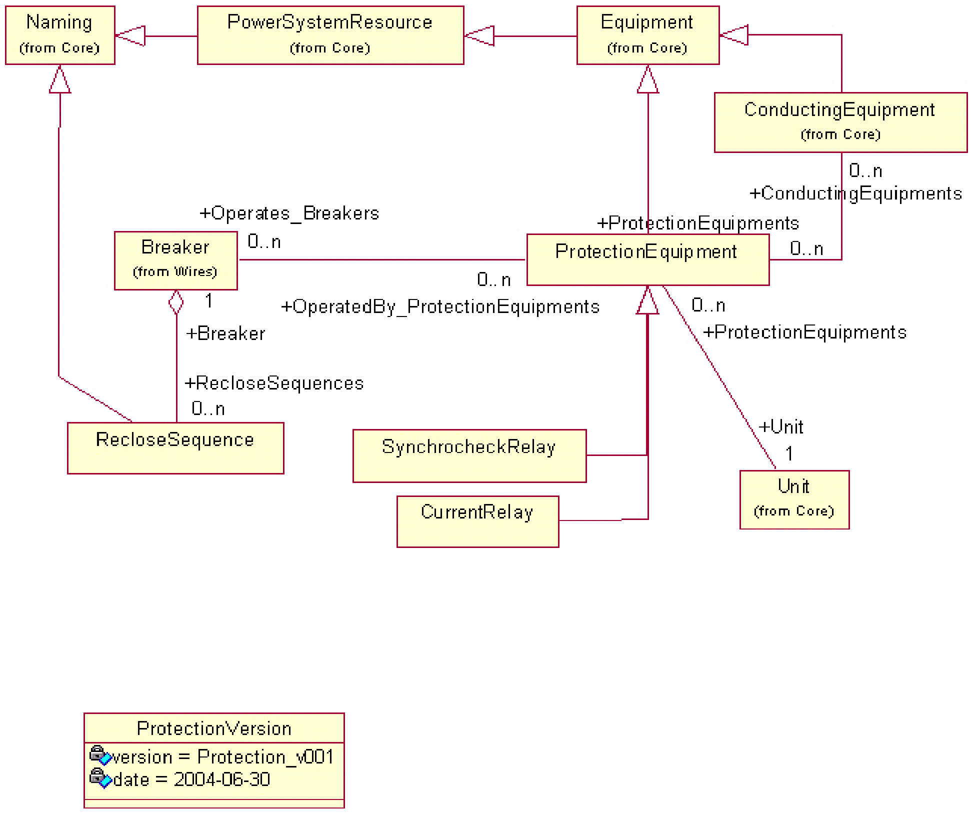


Figure 2-8: 61970-301: Protection package object classes' diagram

2.2.2.8. Package: Outage

Outage package extends Core and Wires packages to provide objects classes used for network configuration, either current, either planned.

Table 2-XI: IEC 61970-301 LoadModel package classes

Classes	AreaLoadCurve	AreaLossCurve	CustomerMeter
DayType	EquivalentLoad	InductionMotorLoad	LoadArea
LoadDemandModel	NonConformLoadSchedule	Season	StationSupply
PowerCutZone	LoadModelVersion		

2.2.2.9. Package: Topology

Topology package extends Core package to provide a physical definition of the equipment connection independently of other electrical characteristics.

Table 2-XII: IEC 61970-301 Topology package classes

Classes	ConnectivityNode	TopologicalIsland	TopologicalNode
TopologyVersion			

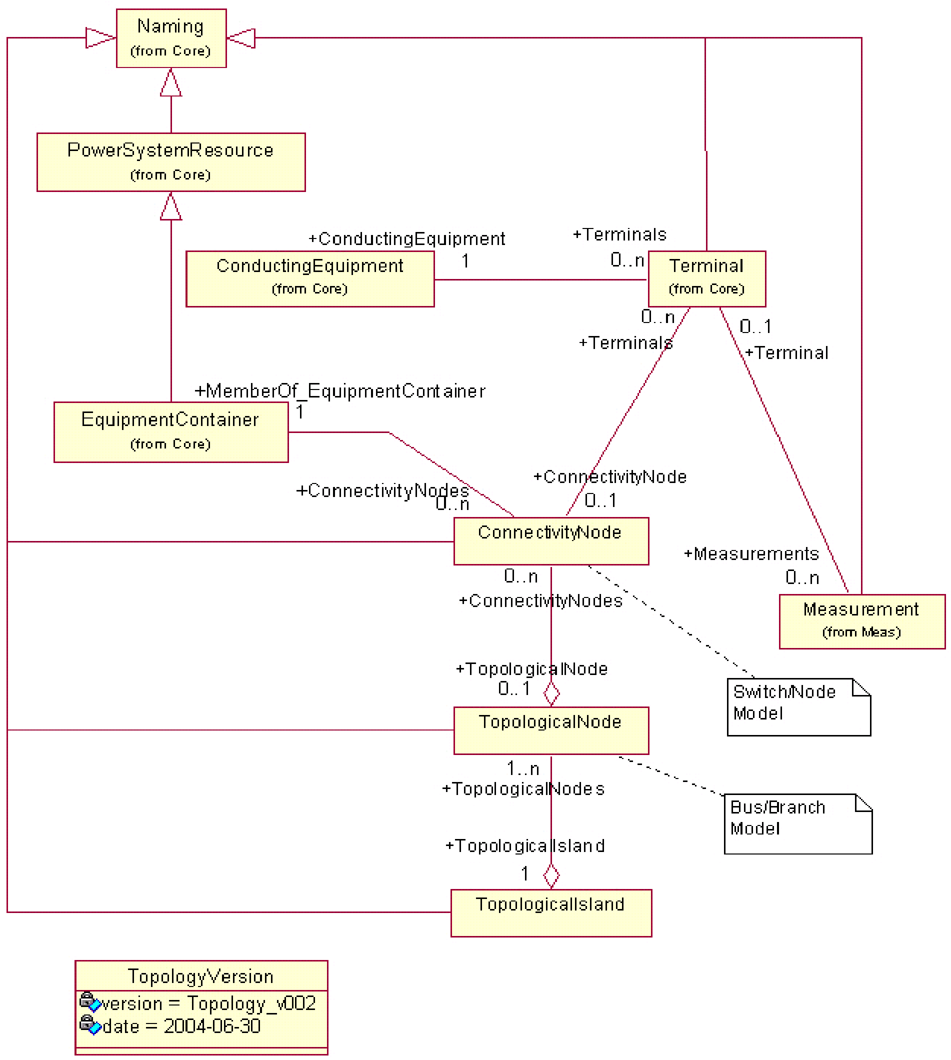


Figure 2-9: 61970-301: Topology package object classes' diagram

The topology connection model is based on ConnectivityNode and Terminal (from core package) class objects allowing two connectivity models. The first model is a detailed connection layout where every single electrical node is systematically identified to provide a Switch/Node model (i.e. for topology processors, etc.) as seen in Figure 2-10. The second model summarizes closed switching elements into a single connection point defining a Bus/Branch model (i.e. for power flow applications) where intermediate switching elements disappear.

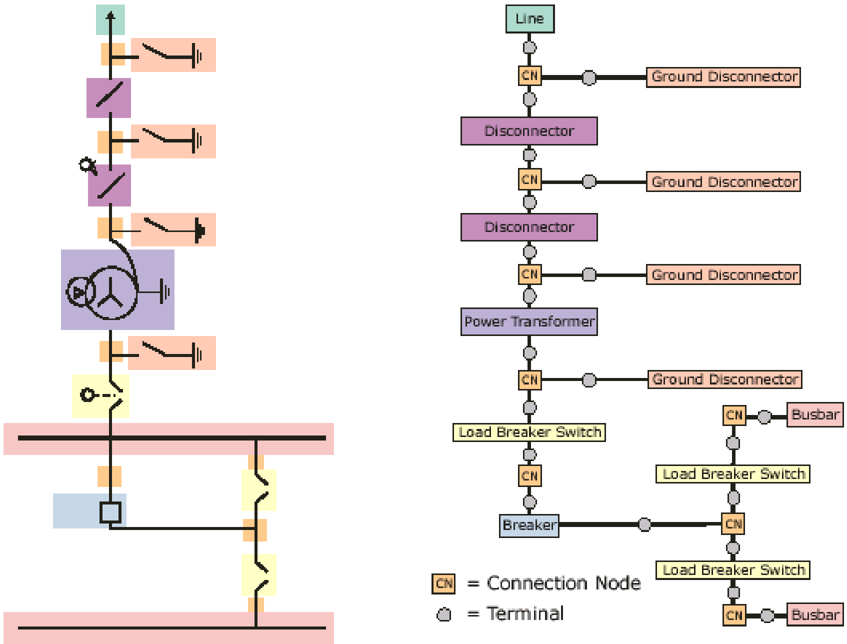


Figure 2-10: 61970-301: Example of Switch/Node model.

2.2.2.10. Package: Wires

Wires package contains object classes to model transmission and distribution network components and their electrical characteristics. It is produced as an extension of Core and Topology packages

Table 2-XIII: IEC 61970-301 Wire package classes

Classes	ACLineSegment	Breaker	BusbarSection
Compensator	Conductor	ConductorType	DCLineSegment
Disconnector	Fuse	Ground	HeatExchanger
Jumper	RectifierInverter	RegulationSchedule	StaticVarCompensator
Switch	TapChanger	PowerTransformer	TransformerWinding
Line	VoltageControlZone	WindingTest	SynchronousMachine
MVArCapabilityCurve	EquivalentSource	WireType	WireArrangement
LoadBreakSwitch	Junction	EnergyConsumer	Connector
RegulatingCondEq	GroundDisconnector	CompositeSwitch	WiresVersion
FrequencyConverter			

2.2.2.11. Package: Financial and Energy Scheduling

So far this package remains empty without any update since its creation.

Table 2-XIV: IEC 61970-302 Financial & Energy Scheduling package classes

Classes			

2.2.2.12. Package: Market Operation

Market Operation package is intended to cope with the data structures required by the energy market procedures and processes. It is worth mention that, same as Reservation package, it is not being maintained at its current state (see 3.1 IEC 62325).

Table 2-XV: IEC 61970-302 Market Operations package classes

Classes	RampRateCurve	ResourceBid	BilateralTransaction
Pnode	StartUpCostCurve	EnergyPriceCurve	BidClearing
…	…	…	…
MarketProduct	Bid	ProductBidClearing	ReserveReq
…	…	…	…
SchedulingCoordinator	Settlement	PassThroughBill	ChargeProfile
ChargeProfileData	CapacityBenefitMargin	TransmissionReliabilityMargin	

2.2.2.13. Package: Reservation

Reservation package is intended to describe data models regarding energy transaction scheduling, generation & transmission capacity and ancillary services. It should be noticed that this packages remains frozen since its last review (June/2006).

Table 2-XVI: IEC 61970-302 Reservation package classes

Classes	AreaLoadCurve	AreaLossCurve	CustomerMeter
DayType	EquivalentLoad	InductionMotorLoad	LoadArea
LoadDemandModel	NonConformLoadSchedule	Season	StationSupply
PowerCutZone	LoadModelVersion		

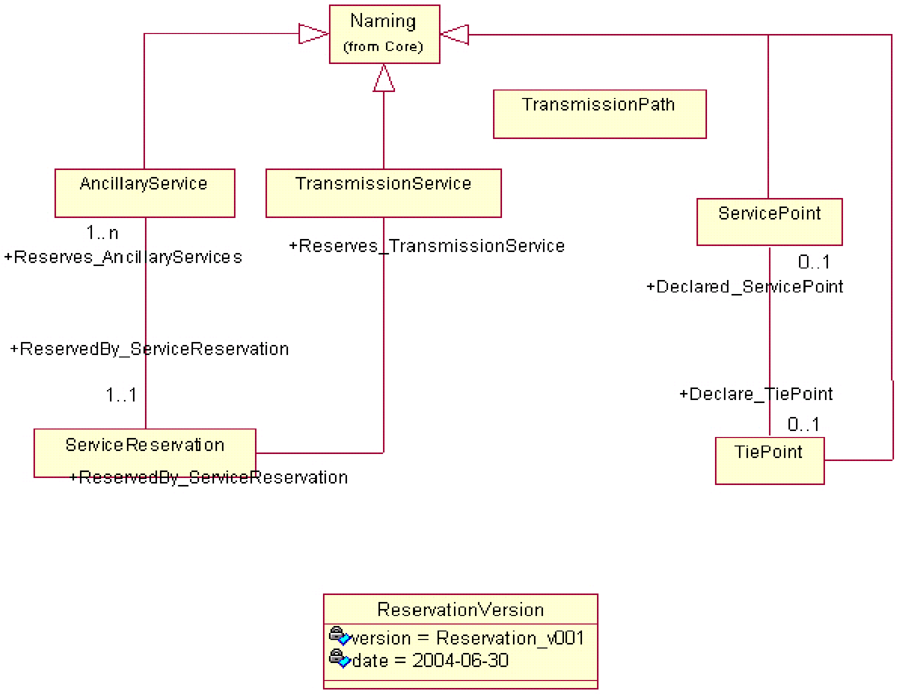


Figure 2-11: 61970-302: Reservation package object classes' diagram

2.2.2.14. Package: SCADA

SCADA package is aimed for information used by SCADA applications. It includes from switching equipment operations to remote metered data coherently with IEC 61850 standard and signalling.

Table 2-XVII: IEC 61970-303 SCADA package classes

Classes	CommunicationLink	RemoteUnit	RemoteSource
RemoteControl	RemotePoint	SCADAVersion	

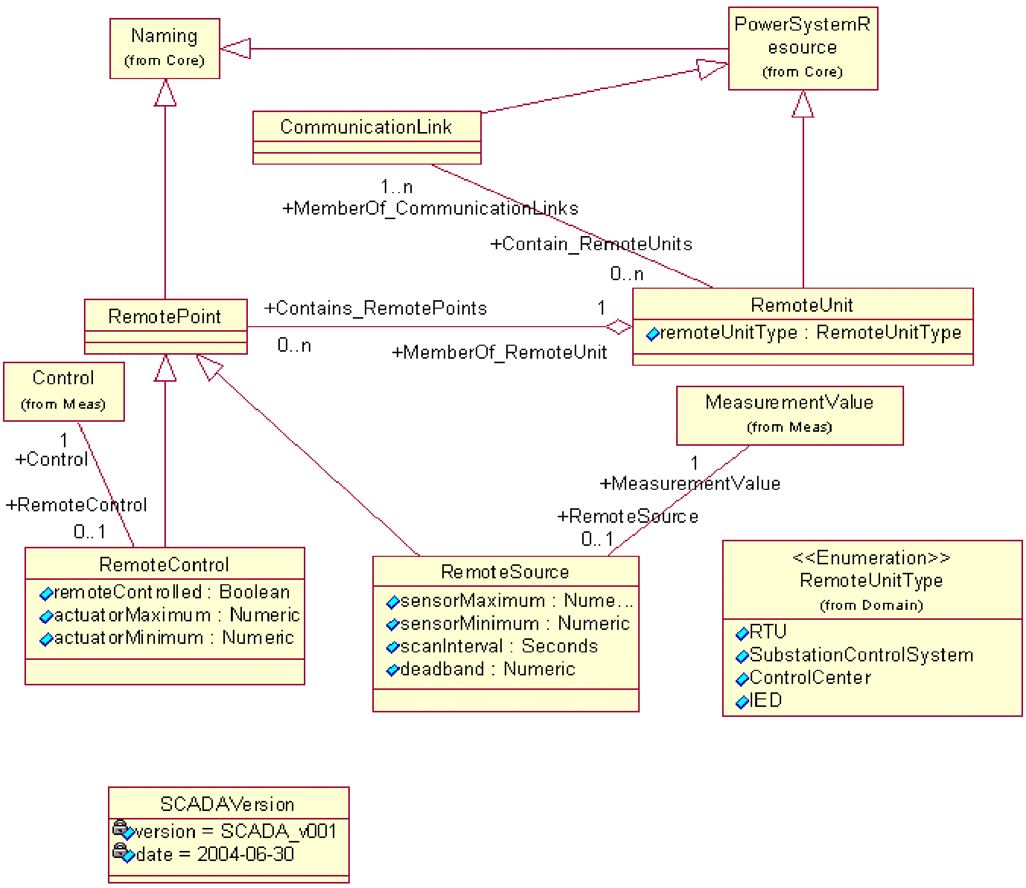


Figure 2-12: IEC 61970-303: SCADA package object classes' diagram

2.2.3. CIS Overview

The Component Interface Specification is published as IEC 61970-401 and due to its mere informative nature it is classified as technical specification and not as standard. The internal arrangements within the different parts are as follows:

- IEC 61970-401 provides the general framework covering other related standards.
- IEC 61970-402 to 449 specify the generic services to be supported. These services are to be used by applications to exchange information. The specification is implemented by means of a narrative description completed with UML notation.
- IEC 61970-450 defines common requirements for parts 451 to 499 and provides a summary of the use cases employed to define the information model.
- IEC 61970-451 to 499 identify the specific requirements imposed by target applications. The specification is completed by means of use cases and sequence diagrams.

The generic services are intended to follow the design objectives of the standard (integration of applications, implementation independent, shared data model…) while keeping a safe distance to a very detailed API though a set of data exchange mechanisms with a reduced API, general enough to support any need and complementary.

The different interface specifications are based on two source standards and a previous effort:

- OLE for Process Control (OPC) is a standard produced by OPC Foundation based on many formerly standard wannabes created by Microsoft (OLE, ActiveX, COM, DCOM…). There has been a considerable success in the use of OPC for process control and manufacturing automation applications with many providers and solutions.
- The Object Management Group (OMG) started creating standards around CORBA but has changed into a Model Driven Architecture (MDA) to provide independence from the underlying implementation technology.
- Generic Interface Definition (GID) was an EPRI open request launched following the CCAPI project. The specification is based on CCAPI technical requirements and merges OMG and OPC standards.

IEC 61970-4XX series constitute the 'level 1' as the technology independent layer specifying the services while IEC 61970-5XX set define the 'level 2' with implementation dependent mappings.

2.2.3.1. Common Services (IEC 61970-402)

The Common Services are expected to be defined by the future standard IEC 61970-402. Theses common services include:

- Naming
- Resource ID service
- Description (Intended to exchange information about CIM resources(
- Connection and Transaction Module

2.2.3.2. Generic Data Access (IEC 61970-403)

The Generic Data Access (GDA) provides CIM based public data access through an request-response mechanism intended for non-real time synchronous operation to complex data structures.

GDA services, based on Data Access Facility (DAF by OMG) and GDI Common Data Access (CDA by EPRI), include:

- Read/Write
- Schema query
- Change notification events
- Service browsing and searching
- Read transaction with multiple operations

2.2.3.3. High Speed Data Access (IEC 61970-404)

The High Speed Data Access (HSDA) is intended for efficient data exchange of simple data structures that may be combined into data groups.

HSDA services are founded after Data Acquisition for Industrial Systems (DAIS by OMG) and OPC Data Access (DA).

2.2.3.4. Generic Eventing and Subscription (IEC 61970-405)

The Generic Eventing and Subscription (GES) provided services for general subscribe/publish methods for events and alarms notification.

The HSDA service requires the server to keep a data client list while GES is more bulletin board oriented, data is published without any audience list being maintained.

DAIS Simple Events (SE by OMG), OPC Alarms and Events and GID Publish/Subscribe are industry standards onto which GES is built.

2.2.3.5. Time Series Data Access (IEC 61970-407)

The Time Series Data Access (TSDA) targets historical data services.

The TSDA service is based on Historical Data Access for Industrial Systems (HDAIS by OMG) and OPC Historical Data Access.

2.2.4. Review

The IEC 61970 set of standards still present a high number of open issues, for instance:

- There are far more High Voltage than Medium Voltage models
- Load models for transient studies are not being covered at all while generator models are part of the architecture.

- The classification of packages and objects seems to be arbitrary some times.
- The same UML model is used to support distinct targets and goal with completely different efforts and upgrade states.
- The up to now conducted interoperability tests have required of additional work and specification performed outside the IEC group in order to have alternative implementations interpreting data in the same way, gaps and gray zones are discovered and solved temporally for testing purposes ranging from how ‘peak’ time is defined or how equivalent networks are handled (involving fake components, strange electrical parameters and so on).

It is clear that this standard will be the reference in a near future even when gaps are still there. The effort devoted by the main manufacturers in this early stage demonstrates the perception about the standardization need.

2.3. IEC 61968

2.3.1. Summary

2.3.1.1. Description

The IEC 61968 set of standards targets the integration of distribution management applications providing system interfaces built on top of the data model provided by the IEC 61970 and extending it through new objects when needed.

The IEC 61968 is designed for inter-application data exchanges as opposite to intra-application. Inter-application is that appearing at connection disparate applications with no so tight speed requirements and usually with lower communication speed needs.

The overall picture of the business processes covered by this standard is shown in Figure 2-13. The role of IEC 61968 as merging glue becomes apparent by means of the middleware services but it lacks of the definition of one public interface that should be in use. Instead of this, each application interface is to be identified following the Interface Reference Model (IRM).

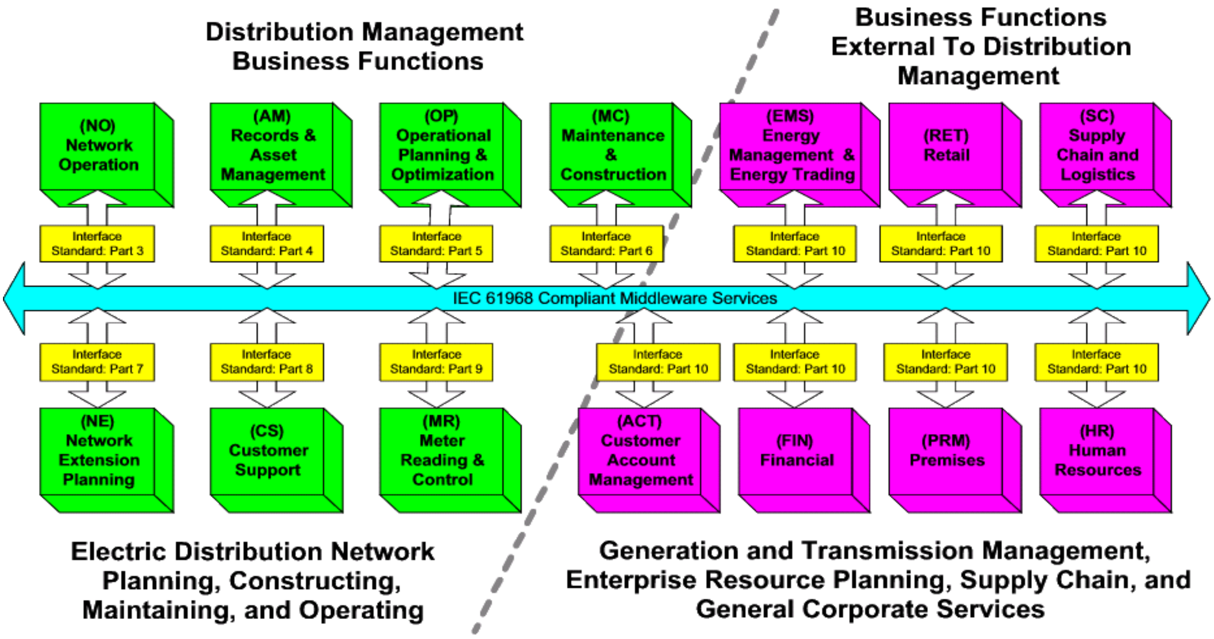


Figure 2-13: IEC 61968 Interface Reference Model

The IEC 61968 compatible middleware services manage messages between applications. The information is decoupled by a publisher-subscriber model where the source application notifies an event (properly formatted message) to the list of registered subscriber. Each subscriber is in charge of filtering the information for the application.

Message types are defined following the definition of use cases and the associated information exchange requirements.

2.3.1.2. Status

Table 2-XVIII: IEC – Search > Publications & Work in progress > Reference IEC61968

Part	Date	Description	Status[4]
-1	2003-10	Interface architecture and general requirements	IS
-2	2003-11	Glossary	TS
-3	2004-03	Interface for network operations	IS
-4		Interfaces for records and asset management	CCDV
-9		Interface Standard for Meter Reading and Control	ANW
-13		CIM RDF Model exchange format for distribution	CCDV

WG14 is actively working on the IEC 61968 set of standards. Apart from the official list of documents (Table 2-XVIII) the current outline of the work is the summarized in Table 2-XIX.

Table 2-XIX: WG14 parts

Part	Description
-4	Records and Asset Management
-5	Operational Planning and Optimization
-6	Maintenance and Construction
-7	Network Extension Planning
-8	Customer Support
-9	Metering Reading and Control
-11	CIM defined by WG14 (Extension to WG13 CIM)
-12	DMS Use cases

2.3.1.3. Support

The support of IEC 61968 is closely related to that expected to IEC 61970. So far, the IEC 61970 has requested attention and growing support but it still is an uncompleted work. In any case, EMS/DMS manufacturers are deeply involved.

2.3.2. Data Model Overview

The CIM components added by the IEC 61968 follows the same structure divided into packages as the full CIM model and it is also maintained in UML form for implementation

[4] IEC Stage Codes, see http://www.iec.ch/ or Annex A: IEC Stage Codes

independency. For model exchange purposes, the IEC 61968 takes the same approach that IEC 61970 relying on RDF and XML.

Again, package classification does not define any application boundaries, each application would use object classes from distinct packages without any restriction.

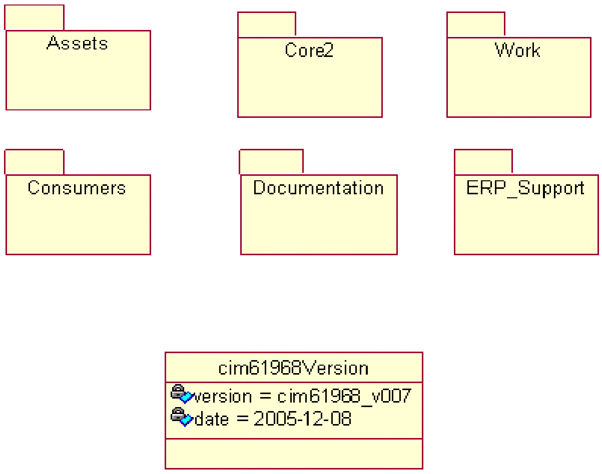


Figure 2-14: IEC 61968-11 Logical View

2.3.2.1. Package: Assets

Assets package defines models for asset-level objects. In general, any asset may comprise other assets, have relations to other assets, be owned and have values.

Assets package is composed by four different sub-packages with their respective object classes:

- Asset Basics
- Asset Work Trigger
- Point Asset Hierarchy
- Linear Asset Hierarchy

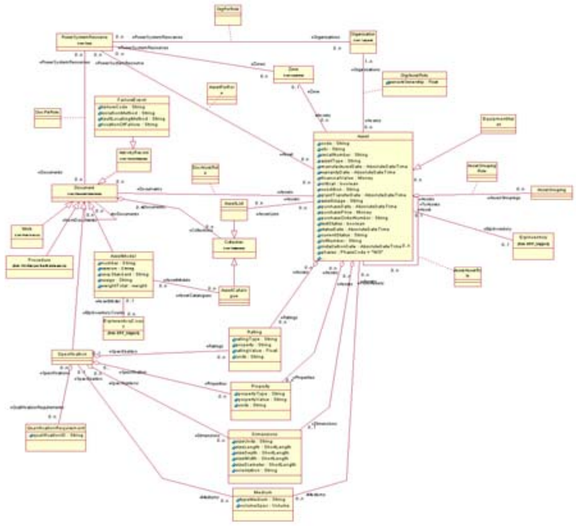


Figure 2-15: IEC 61968-11: Asset Basics package object classes' diagram

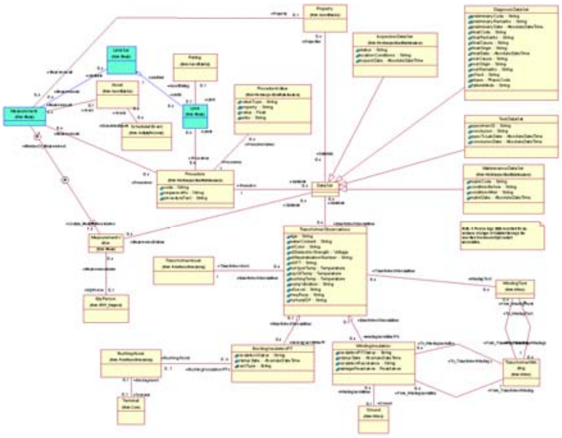


Figure 2-16: IEC 61968-11: Asset Work Trigger package object classes' diagram

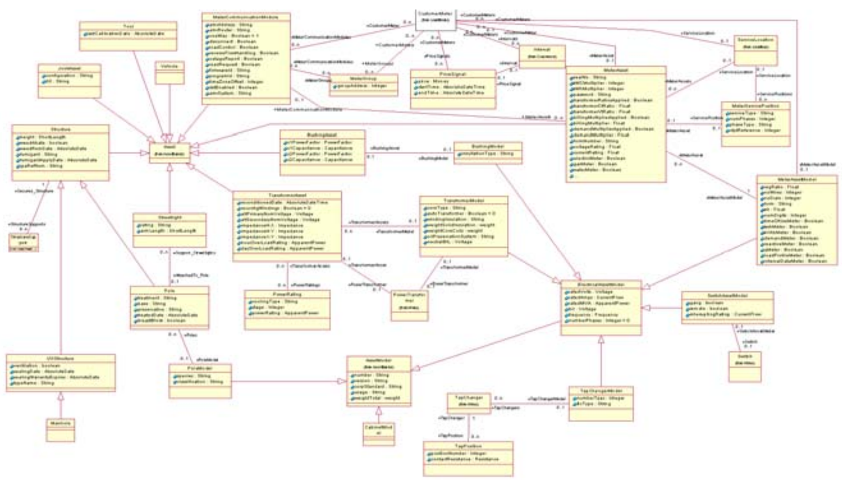


Figure 2-17: IEC 61968-11: Point Asset Hierarchy package object classes' diagram

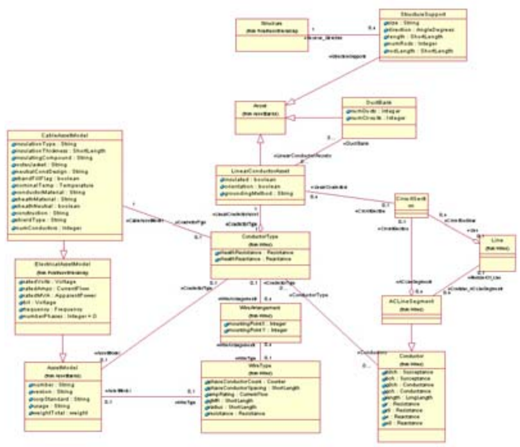


Figure 2-18: IEC 61968-11: Linear Asset Hierarchy package object classes' diagram

2.3.2.2. Package: Consumers

Consumers details consumer models.

Table 2-XX: IEC 61968-11: Consumers package classes

Classes	WorkBillingInfo	CustomerAccount	CustomerAgreement
PowerQualityPricing	Tariff	Customer	StandardIndustryCode
ExternalCustomerAgreement	PricingStructure	CustomerBillingInfo	CustomerList
Interval			

2.3.2.3. Package: Core2

Core2 package contains distribution management required data. This package extends the IEC 61970-301 but object classes should be considered in the same way Core package.

Table 2-XXI: IEC 61968-11: Core2 packages

Packages	ActivityRecords	Domain2	Locations
TopLevel	Naming	Presentation	Collections

Core2 packages contain other object classes aimed to DMS purposes taking special issues not considered when the IEC 61970-301 standard was released.

2.3.2.4. Package: Documentation

Documentation package and its sub-packages are oriented to model processes normally supported with documents.

Table 2-XXII: IEC 61968-11: Documentation packages

Packages	DatasSets	DocumentInheritance	Operational
Outages	TroubleTickets		

2.3.2.5. Package: ERP Support

This package is intended to provide classes linking Enterprise Resource Planning (ERP) tools and other electric utility applications.

The approach takes part of the ERP model provided by the Open Applications Group (OAG) extending the model to the current CIM model.

Table 2-XXIII: IEC 61968-11: ERP Support package classes

Classes	ErpSalesOrder	ErpAddress	ErpPartner
ErpPerson	ErpPersonnel	ErpCompetency	ErpSiteLevelData
…	…	…	…
ErpJournal	ErpJournalEntry	ErpLedger	ErpLedgerEntry
ErpTimeSheet	ErpTimeEntry		

2.3.2.6. Package: Work

Work package and its sub-packages model work operations including crew management, outages, maintenance, etc.

Table 2-XXIV: IEC 61968-11: Work packages

Packages	WorkClosing	WorkDesign	WorkInitiation
WorkInspectionMaintenance	WorkSchedule	WorkService	WorkStandards
Crew			

2.3.3. IRM Overview

The IEC 61968 takes the general DMS identifying several distributed application components covering from monitoring and control to outage management. The standard takes as base components UML and XML to define the standard interfaces to be implemented by each different application defining compatibility at protocols and message formats and contents defined by the Interface Reference Model (IRM). The middleware services are implemented by means of standardized messaging technologies.

The IRM is defined with the help of a table mapping, business functions, sub-functions and abstract components.

- Business Functions are top level utility applications such as Network Operation (NO), Records and Assets Management (AM), etc. This business functions and their corresponding standard part are detailed at Table 2-XIX.
- Business sub-Functions are fine grained specific modules such as Network Operation Monitoring, Network Control, Fault Management, and so on.
- Abstract components identify tasks relevant for all sub-functions. These components may be used by various sub-functions, for instance a load flow is used whenever a network simulation is required, either for real time operation, either for planning purposes.

The interface specification imposes a set of requirements on three parts:

- Component specific. These define what each individual application -task devoted- shall provide: satisfy the respective standard part, interaction type and context, register and unregister, transaction support, etc.
- Distribution management domain services: Unique identifications, persistency, administration…
- Distributed computing services: These are general for any distributed system like life cycle control, naming, security..,

2.3.3.1. Service oriented

The event service is achieved by means of message oriented technologies providing:

- Event notification supports asynchronous and synchronous operation.
- Producer and Consumer services comply publish/subscribe model as well as publish/reply and request/reply.

- Each component is in charge of register and unregister the service availability.
- Different context are considered such as real-time, test, study, etc.

2.3.3.2. Other

The pure event notification is completed by mean of meeting functionality to:

- Error handling, catching and recovery.
- Transaction oriented process with commit and roll-back features on both atomic and full stages.
- Security, concurrency control and explicit request for scalability.

2.3.4. Review

The IEC 61968 standard success and suitability to perform the targeted objective is linked to the success of IEC 61970. Both share the same core data model, the Common Information Model, but aim to different objectives. Assuming that CIM will succeed in a near future, the set of services, data access methods and application modelling internals, etc. agreement proposed by IEC 61968 could follow.

It should be noticed that IEC 61968 practically models applications (i.e. work management) minimum data sets and data access which is far more ambitious that CIM. The general CIM requires some kind of common understanding on how real equipment is effectively modelled; the equipment is the same for all applications and physical electrical parameter relations exists. One company may use per unit values, other prefers them in ohms but it is always possible to translate from one to another with some automatic calculation procedures, the real issue is accept one single template as shared exchange format.

The IEC 61968 proposes a step forward entering into details about processes and applications and therefore will require a more deep involvement of purveyors. The approach so far has consisted on developing Use Cases latter employed to identify the key aspects of each application and their relationships.

2.4. IEC 60870

2.4.1. Summary

IEC 60870 Standard was developed by different Working Groups belonging to IEC Technical Committee 57. These WGs were formed in the early 1980s, with the object of producing an international standard for a communication protocol, principally for the telecontrol of electric power transmission systems.

The work of the WG took longer than might have been expected, because of the continuous evolution of the practice and technology of telecontrol. One of the objectives was to avoid standardising obsolescent techniques, and so technological evolution had to be considered.

2.4.1.1. Description

2.4.1.2. Status

Table 2-XXV: IEC – Search > Publications & Work in progress > Reference IEC60870

Part	Date	Description	Status[5]
-1-1	1988-12	General considerations. Section One: General principles	IS
-1-2	1989-11	General considerations. Section Two: Guide for specifications	IS
-1-3	1997-04	General considerations. Section 3: Glossary	TR
-1-4	1994-07	General considerations. Section 4: Basic aspects of telecontrol data transmission and organization of standards IEC 870-5 and IEC 870-6	TR
-1-5	2000-09	General considerations – Influence of modem transmission procedures with scramblers on the data integrity of transmission systems using the protocol IEC 60870-5	TR
-2-1	1995-12	Operating conditions – Section 1: Power supply and electromagnetic compatibility	IS
-2-2	1996-08	Operating conditions – Section 2: Environmental conditions (climatic, mechanical and other non electrical influences)	IS
-3	1989.05	Interfaces (electrical characteristics)	IS
-4	1990-04	Performance requirements	IS
-5-1	1992-02	Transmission protocols – Section One: Transmission frame formats	IS
-5-2	1992-04	Transmission protocols – Section 2: Link transmission procedures	IS
-5-3	1992-09	Transmission protocols – Section 3: General structure of application data	IS
-5-4	1993-08	Transmission protocols – Section 4: Definition and coding of applications information elements	IS
-5-5	1995-06	Transmission protocols – Section 5: Basic application functions	IS
-5-6	2006-03	Guidelines for conformance testing for the IEC 60870-5 companion standards	IS
-5-101	2003-02	Transmission protocols – Companion standard for basic telecontrol tasks	IS
-5-102	1996-06	Transmission protocols – Section 102: Companion standard for the transmission of integrated totals in electric power systems	IS
-5-103	1997-12	Transmission protocols – Companion standard for the informative interface of protection equipment	IS
-5-104	2006-06	Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles	IS
-5-601	2006-06	Conformance test cases for the IEC 60870-5-101 companion standard	TS
-5-SER	2006-07	Transmission protocols – ALL PARTS	IS
-6-1	1995-05	Telecontrol protocols compatible with ISO standards and ITU-T	TR

[5] IEC Stage Codes, see http://www.iec.ch/ or Annex A: IEC Stage Codes

Part	Date	Description	Status[5]
		recommendations – Section 1: Application context and organization of standards	
-6-2	1995-10	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – Section 2: Use of basic standards (OSI layers 1-4)	IS
-6-501	1995-12	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – Section 501: TASE.1 service definitions	IS
-6-502	1995-12	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – Section 502: TASE.1 Protocol definitions	IS
-6-503	2002-04	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – TASE.2 Services and protocols	IS
-6-504	1998-12	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – TASE.1 User conventions	TS
-6-505	2002-08	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – TASE.2 User guide	TR
-6-505	2005-09	Amendment 1 – Telecontrol protocols compatible with ISO standards and ITU-T recommendations – Tase.2 User guide	TR
-6-601	1994-12	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – Section 601: Functional profile for providing the connection oriented transport service in an end system connected via permanent access to a packed switched data network	IS
-6-602	2001-04	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – TASE transport profiles	TS
-6-701	1998-08	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – Functional profile for providing the TASE.1 application service in end systems	IS
-6-702	1998-10	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – Functional profile for providing the TASE.2 application service in end systems	IS
-6-802	2005-09	Telecontrol protocols compatible with ISO standards and ITU-T recommendations – TASE.2 Object models	IS
-5-604		Conformance test cases for the IEC 60870-104 Companion standard	CDTS
-6-505		Telecontrol protocols compatible with ISO standards and ITU-T recommendations – TASE.2 User guide	BPUB

2.4.1.3. Support

In general IEC 60870 series is accepted and supported but it should be noticed that it includes communication protocols for several different purposes, from measurements for billing purposes to real time measurements for control system applications, from protection devices communications to inter-control centre communications.

2.4.2. IEC 60870-5 Overview

IEC 60870-5 international standard, developed by WG3, provides rules for communicating between telecontrol stations. Such rules are known as a telecontrol communication protocol. Several stations, which use this protocol, may be assembled into an interconnected installation for controlling and monitoring the operational equipment of a widely distributed electric power system, from a central point.

It initially focused on producing an extremely reliable data link layer protocol for slow serial links. This data link layer was designed to be used in either balanced point-to-point links or unbalanced multi-drop links, with several levels of reliability which were thoroughly characterized in the annexes of the following two specifications:

- 60870-5-1 Transmission Frame Formats
- 60870-5-2 Link Transmission Procedures

The next three specifications from WG3 described in general terms the most common utility application protocol functions used by proprietary protocols at the time. These functions included such features as initialization, select-before-operate and direct controls, accumulator freezing, report-by-exception, periodic reporting, remote parameter setting, and file transfer.

- 60870-5-3 General Structure of Application Data
- 60870-5-4 Definition and Coding of Application Information Elements
- 60870-5-5 Basic Application Functions

The five basic parts of the standard were published at the beginning of the 1990s.

Because the standard might be used for several applications and because evolution of requirements would continue, it was decided that the standard for each application area would be published as a “Companion Standard”. Each companion standard contains a selection of provisions taken from the base standards sections. These are tailored to suit a particular application by adding further provisions that are defined within the companion standard itself. The applications covered are all related to performing tasks needed by electric power systems, although companion standards for other types of system could also be produced.

The work of WG3 continued in the direction of producing a companion standard for “Basic Telecontrol Tasks” called IEC 60870-5-101, developed as a 3-layer communications protocol standard for use by utilities for SCADA. It was finally published as a Final Draft International Standard (FDIS) in 1995.

It was designed primarily to meet the needs of real-time exchange of data between compute-constrained devices over media-constrained communication channels (typically less than 1200 bps). This protocol is widely used in Europe and other countries, but is not typically used within the United States or Canada. In these two counties, a variation of IEC60870-5 Part 101 was developed, called DNP.

Meanwhile co-operation between WG3 and other WGs led towards the publication of two further companion standards.

- IEC 60870-5-102 Load Profiling (energy measurement through accumulators): this defines a protocol for transmitting “Integrated Totals” between the electricity users and suppliers who utilise the electric power transmission system.
- IEC 60870-5-103 Protection Equipment (monitoring and control of relays): this defines the protocol for an “Informative Interface”, for local use inside an electric substation. It connects the protection equipment to the substation automation equipment or to its telecontrol outstation.

After the publication of IEC 60870-5-101, the WG produced two addendums. Addendum “A1”, which adds some long Time Tags, and “A2”, which adds some details to the standard, so as to aid compatibility of implementation, and makes certain small but significant improvements to the protocol. WG3 also produced some supporting documentation, including information on which synchronous modems may be used in the physical layer of “101”, without reducing the protocol’s integrity.

These companion standards were three-layer serial protocols only, with no networking capabilities. Due to the advent of WANs in distribution automation, in 1996 WG3 started developing a standard to enable the Application messages (ASDUs) defined in “101” to be transported using Internet services (over the TCP/IP Protocol stack). This resulted in a new Companion Standard called IEC 60870-5-104 Telecontrol over TCP/IP, which has recently been published. It is equivalent to DNP when it runs over the TCP/IP.

Although the 60870-5 companion standards can technically be used within a substation, TC57 has designated IEC 61850 (Working Groups 10, 11 and 12) as the primary standard within substations, while 60870-5 is to be used for telecontrol (to remote sites) only.

WG3 recently released a revised edition of the original 101 companion standard and is currently investigating security solutions for the IEC 60870-5 protocols along with Working Group 15.

2.4.2.1. Reference Model

The Basic Reference Model divides a protocol into seven layers. The top three layers are directly concerned with the actual Application messages being sent between stations. The bottom four layers are concerned with the method used to Transport these messages between stations.

The simplified reference model used in the IEC 60870-5-101 standard (and the other companion standards) has fewer layers, because some of the facilities supported by the full seven layer model are not required and enhanced working of the remaining facilities is desired. Hence the model is often called the Enhanced Performance Architecture (EPA) Model.

Communication between Application Processes in the central station and those in remote outstations is performed according to the communication protocol.

Each station in an installation performs its own local application tasks, called *Application Processes.* For example the central station would drive the keyboard/display or other operator interface equipment and manage the database containing all the information about the installation, for instance, current values of measured variables obtained from remote outstations etc. Each station has a “stack” of protocol layers providing communication services to the station Application Processes at the top and accessing the communications medium at the bottom.

Each outstation would have Application Processes for scanning, reading and storing their local measurements and performing local control actions etc.

In general Application data is accepted at the top of the protocol stack in one station and passes down through the stack, acquiring in each layer any necessary extra data needed to control the working of the protocol, until it emerges in serial form at the bottom. It is then transmitted to the other station where it enters at the bottom of the protocol stack. The data passes up this stack until the original Application data emerges at the top and is passed to the Application Processes in the second station. This is called “peer to peer” communication because all data originating in a particular layer is transported to the same layer in the remote station.

2.4.2.2. Message Structure

Serial messages, as viewed outside of the stations, have a nested structure which derives from the layered structure of the protocol.

All data fields consist of octet strings of one or more octets.

The ASDU (Application Service Data Unit) is a block of data being sent from the Application Processes in one station to the Application Processes in another station.

According to the EPA model, some APCI (Application Protocol Control Information) is in general added to the ASDU to form the APDU (Application Protocol Data Unit). However the APCI is not needed in the IEC 60870-5-101 protocol, so the APDU is equal to the ASDU.

The Link layer adds its own LPCI (Link Protocol Control Information) to the APDU to form the LPDU (Link Protocol Data Unit). In addition it prepares each data octet in the LPDU to be transmitted as an Asynchronous start/stop serial character having one start bit (value=0), eight data bits (the data octet), one even parity bit and one stop bit (value=1).

The LPDU is transmitted as a contiguous frame with no idle line (“gaps”) between the asynchronous characters:

- LPCI = S+L+L+S+C+A+CS+E
- S = Start character which has a fixed defined bit pattern.
- L = Length character which specifies the length in octets of the ASDU+C+A
- C = The Link Control character.
- A = The Link Address field which is one or two characters chosen to suit the installation.
- CS = The Check Sum character.
- E = End character which has a fixed defined bit pattern.

The protocol specifies that, for transmission speeds up to 1200 bits/second, the Physical layer shall convert each transmitted bit directly into one of two frequencies, representing the binary one state and the binary zero state respectively. This form of modulation is called Frequency Shift Keying (FSK) and it is both symmetrical and memory-less. It is suitable for most voice frequency (v.f.) analogue channels on base band transmission line, power line carrier or radio communications media.

2.4.2.3. Frame Integrity

The LPDU frame provides a very high data integrity (IEC Integrity Class I2). There must be at least four bit errors in a received frame before an undetectable frame error is possible. This corresponds to a code hamming distance of four (hd=4).

The frame consists of two parts which may be called the “header” and the “body”.

The header contains the S+L+L+S characters and the body contains the remaining characters. Each frame is preceded and succeeded by a period of idle line (continuous binary one state). The header specifies the length of the ASDU+C+A and hence the length of the body. Due to the parity protection, at least two bit errors in the contents of any asynchronous character are required to cause an undetectable character error.

In the frame body, at least two characters with undetected errors are required to produce an undetectable Sum Check error. Thus a total of four data or parity bit errors are required to produce a received frame body with a possible undetectable error.

In order to transmit messages at speeds over 1200 bits/second, synchronous modems may be used. These have bit scramblers to ensure that the receiver clock does not lose synchronisation during prolonged periods without change of binary state in the data being sent.

Faster transmission is possible on directly connected data circuits using digital signal multiplexers. Speeds up to 19,200 bits/sec for asynchronous characters and faster for the same characters sent isochronously are possible.

2.4.2.4. The Link and Physical Layers

The protocol is intended for use with permanent directly connected data circuits between the central station and the outstations. These may be implemented as follows:

- With a multi-drop party line connection which is time shared between several or all outstations, using different Link addresses to identify individual outstations. This would normally be operated in a half-duplex mode on a single channel, sending to and receiving from each outstation in turn, using unbalanced (“speak when you are spoken to”) media access for the Link protocol.
- With individual full duplex connections to some or all outstations, with a single v.f. channel for each direction of communication in each connection. The individual connections permit balanced media access for the Link protocol, enabling spontaneous sending of data in both directions.

The protocol provides Link functions for supporting balanced and unbalanced media access. However practical considerations (including higher cost) may limit the extent to which full duplex balanced connections are used.

2.4.2.5. Internet Transport Interface

Every Telecontrol station conforming to the IEC 60870-5-104 standard has an Internet Transport Interface between its Application layer and the layers below. The interface and the lower layers are defined by the appropriate Internet standards. These include the Transmission Control Protocol (TCP), according to RFC 793, for the Transport layer immediately below the Transport Interface.

2.4.2.6. Provisions of the Application Layer

The Application layer of the protocol includes all the functions required to perform basic telecontrol tasks for distributed electric power systems in a standard way. The standard defines two sets of provisions for the Application protocol:

a) Application Functions

- Station Initialisation: After the central Controlling station and the various Controlled stations (outstations) have been initialised (made active), it is necessary for the Controlling station to obtain an image of the present states of all those digital (on/off) inputs, which are normally reported spontaneously, and all the values of the analogue inputs, which are similarly reported. To do this, a Station Initialisation command may be sent to all outstations, requesting that they return all their designated data as soon as possible.
- Data acquisition by polling or General interrogation: This function may be used to ensure that the network image values are up to date and have not been falsified by the undetected loss of spontaneously reported events since the last scan cycle. This function relies on the Request for User data class 1 & class 2 Link functions, defined in IEC 60870-5-2; these functions are not available when using the “104” protocol, because all layers below the Transport Interface are defined by Internet standards, which do not provide them.
- Cyclic data transmission: This function may be used to continuously update another central image with information data obtained from measurements taken at regular intervals of time. It is often used for monitoring the less vital inputs to an installation; that is those which are slow moving or do not require fast action at the Controlling station. When using the “104” protocol, this function should be used with care, taking due regard of the relatively long Transportation times likely to be encountered when using the

Internet. Too many APDUs of this type per second may cause queues of Telecontrol data to form, potentially delaying more important Telecontrol messages.

- Acquisition of events: Once the network image has been constructed, using the static data obtained from Station Interrogation, the image must be kept up to date with dynamic data obtained by the Acquisition of Events function, when changes take place. In the case of “104” protocol, event ASDUs that are tagged with their time of occurrence use the long Time Tag (ms to years) ensure that there can be no ambiguity about the time of occurrence due to any long transmission delays introduced by the Internet services.
- Clock synchronisation: In order to ensure accurate time tags, it is necessary for the clocks in all the outstations to be synchronised to the clock in the Controlling station. The protocol provides facilities for this to be done, using the Clock Synchronisation function.

When using the Internet, there is a variable delay before a transmitted message arrives at an outstation. This causes a time uncertainty that depends on the maximum transmission time offered by the Internet service provider. The resulting clock synchronisation setting is unlikely to be more accurate than within one second. Thus individual accurate clocks (radio, GPS…) will be required at each outstation when time tags having a better accuracy than this are required.

- Acquisition of transmission time delay: This function may be used to obtain the value of the transmission delay to be used when making allowance for it during the reset of an outstation clock.
- Command transmission: ASDUs containing Commands are sent from the Controlling station to the outstations when required. There are two main kinds of Commands: those for process information and those for system information.

When using the Internet, it is sometimes possible for a Command message to an outstation to be seriously delayed. The “104” protocol offers Time Tagged Command ASDUs so that the receiving outstation can check the time they were sent and potentially ignore any Commands that are “dangerously” late.

- Transmission of Integrated Totals: Integrated totals (such as Kilowatt-hours) are accumulated in counters, which may be read by outstations. The accumulating total in a counter may be sampled using a freeze command. After which the total may continue to accumulate (for integrated totals information) or start accumulating again from zero (for incremental information) by using a reset command.

Four modes of operation are provided.

- Mode A: the freeze and reset (if required) commands are derived from time signals from the outstation local clock. The resulting integrated totals or incremental information are transmitted to the Controlling station in ASDUs with Cause of Transmission = spontaneous, with or without a time tag.
- Mode B is the same as mode A except that ASDUs to be transmitted are held at the outstation until they are requested by a counter interrogation command from the Controlling station. The responding ASDUs from the outstation have Cause of Transmission = Requested by counter interrogation.
- Mode C, Counter interrogation commands are sent periodically to outstations requesting integrated totals/incremental information. The freeze and reset at the outstation are controlled by command settings within these interrogation commands (not by signals from the local clock). Several combinations of settings are permitted. Further Counter interrogation commands are then sent to collect the totals/incremental information, the responding ASDUs have Cause of Transmission = Requested by counter interrogation.
- Mode D is a combination of modes C and A, in which the freeze and reset at the outstation are controlled by Counter interrogation command settings sent from the Controlling station. But the resulting totals/incremental information is returned spontaneously.

• Parameter loading: Parameters, such as the threshold (minimum change needed) for reporting an analogue input or the High or Low limit for reporting an analogue input etc, are defined as Information Objects.

• Test procedure

• File transfer (for simple files): In general files are held in the part of a system where they are generated. For example within an electric power substation: disturbance data could be held in the protection equipment; event records could be held in the automation equipment or in the telecontrol outstation itself.

The Controlling station may request a Directory or Subdirectory from an outstation, to inform it what files are currently available for transfer. If the contents of a Directory/Subdirectory change it may be transmitted spontaneously to the Controlling station.

Files may also be transferred from the Controlling station to an outstation.

b) Application Service Data Units (ASDU)

The protocol offers a set of different types of ASDU suitable for the Application. However they all have the same general format.

- T = Type Identification (1 data octet)
- Q = Variable Structure Qualifier (1 data octet). It indicates the number of Information Objects in the ASDU or the number of Information Elements in a single Information Object.
- C = Cause of Transmission (1 or 2 data octets, fixed per installation). Causes include: periodic/cyclic, spontaneous, Request/Requested, Activation (of a Control action), etc.
- CA = Common Address (1 or 2 data octets, fixed per installation). Distinguishes the Station Address/Station Sector Address housing the Information Objects (IO1 to IOn).
- OA = Information Object Address (1, 2 or 3 data octets, fixed per installation).
- IE = Set of Information Elements (as defined for the type of ASDU specified in the T field).
- TT = Time Tag of Information Object (if specified for the type of ASDU specified in the T field).

When using the “104” protocol, some Application Protocol Control Information (APCI) is added to each Application Service Data Unit (ASDU) so as to obtain an Application Protocol Data Unit (APDU) that is suitable for Internet transportation.

The APCI includes a copy of some of the control information fields used by the Packet layer of the X25 protocol (according to ISO/IEC 8208). The associated control procedures are also copies of those used by X25.

The purpose of the APCI and associated procedures is to ensure that Application messages, each consisting of an individual APDU, are not lost or duplicated. It also enables message transfers to be started/stopped and supervises Transport connections. Some messages are used for control purposes only and do not include an ASDU.

2.4.3. IEC 60870-6 overview

The IEC60870-6 Telecontrol Application Service Element 2 (TASE.2) protocol (also known as the InterControl Center Communications Protocol (ICCP)) was developed by IEC TC57

WG07 for data exchange over Wide Area Networks (WANs) between a utility control center and other control centers, other utilities, power plants and substations.

TASE.2 (ICCP) is used in almost every utility for inter-control center communications between SCADA and/or EMS systems. It is supported by most vendors of SCADA and EMS systems.

Since it was first developed in the mid 1990's before object models had been developed for SCADA applications, TASE.2 (ICCP) was not designed to support the transfer of different types of object models, beyond those defined in Part 802.

The definition of TASE.2 consists mainly of following documents:

- 60870-6-503 Services and Protocol: This part of IEC 60870 defines a mechanism for exchanging time-critical data between control centers. In addition, it provides support for device control, general messaging and control of programs at a remote control center. It defines a standardized method of using the ISO 9506 Manufacturing Message Specification (MMS) services to implement the exchange of data. This part of IEC 60870 defines the TASE.2 application modeling and service definitions.
- 60870-6-602 Transport Protocols: This Technical Report describes the Transport Profiles for the IEC 60870-6 Series over WAN with Reference to International Standardized Profiles (ISP's) used by distributed SCADA/EMS applications in control centers, power plants and substations. The Transport Profiles use virtually any standard or de-facto standard (including TCP/IP) connection-mode and connectionless-mode network services over any type of transmission media.
- 60870-6-702 Profiles: This specification defines the Application Profile (Layers 5-7) for use with ICCP. It is needed for vendors implementing protocol stacks that support the ICCP application layer. Most users of ICCP will not be concerned with this specification.
- 60870-6-802 Object Model: This part of IEC 60870 proposes object models from which to define object instances. The object models represent objects for transfer. The local system may not maintain a copy of every attribute of an object instance.

2.4.3.1. ICCP/TASE

Inter Control Centre Communications (ICCP) and Telecontrol Application Service Element (TASE 2) is aimed to provide control centre data exchange but it is not limited to power systems targeting also power plants, factory automation and others.

IEC 60870-6-502 defines services and protocols able to provide time critical data exchange over ISO compliant protocol stack.

The TASE.2 standard is built on top of MMS describing an advanced standardized application of MMS (based on both, MMS services and protocols) to enhance the available functionality by means of structured data and associated semantics into supporting several data types such as real time, time series, eventing and others.

	Control Centre Application
7	TASE
	MMS
6	Presentations
5	Session
4	Transport
3	Network
2	Data link
1	Physical

Figure 2-19: TASE, MMS and ISO protocol stack

The standard establishes a client-server model for data access as well as some security functionalities supporting both, distributed and centralized architectures.

Today, ICCP-TASE.2 is widely used world-wide for inter-utility data exchange and power plant dispatching.

Although profiles for the IEC60870-5 standards were developed for this same application space (IEC60870-5- 102), the ICCP-TASE.2 standard is more widely used particularly in large-scale systems in North America, South America, Asia, and Europe.

2.4.4. Review

In general terms IEC 60870 set of standards are widely in use sharing real world communications with older legacy communication protocols.

2.5. IEC 61850

2.5.1. Summary

2.5.1.1. Description

IEC 61850 Standard was developed by WGs 10, 11 and 12 belonging to IEC Technical Committee 57. These working groups focused on communications within substations, as opposed to distributed Telecontrol, which was the focus of Working Group 3, or communications between control centers, as in Working Group 7. Communications within the substation was divided into three levels: station, process, and unit. Initially each Working Group handled a different part of the architecture, but in later years they formed joint task forces to address mutual issues. The initial specifications focused on a “top-down” approach, characterizing the interactions between substation components at a requirements level:

- 61850-1 Introduction and Overview
- 61850-2 Glossary
- 61850-3 General Requirements
- 61850-4 System and Product Management
- 61850-5 Communications Requirements

These WGs also had within their scope the task of developing a standard file format for exchanging information between proprietary configuration tools for substation devices. This standard is based on Extensible Markup Language (XML), and draws on the data modelling concepts found in the other parts of IEC 61850, and the capability of the IEC 61850 protocols to “self-describe” the data to be reported by a particular device.

- 61850-6 Substation Configuration Language

At about the time when the requirements parts of the work were approaching completion, experts involved in the WGs 10-12 became aware of the work that the Electrical Power Research Institute (EPRI) and the Utility Communications Architecture (UCA®) Forum had completed on UCA, especially on developing a standard set of services and data models for intra-substation communications. This work was incorporated into IEC 61850, with some significant modifications, in the following specifications:

- 61850-7-1 Principles and Models

- 61850-7-2 Abstract Communications Service Interface
- 61850-7-3 Common Data Classes (Object Models)
- 61850-7-4 Compatible Logical Node Classes and Data Classes (Object Models)

Most of the IEC 61850 specifications describe the protocol in a very abstract manner, and only the last parts of the standard describes “Specific Communication Service Mapping” onto a particular set of protocols. The initial protocol profiles for IEC 61850 are nearly identical to those developed for IEC 60870-6 (TASE.2) between substations, using the Manufacturing Message Specification (MMS) and both Internet and OSI protocol stacks. These are mainly full 7-layer profiles, but there are also high-speed profiles used directly over Ethernet (IEEE 802.x) LANs for “process bus” and protection tripping. The profiles are described in:

- 61850-8 Protocol Mapping

The initial intent was that IEC 61850 would be a superset of UCA 2.0 and that devices implementing the two protocol suites could interoperate. Another significant contribution of IEC 61850 is a high-speed Ethernet-based protocol to be used for communications between “smart transformers” and higher level devices, to permit several different devices to simultaneously receive sampled waveform values from a given transformer in real-time:

- 61850-9 Sampled Measured Values

Parts 7.1, 7.2, 7.3, 7.4, and 9.1 of 61850 have become International Standards with the remaining protocol pieces reaching International Standard status in 2003 to early 2004. The final work in IEC 61850 was to develop test procedures for verifying conformance to the protocol, finished in 2005:

- 61850-10 Certification Test Procedures

The major work on IEC 61850 being done, TC57 decided in 2003 to merge the first three WGs 10, 11 and 12 into one new WG10. This new WG10 has the following tasks:

- Maintain all documents of the IEC 61850 series
- Work on future projects within the scope of the new WG

2.5.1.2. Status

Table 2-XXVI: IEC – Search > Publications & Work in progress > Reference IEC61850

Part	Date	Description	Status[6]
-1	2003-04	Introduction and overview	TR
-2	2003-08	Glossary	TS
-3	2002-01	General requirements	IS
-4	2002-01	System and project management	IS
-5	2003-07	Communication requirements for functions and device models	IS
-6	2004-03	Configuration description language for communications in electrical substations related to IEDs	IS
-7-1	2003-07	Basic communication structure for substation and feeder equipment – Principles and models	IS
-7-2	2003-05	Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)	IS
-7-3	2003-05	Basic communication structure for substation and feeder equipment – Common data classes	IS
-7-4	2003-05	Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes	IS
-8-1	2004-05	Specific communication Service Mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and ISO/IEC 8802-3	IS
-9-1	2003-05	Specific communication Service Mapping (SCSM) – Sampled values over serial unidirectional multidrop point to point link	IS
-9-2	2004-04	Specific communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3	IS
-10	2005-05	Conformance testing	IS
-6		Configuration description language for communications in electrical substations related to IEDs	ACDV[7]
-7-3		Basic communication structure for substation and feeder equipment – Common data classes – Amd. 1: Clarifications and Corrections, and Extensions for Power Quality and Representation of Historical and Statistical Information	ACDV
-7-4		Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes – Amd 1: Addition of power quality monitoring	ACDV
-7-4		Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes – Amd 2	ACDV
-7-420		Communication systems for distributed energy resources (DER) – Logical nodes	CCDV
-9-2		Specific Communication Service Mapping (SCSM) – Sampled values over ISO 8802-3	ACDV

2.5.1.3. Support

There are already real experiences of interoperability in substations. These substations are the result of projects developed jointly by one utility and several vendors. And the conclusion that can be drawn is that interoperability is only demonstrated with devices of different vendors working together in a substation; certifications of compliance with the standard don't guarantee such interoperability, but demonstrate a minimum of conformance.

A pilot project (R&D) was developed between 2001 and 2004 in *SE Gernika* (Spain), running in parallel with a conventional system. And subsequently, two more projects of completely

[6] IEC Stage Codes, see http://www.iec.ch/ or Annex A: IEC Stage Codes
[7] Some published parts of the standard are under revision and new versions are in progress.

new substations were carried out, *SE Ciudad Universitaria* (Spain) and SE Wind Farm *La Venta II* (Mexico). In the meantime there have been many installations of real IEC 61850 substations, that are already commissioned and working satisfactorily.

2.5.2. Overview

2.5.2.1. Object Models & Information Models

As defined by the IEC 61850 standard: *Object Models are standardized formats or templates for exchanging data between different equipment or systems. Standard object models, combined with standard service models (methods for sending the data, e.g. report-by-exception, periodic, control commands) and standard protocols (the bits and bytes actually send over the communication channel), permit different systems to interact with minimal customization and greater interoperability. The combination of object model, service model, and protocol profiles can be termed the "information model"*

The concepts of information model and object model become extremely significant to understand the spirit of the standard due to its sense of abstraction. It shouldn't be forgotten that the main objective of IEC 61850 standard is to define an interoperable communication system for the exchange of information between IEDs. Further aims are to define the semantics (meaning and behavior) and syntax of the data being communicated, and the ability of a device to describe itself.

2.5.2.2. Abstract Communication Service Interface (ACSI) and the Application

An "abstract service" can be defined as a service that specifies the information to be interchanged without defining its format. IEC 61850 standard specifies in its part 7-2 a set of abstract services and objects which may allow applications to be written in a manner which is independent from a specific protocol. This abstraction allows both vendors and utilities to maintain application functionality and to optimize this functionality when appropriate. The concrete implementation of the device internal interface to the ACSI services is a local issue.

This abstract interface specifies the models and services that can be utilized for access to the devices of substation automation object model. Communication services provide mechanisms for a wide variety of operations, as reading and writing of object values, and also for example for controlling primary equipment. Then the ACSI is mapped to the available services on application layer, as specified within a given Specific Communication Service Mapping (SCSM). And it's necessary to highlight that only application components that implement the same SCSM will be interoperable. Making use of this ACSI, IEC 61850 uncouples applications and communications (Figure 2-20).

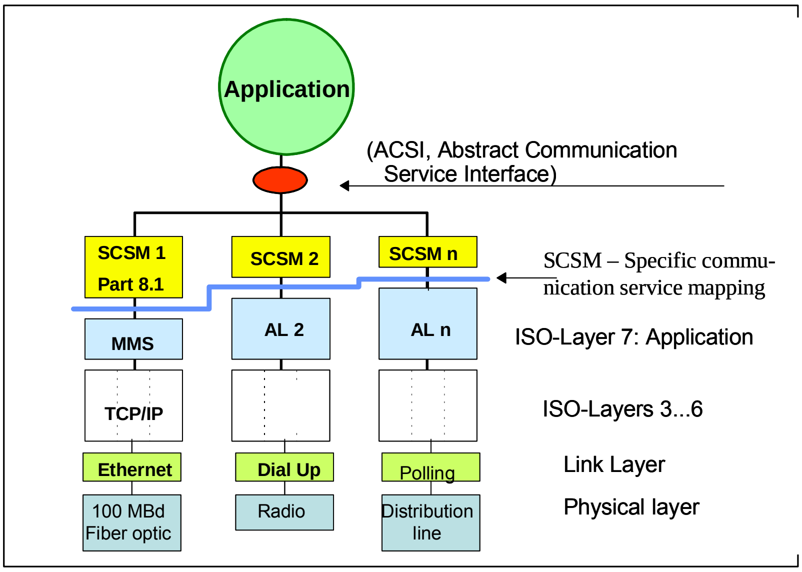


Figure 2-20: Reference model of IEC 61850 and its application to integrate different physical and link layers in accordance with the use of existing infrastructure in distribution systems (SCSM 1 in accordance with IEC 61850-8-1)

The structure to implement this system is the ISO's 7-layer communication model, and the basic protocols chosen for the layers are Ethernet (Data link layer), IP (Network layer), TCP (Transport layer), and MMS (Manufacturing Messaging Specification) as SCMS protocol (Application layer).

Two superior levels constitute the "information model", and are specified in parts 7-3 and 7-4 of the standard.

In the first superior level, standard establishes a set of "Common Data Classes" (CDC). One common data class defines structured information consisting of one or more attributes. The data type of an attribute may be a basic type (for instance INTEGER), but also may be a more complex type composed by several basic types.

And in the top level, "Compatible logical node classes" and "data classes" are specified. No additional specification is required as the identification and meaning of the logical node and data classes are defined. Logical nodes are very similar to 'bricks' defined in Utility Communications Architecture (UCA) Version 2.0.

2.5.2.3. Conceptual Class Models

The conceptual models to build the domain-specific class models are:

- SERVER, that represents the external visible behaviour of a device. All other ACSI models are part of the server. A server has two roles: to communicate with a client (most service models in IEC 61850 provide communication with client devices) and to send information to peer devices.
- LOGICAL-DEVICE (LD), that contains the information produced and consumed by a group of domain-specific application functions; functions are defined as LOGICAL-NODEs.
- LOGICAL-NODE (LN), that contains the information produced and consumed by a domain-specific application function, for example, overcurrent protection or circuit-breaker.
- DATA, that provide a way to specify concrete information, for instance, position of a breaker with quality information and timestamp, contained in LOGICAL-NODEs. These DATA class may be defined recursively.

Each of these information models is defined as a class. The classes consist of attributes and services, and are the basic building blocks that provide the framework for substation automation device models.

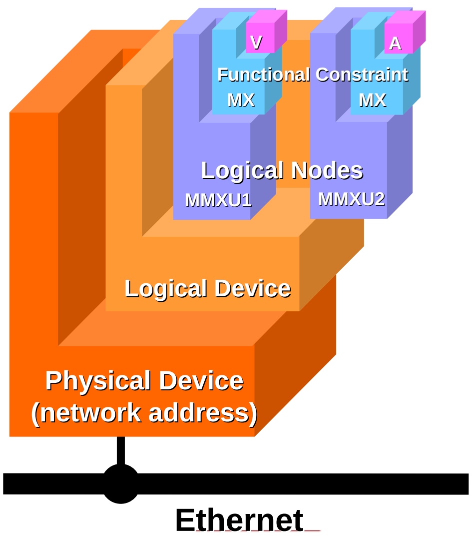


Figure 2-21: SERVER Anatomy

2.5.2.4. Conceptual Service Models

In addition to the information models listed above, the ACSI comprises the following models that provide services operating on data, data attributes, and data sets:

- DATA-SET, that permits the grouping of data and data attributes and is utilized for direct access and for reporting and logging.
- Substitution, which supports replacement of a process value by another value. It's restricted to the lowest level in the DATA class.
- SETTING-GROUP-CONTROL-BLOCK, that defines how to switch from one set of setting values to another one and how to edit setting groups.
- REPORT-CONTROL-BLOCK and LOG-CONTROL-BLOCK, that describe the conditions for generating reports and logs based on parameters set by the client. Reports may be triggered by changes of process data values (for example, state change or dead band) or by quality changes and may be sent immediately or deferred, providing change-of-state and sequence-of-events information exchange. Logs can be queried for later retrieval.
- Control blocks for generic substation event (GSE), which supports a fast and reliable system-wide distribution of input and output data values. This means peer-to-peer exchange of binary status information, for example, a trip signal.
- Control blocks for transmission of sampled values, for fast and cyclic transfer of samples, for example, of instrument transformers.
- Control, which describes the services to control, for example, a breaker. It's also restricted to the lowest level in the DATA class.
- Time and time synchronization, that provides the time base for the device and system.
- File transfer, which defines the exchange of large data blocks such as programs.

It's worth highlighting that LN is one of the major building blocks that has associations to most of the other information exchange models, for example, report control, log control, and setting control.

Of these services, most are taken care of automatically by the basic communications software. The key services that are important for the substation engineer to become involved with are the Data Sets. The substation engineer should help define the data groupings, based on substation requirements as well as other user and software application requirements.

Although clearly initial Data Sets must be defined, they can be changed at any time. Therefore, one of the requirements from the vendors must be an HMI (human-machine interface) tool that permits the easy definition and modification of these Data Sets.

Piece of Information for COMmunications (PICOM) is a term defined by CIGRE WG34.04 to describe the information passed between Logical Nodes. The components of a PICOM are:

- Data, meaning the actual data items sent from one LN to another LN
- Type of data, meaning its format
- Performance of the information exchange

The PICOMs are used primarily to define what data needs to be exchanged between protective relaying IEDs. The detailed exchange parameters of PICOMs should be part of a protective relaying vendor's package; however, the substation engineer will need to specify very precisely what protection events should trigger what actions.

The abstract objects and communication services have to be "mapped" to real-world bits and bytes, in other words, to actual communication protocols. IEC61850 currently has two protocol mapping specified, namely, the GSE protocol for transmissions between very high speed devices (such as protection relays) and MMS over the TCP/IP suite of protocols.

2.5.2.5. Information Models

IEC61850 Parts 7-3 and 7-4 comprise the Substation Object Models. These two Parts of the IEC 61850 specifications describe the object models as abstract objects, and only the last parts of the standard describes "Specific Communication Service Mapping" onto a particular set of protocols.

Object Models (OM) are Nouns with pre-defined names and pre-defined data structures. Objects are the data that is exchanged among different devices and systems. The OM rests on top of the services model (SM) and the communications protocols (CP).

It should be noted that new object models are continually being developed. Specifically, work is under way to add a suite of Power Quality object models to deal with sag, swell, harmonics, snapshots, and a variety of averaged values.

The OM structure from the bottom up is described below:

- Standard Data Types: common digital formats such as Boolean, integer, and floating point.
- Common Attributes: predefined common attributes that can be reused by many different objects, such as the Quality attribute. These common attributes are defined in IEC61850-7-3 clause 6.
- Common Data Classes (CDCs): predefined groupings building on the standard data types and predefined common attributes, such as the Single Point Status (SPS), the Measured Value (MV), and the Controllable Double Point (DPC). In essence, these CDCs are used to define the type or format of Data Objects. These CDCs are defined in IEC61850-7-3 clause 7.
- Data Objects (DO): predefined names of objects associated with one or more Logical Nodes. Their type or format is defined by one of the CDCs. They are listed only within the Logical Nodes. An example of a DO is “Auto” defined as CDC type SPS. It can be found in a number of Logical Nodes. Another example of a DO is “RHz” defined as a SPC (controllable single point), which is found only in the RSYN Logical Node.
- Logical Nodes (LN): predefined groupings of Data Objects that serve specific functions and can be used as “bricks” to build the complete device. Examples of LNs include MMXU, which provides all electrical measurements in 3-phase systems (voltage, current, watts, vars, power factor, etc.); PTUV for the model of the voltage portion of under voltage protection; and XCBR for the short circuit breaking capability of a circuit breaker. These LNs are described in IEC61850-7-4 clause 5.
- Logical Devices (LD): the device model composed of the relevant Logical Nodes. For instance, a circuit breaker could be composed of the Logical Nodes: XCBR, XSWI, CPOW, CSWI, and SMIG. Logical Devices are not directly defined in any of the documents, since different products and different implementations can use different combinations of Logical Nodes for the same Logical Device. However, many examples are given in IEC61850-5.

2.5.3. Review

During the coming years an increasing number of the Substations used in Electric Power Transmission Systems will benefit by having more elaborated distributed Automation equipment, but this will be an evolutionary process.

In some situations, new Power Transmission Systems with new highly Automated Substations will be built. In other situations existing Substations will have their Automation extended or improved. But many situations (both existing and new) will not require the more elaborate Automation supported by IEC 61850.

2.5.3.1. IEC 61850 vs. DNP3

The International Electrotechnical Commission (IEC) Technical Committee 57 (TC57) began releasing the IEC60870-5 series of standards related to data communication protocols for intelligent electronic devices (IED) over serial links in 1990. After several more years of effort, the application layer protocols needed to build actual implementations of these standards had not been finalized.

In 1993, the substation automation division of GEHarris in Calgary, Alberta, Canada took the existing IEC work, finished it internally, and released it as the Distributed Networking Protocol Number 3 (DNP3). Simultaneously, GE-Harris formed a non-profit organization with open membership and transferred the ownership of and responsibility for DNP3 to this group called the DNP Users Group. The DNP Users Group attracted a critical mass of North American suppliers and utilities as members and supporters that resulted in DNP3 becoming widely used in North America.

The IEC TC57 continued its work and did finally release the application protocols for serial link based communications as IEC60870-5-101 in 1994.

Both DNP3 and IEC60870-5-101 specified a master-slave protocol for point-to-point serial links. A major consideration in the early 90s was the relatively high cost of bandwidth for the communications channels available to utilities. The byte efficiency of DNP3 and IEC60870-5-101 made them suitable for immediate applications in these low bandwidth environments. Since then, as bandwidths costs have declined and as the use of high-speed networking technology like Ethernet became widespread, even in substations; both the IEC and DNP3 have offered Ethernet based versions of these protocols that transmit the same byte sequences used on serial links over high-speed local area networks (LAN) using the TCP/IP or UDP/IP protocols over Ethernet.

The resulting IEC standards had minor differences with DNP3. Although seemingly minor, these differences resulted in incompatibilities that have fragmented the market. DNP3 became very widely used in North America and in other countries where North American suppliers had strong market share, while IEC60870-5-101 became dominant in Europe and other countries where European suppliers were dominant.

IEC61850 specifies a set of communications requirements for substations, an abstract service model for commonly required communications services in substations, an abstract model for substation data objects, a device configuration language based on XML, and a mapping of these abstract models to the MMS application layer protocol running over TCP/IP based Ethernet networks. The virtualized architecture of the IEC61850 standard (whereby an abstract model for services and objects are mapped onto a specific protocol profile) provides a flexible approach that could, theoretically, be mapped onto other protocols in the future.

The most significant differences in the roots of DNP3 (including IEC60870-5) and IEC61850 is that DNP3 was originally defined as an RTU protocol for low-bandwidth point-to-point serial link requirements that was later migrated for use over high-speed substation networks. IEC61850 was designed specifically for application in the substation LAN environment. Most of the technical differences between these protocols can be directly traced to these different roots.

a) Comparison of Communications Profiles

The DNP3 profiles enable the transmission of the same protocol originally developed for serial links over either connection-oriented or connectionless LANs. This results in the essential character of the protocol being preserved (i.e. master-slave) while supporting the very significant performance improvements that the use of modern LAN technology affords. The only real difference in the DNP3 connection-oriented versus connectionless environments is that the latter avoids the small TCP overhead of maintaining separate TCP connections between each master and slave.

The IEC61850 connection oriented profiles offer a similar capability as the DNP3 profiles offer for basic station level and SCADA services using a client-server approach that enables independent communications between nodes. IEC61850 connectionless profiles support other capabilities for specific substation applications that go beyond the original intent of DNP3.

b) Comparison of Service Models

The services supported by DNP3 are a large subset of that offered by IEC61850. This is not surprising since both are intended for similar applications in substation automation. In several areas where either DNP3 or IEC61850 has a capability not supported by the other, it is still possible to implement these services by combining other services.

For instance, event logs can be implemented using files in DNP3 even though the DNP3 standard does not specify how to implement event logs. While the advantage of having the standard define these capabilities directly might be lost, the basic functionality is still available.

Table 2-XXVII: 2.5.3.1. IEC 61850 vs. DNP3 services comparison

Service Description	DNP3	IEC 61850
Read/Write	YES	YES
Reporting	YES	YES
Control (SBO and Direct)	YES	YES
Enhanced Control (with Reports)	*	YES
Files	YES	YES
Start/Stop	YES	*
Event Logs	*	YES
Substitution (Forcing)	YES	YES
Object Discovery	-	YES
Substation Configuration Language (XML)	-	YES
Peer-to-Peer Messaging (GOOSE/GSSE)	-	YES
Sampled Measured Values (SMV)	-	YES

*Not in the standard, but can be implemented

There are services that IEC61850 offers that cannot be practically supported using the current version of DNP3. These services include high-level (object discover) or very high-performance (GOOSE, GSSE, and SMV) services were not practical for low-bandwidth serial link applications.

c) Comparison of Object Models

Both IEC61850 and DNP3 define various objects for representing power system data.

The DNP3 object model is based on a traditional remote terminal unit (RTU) device model. A traditional RTU is general purpose device capable of collecting I/O signals in a variety of formats (digital, analogy, state, etc.) and communicating those I/O points using a given SCADA protocol, like DNP3. Because RTUs were traditionally general purpose, it was the user or system engineer that determined the specific function a specific I/O point represented when they wired that I/O point within the substation. Furthermore, the use of small 8-bit numbers to represent object and variation types for specifying a data point allows DNP3 to maximize the number of data points that could be fit into a single DNP3 data frame. This byte efficiency was critical to the effectiveness of DNP3 as a solution for low-bandwidth serial links.

The IEC61850 data model is an object oriented model that not only defines the basic data types for common data points, but also rigorously defines the naming conventions used and how the data is organized into functional groupings called logical nodes. IEC61850 does not use compact numbers to describe data points. Instead, IEC61850 uses names that specify a fixed hierarchical organization for the data to describe each data object. The name specifies not the only the way you access the data point via the protocol, but it also defines its functional characteristic within the device. In other words, the engineer can determine that a given point is a voltage without having to know how the device is wired.

Additionally, IEC61850 includes a Substation Configuration Language that can be used to express the configuration of all the data objects in a given device using XML. An SCL file will contain a description of all the logical devices, logical nodes, etc. that are defined for a given device. The SCL file can be used for many purposes that can significantly lower costs and improve productivity including: automated tools can be developed to automatically configure devices with specific objects, configuration information on devices can be exchanged among devices improving the interchangeability of devices and applications, and many other future uses limited only by the creativity of users and suppliers.

d) Conclusion

In many ways, a direct head to head comparison between DNP3 and IEC61850 is not fair, and depending on the circumstance, might not even be valid. They are not mutually exclusive, each protocol has characteristics that will make it optimal for a given set of application constraints and was designed to be optimized for a given set of requirements.

The byte efficiency of DNP3 makes it an excellent choice for bandwidth constrained applications in distribution like pole-top devices or where existing systems already provide DNP3 connectivity.

The high-level object models and high-performance services of IEC61850 will make it an excellent choice where large numbers of devices must be configured, where the number of communicating entities is difficult to fix or is constantly changing, and where changes in device configuration is frequent cause maintenance problems in existing applications.

2.5.3.2. IEC 61850 vs. IEC 60870-5-101/104

Whereas IEC 60870-5-101 and IEC 60870-5-104 both define the use of simple Information Objects, consisting of an ADDRESS+VALUE+TIME TAG (Optional) for individual single points in the Process Plant (Substation), IEC 61850 defines more elaborate Information

Objects, each relating to a complete piece of equipment (multipoint entity) in the Process Plant (more elaborately Automated Substation).

The IEC 61850 enables the various Automation functions to be broken down into elementary functions, which may then be allocated to various IEDs distributed within the Substation and interconnected by Substation Internal highways.

The transmission of messages, containing the more elaborate Information Objects, between the central Controlling station and the remote Substations requires broadband communication media, because each message contains more data than the simpler IEC 60870-5-101/104 messages. Similarly broadband media are required for the Substation Internal highways.

For each particular situation, the following should be considered:

- Is there a need to have more elaborated Automation in the Substations?
- To what extent would IEC 61850 conforming equipment benefit the System?
- Will the necessary Broadband Communication paths be available?

In general the requirement to manufacture, maintain, and sometimes to convert, equipment conforming to IEC 60870-5-101 and IEC 60870-5-104 will continue for many years.

2.6. IEC 61400-25

2.6.1. Summary

2.6.1.1. Description

The IEC 61400 is devoted to wind power and the TC88 has produced the part 25 of this standard. The part 25 covers data models, data exchange models, mapping to specific communication means and conformance testing. The set of standards grouped below part 25 is based on IEC 61850 standard extending it to provide support to wind power plants.

2.6.1.2. Status

Table 2-XXVIII: IEC – Search > Publications & Work in progress > Reference IEC61400-25

Part	Date	Description	Status[8]
-1	2005-08	Design requirements	IS
…	…	…	…
…	…	…	…
-25-1		Communications for monitoring and control of wind power plants – Overall description of principles and models	CDIS
-25-2		Communications for monitoring and control of wind power plants – Information models	CDIS
-25-3		Communications for monitoring and control of wind power plants – Information exchange models	CDIS
-25-4		Communications for monitoring and control of wind power plants – Mapping to XML based communication profile	PWI
-25-5		Communications for monitoring and control of wind power plants – Conformance testing	CDIS
-25-6		Communications for monitoring and control of wind power plants – Logical node classes and data classes for condition monitoring	1CD
…	…	…	…

The different parts of the standard are almost draft international standards with the committee drafts already voted.

The most significant issue regarding the state is that part 25-4 was providing a specific mapping to web services but defining just one possible communication profile was judged too restrictive. Therefore this part of the standard was delayed until it is completed with more mappings ensuring a wider range of alternatives.

[8] IEC Stage Codes, see http://www.iec.ch/ or Annex A: IEC Stage Codes

2.6.1.3. Support

The IEC 61400-25 is not supported at all. There has been an available implementation of this standard for demo purposes but the vast majority of the commissioned wind farms are using proprietary control systems with private owned data models and communications protocols.

There have been some successful experiences of the integration of a large quantity of wind farms control centres in one single remote location acting as delegate dispatch (see [www-4]).

Short term success depends on the technical requirements imposed to build wind power plants (procurement specifications) while, on the medium and long term, this standard is closely linked to IEC 61850's future and has pretty good chances of gaining public acceptance after some cross consistency effort to guarantee coherency among all 61850 derivatives.

2.6.2. Overview

The IEC 61400-25 aims to the integration of SCADA applications into the wind turbine controllers from different vendors in a uniform way using a client-server model approach. In order to do so, meta-data (that is data about data) and unique semantics are provided along with the proper control information.

2.6.2.1. Data Model

The information model is structured in several components:

- Wind Turbine: Rotor, transmission, generator, converter, nacelle, yawing, tower and alarms.
- Meteorological data
- Wind Power Plant
- Grid Connection

At the same time, the information covers five functional targets, namely: Process, cumulative, historical, settings and meta-data.

Merging information scope with the different components produces a set of eighteen Logical Nodes (following the IEC 61850 nomenclature) summarized in Table 2-XXIX .

Table 2-XXIX: IEC 61400-25-2 Logical nodes

LN name	Description	Notes
LLN0	Logical node zero (root at IEC 61850-25-2 hierarchy)	System
LPHD	Physical device information	“”
WTUR	Wind turbine general information	Wind Power Plant spec.
WROT	Wind turbine rotor information	“”
WTRM	Wind turbine transmission information	“”
WGEN	Wind turbine generator information	“”
WCNV	Wind turbine converter information	“”
WGDC	Wind turbine grid connection information	“”
WNAC	Wind turbine nacelle information	“”
WYAW	Wind turbine yawing information	“”
WTOW	Wind turbine tower information	“”
WALM	Wind turbine alarm information	“”
WSLG	Wind turbine state log information	“”
WALG	Wind turbine analogue information	“”
WREP	Wind turbine report information	“”
WMET	Wind power plant meteorological information	“”
WAPC	Wind power plant active power control	“”
WREA	Wind power plant reactive power control	“”

In order to establish each data object attributes a reference wind turbine model is considered: the most prevailing wind turbine with three blades, variable speed, active pitch control and gear box transmission. As consequence, other wind turbines would require extending the base standard to cope with their specific characteristics.

In the same specialized logical nodes are defined for this standard, the corresponding data containers are also derivatives form the base standard. IEC 61400-25-2 required CDC are new (Status Value: STV; …), pure inherited from IEC 61850-7-3 (Measured Value: MV; …) or specialized (Device Name Plate: DPL becomes WDPL).

2.6.2.2. Information exchange model

Services in the information exchange model are divided in two groups:

- Operational Functions: Authorisation, Control, Monitoring and Processed Information (elaborated/filtered/inferred/…)
- Management Functions: Accounts management, set up, diagnostic and synchronisation

The standard provides conceptual designs for these information exchanges and reminds associated issues but without providing any concrete specification. For instance, secure communications for authorisation functions mentions explicitly involved concepts (authentication, authorization, integrity, confidentiality, non-repudiation) but leave details for each available profile/mapping. Hence, exemplary conceptual designs could be considered more as a good practice guide than a proper service specification.

2.6.2.3. Communication profiles

IEC 61400-25-4 draft provides a mapping to web services as only supported communication even when the standard was designed to handle many other profiles as shown at Figure 2-22.

As far as publishing the standard with one single mapping was considered inappropriate – restrictive and technology immature- it is to be completed with the following profiles:

- Web services
- IEC 61850-8-1 MMS (already published)
- OPC XML DA (in progress)
- IEC 60870-5-104 (in progress)
- DNP3 (in progress)

In order to be standard compliant, at least one should be implemented.

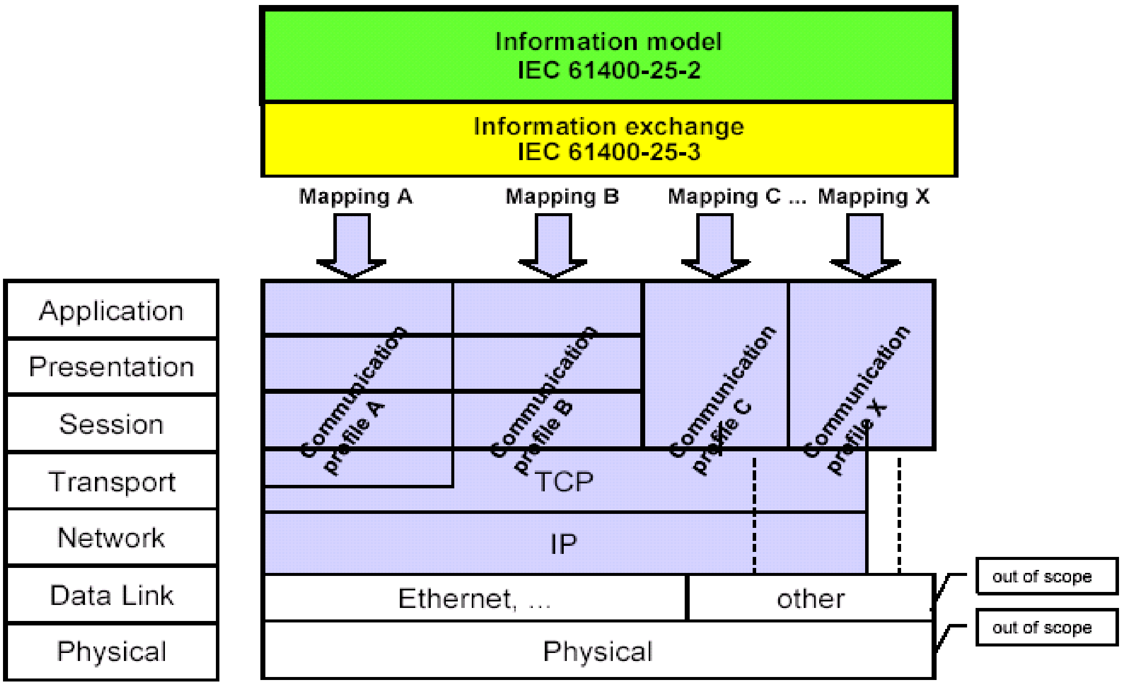


Figure 2-22: IEC 61400-25 conceptual mapping architecture

2.7. IEC 61850-7-420 (former IEC 62350)

2.7.1. Summary

The IEC61850-7-420 standard has been recently published (end of April 2006) as committee draft for vote (CDV) with a closing date set at end of September of 2006. This standard covers several DER types and specifies the applicable object models of DER units information modelling for purposes such as monitor, control, etc.

The IEC TF57 WG17 is behind this standard, formerly known as IEC 62350 (up to committee draft status) and based on a previous work distributed as “Utility Communications Architecture (UCA®) Object Models for Distributed Energy Resources (UCA-DER)” (see [Ref-5]). UCA™ (Utility Communications Architecture) and specially UCA2.0 (IEEE TR 1550:1999) have been used as input for the specification of IEC 61850 within several IEC TC 57 working groups.

The standard focuses the normalization needs of DER devices for a future Advanced Distribution Automation (ADA) environment by means of structured data models based on the UCA™ model.

The IEC document is issued as CDV in order to obtain the feedback of reviewers as soon as possible and admitting that more drafts will be required to handle those technologies left out in the first attempt.

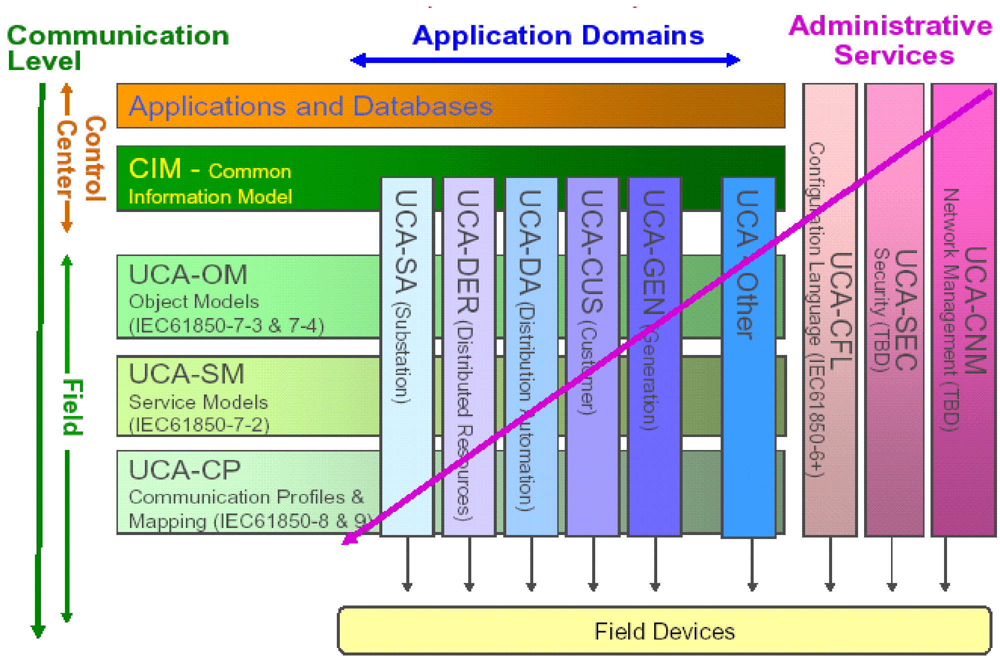


Figure 2-23: UCA architecture[9]

2.7.1.1. Description

The IEC 61850-7-420 grows over the base established by the IEC 61850 standard taking the logical node, logical device, common data classes and remaining available modelling entities as base for the information models of several DER technologies.

The primary sources of energy considered in the standard are reciprocating engines, fuel cells and photovoltaic systems. Combined Heat and Power (CHP) devices are included as to be deeply reviewed and improved by experts on the field. These are completed with the remaining parts of the plant (generator, exciter, etc.).

The data model is completed with general metering and physical measurements models but also requiring a review from a general context which is to be coordinated with some other standards.

The communication profiles are shared with those already available at IEC 61850 series.

2.7.1.2. Status

The very first draft has been published in 2006 and it has been issued admitting the immature state as well as the need for updated versions of the document before it could

[9] The image has been taken from [Ref-5] to take into consideration the restricted access conditions to the current draft. The architecture remains almost the same but for those "UCA-" prefixes.

become a standard. So far no pilot installations have been deployed but for a couple of laboratory tests.

2.7.1.3. Support

The immature state of the standard and the limited number of included devices represent a barrier: No support at all has been obtained till now.

2.7.2. Data Model Overview

The data model is based on the IEC 61850 data model as seen in Figure 2-1 where DER specific logical node is the root for the remaining DER model objects.

The standard defines several logical devices and, for each one, a set of possible logical nodes applicable to such a LD. Any logical node is a class object with a set of mandatory and optional parameters perfectly identified by their type and labelling.

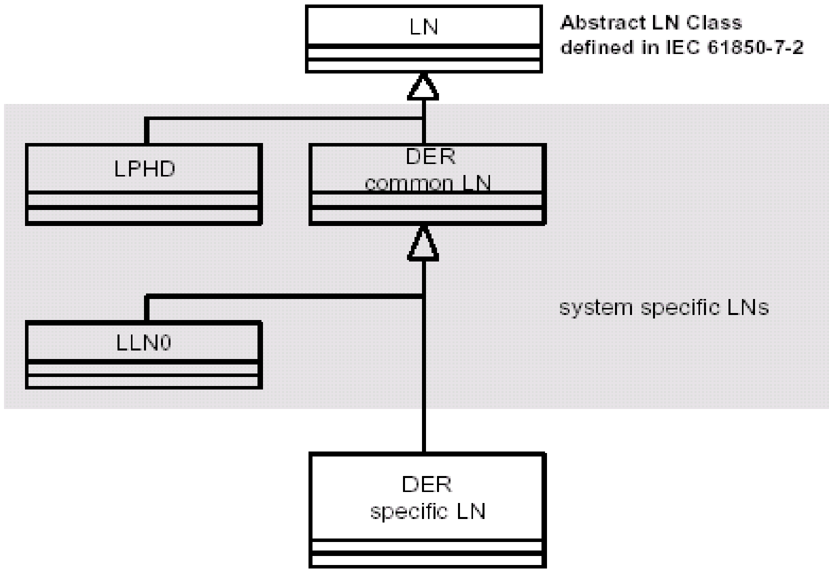


Figure 2-24: UML class relationship

The data model is covers:

- DER Plant Electrical Connection Point: This logical device defines the characteristics of the DER units (one or more) at the common coupling point with the main grid. It has been contemplated the possibility of several DER units together to the same shared connection point. It includes logical nodes from name plate data to a clear identification of the operation, status information, dispatching, etc.

- DER Unit Controller: This logical device groups the local controller characteristics.
- DER Generator: A logical device parent for the logical nodes describing generator identification, ratings and cost characteristics.
- DER Excitation: The generator unit excitation system is defined with several logical nodes for name plate and ratings data.
- DER Inverter/Converter: This logical device is provided to support those generation technologies requiring a DC bus link. The related logical nodes for the rectifier and the inverter are recognised as requiring an expert review.
- Logical nodes are defined for specific technologies: reciprocating engine, fuel cell, photovoltaic systems and Combined Heat and Power (CHP) as well as their respective auxiliary systems.
- Several auxiliary systems are introduced into the model bay means of their respective logical nodes: Interval metering, fuel system, battery system and physical measurements (temperature, pressure…).

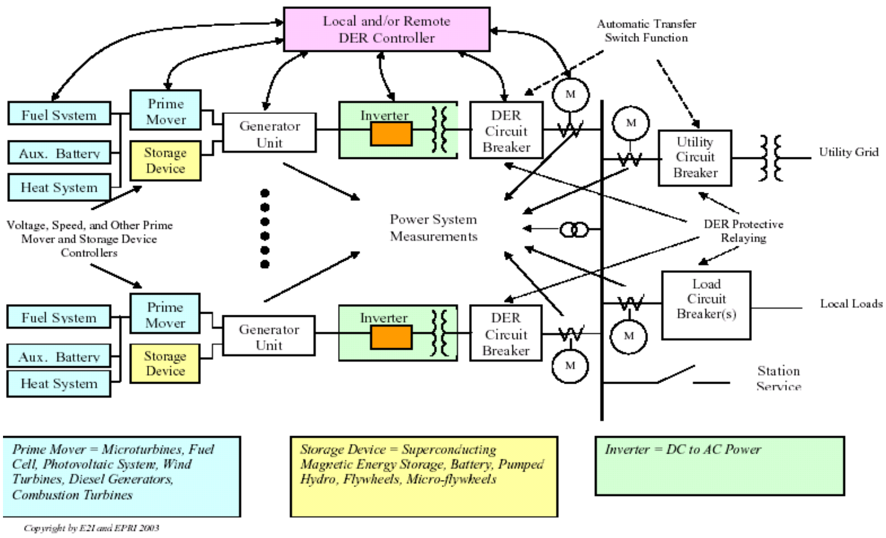


Figure 2-25: Architecture of DER Logical Nodes and Devices[10]

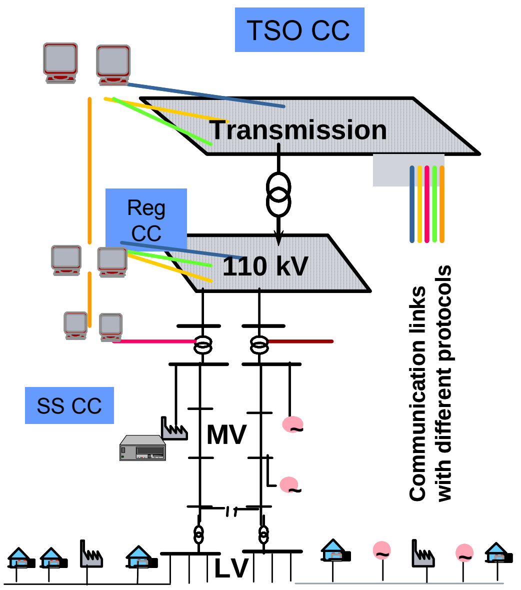
[10] The image has been taken from [Ref-5] to take into consideration the restricted access conditions to the current draft. The architecture is quite similar but for some DER technology names vanishing and the addition of the standardized logical device and node names.

The IEC 61850 defines Common Data Classes (CDC) and types of attributes (for instance an integer); the extension to the standard devoted to DER units introduces a few more data types and CDC.

2.8. Applicability and consistency of DER standards

2.8.1. Current Situation

Electric power systems need permanent control to ensure security and quality of supply. Currently, remote control is designed according to the importance of the system components. It covers the transmission grid, the 110 kV network, and the MV feeders in the 110 kV/MV substations (Figure 2-26). MV and LV networks are not equipped with remote control and the related communication facilities for economical reasons. All operations on this network levels require local staff presence. However, in unplanned situations such as disturbances the personnel can only appear with time delay at the network part affected.



CC - Control centre,

TSO - Transmission system operator,

Reg - Regional

SS - Substation

MV - Medium voltage (10,20,30 kV)

LV - Low voltage (0.4 kV)

Figure 2-26: Current communication structure in power systems

To ensure interoperability between devices of different vendors, standardised IEC communication protocols (see above) are used on different levels of the power system and for different equipment:

- IEC 60870-5-101 for substation control from control centres (point to point)
- IEC 60870-5-104 for substation control from control centres (TCP/IP network)
- IEC 60870-5-102 for meter reading
- IEC 60870-5-103 for protection information inside substations
- IEC 61850 parts 1-10 for all communication inside substations

The communication standards were developed in different time periods and by various IEC working groups. They describe the data objects in different ways, for example the identical trip message from a distance protection is modelled differently on the substation level by use of IEC 60870-5-103 and between substation and the regional or TSO control centre by IEC 60870-5-101. A conversion of the data models is required.

Besides the IEC standards, several proprietary protocols still exist on all communication levels.

The existence of different protocols with various data models and services complicates the engineering and the operation of the power system and causes high costs for ensuring plausibility and consistency. Often, special additional hardware or software is needed to overcome incompatibilities between the different standards or proprietary protocols. These additional hardware and software elements introduce various new potential sources of failures and complicate the maintenance and the expansion of the network.

The latest communication standard series IEC 61850 provide a comprehensive basic concept with generic data models to achieve data consistency in the whole electricity network communication.

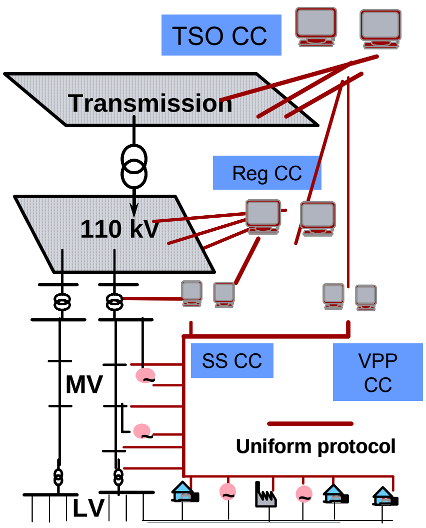
2.8.2. Objectives for Changes

Modern Microgrids control concepts must provide monitoring and control of network, generation, storage and consumption units in real time in order to guarantee a sustainable, competitive, and reliable energy supply. This additional control level requires communication down to the distribution network that is not realized so far. With the existence of communication facilities also new tasks

- in the distribution system automation, e. g. for the reduction of interruption times after faults
- or for metering services, e. g. meter reading for billing purposes or customer information about dynamic tariffs

may be performed.

Therefore, it is necessary to have a simple, flexible, reliable, and cost-efficient communication infrastructure for **all** network levels – including the distribution networks (Figure 2-27).



CC - Control centre,

TSO - Transmission system operator,

Reg - Regional

SS - Substation

MV - Medium voltage (10,20,30 kV)

LV - Low voltage (0.4 kV)

VPP - Virtual power plant

Figure 2-27: Target communication structure in power systems

Even without technical obstacles it is a complex task to build and operate an efficient and reliable communication infrastructure in a wide spread distribution area. Typically, there are not only more active components in a distribution network than in transmission and sub-transmission grids, there are also more different types of components delivering data for communication. Furthermore, data from the distribution level will partly be used in higher control levels up to the transmission control centre.

Therefore, a common standard for the data models and communication services of all network components that allows the transparent and consistent communication over any physical communication channel or network will become mandatory.

Only the “plug and play” behaviour and the interoperability of devices from various vendors obtained by such standard provides the simplicity, flexibility, and robustness that is necessary to built and maintain the communication infrastructure down to distribution level in an efficient way. Standardized existing (e. g. radio channels, communication cables, power line carrier) or future data transmission technology guarantees cost-efficiency and a wide acceptance in practice. The use of existing infrastructure for power system communications will keep communication costs limited and the economical benefits will exceed the additional investments.

2.8.3. Data Consistency

For historical reasons, three fundamentally different approaches of data modelling are applied in the existing IEC communication protocols:

- The meaning of the data is defined by engineering (e. g. trip phase A of line "xy", distance protection is represented by the number "666") in accordance with IEC 60870-5-101/104. This is flexible and expandable, but needs engineering and does not offer "plug and play" interoperability.
- Fixed numbers are assigned for function type (e. g. distance protection "128") and information number (e. g. trip phase A "69") in accordance with IEC 60870-5-103. This is not flexible and expandable but it offers "plug and play".
- Standardised ASCII strings for logical nodes (e. g. distance protection "PDIS" and data (e. g. trip phase A "TrA") in accordance with IEC 61850-7.4. This naming scheme allows flexibility, expandability, "plug and play" without additional engineering effort.

These examples clearly demonstrate that the logical node concept of IEC 61850 is able to meet the main requirements of a uniform data modelling for communication in power systems. In particular

- The generic object oriented data modelling ensures that "plug and play" is available without engineering for all possible data to be communicated.
- The data model is open for expansions based on the principle: all known objects should be defined as models and for possible future extensions fixed building rules should be applied.
- IEC 61850 strongly supports the idea of system conformity and interoperability.
- The principle structure of IEC 61850 with its ACSI and the SCSM allows the future mapping of the common data models and services to different communication structures. This allows communication via different physical channels using various link layers.

In principle, IEC has set the same targets for the new standard projects such as:

- IEC 612400-25-2. Wind Turbines. Communication for monitoring and control of wind turbines. Part 25-2. Information models. IEC 88/214/CD (chapter 2.6)
- IEC 62350. Communication systems for distributed energy resources. IEC 57/750/CD, since March 2006 proposed as IEC 6850-7-420 DER logical nodes (chapter 2.7).

As a goal of the new standards it was declared that all existing services and models of IEC 61850 will be taken over as defined and only the needed extensions will be added. Unfortunately, this goal has not been reached with the existing committee drafts. They

- use a different wording for the same content and cause confusion,
- define data models for the same objects in different ways instead of using the existing models,
- do not use the building bricks of IEC 61850 for supplement models.

Table 2-XXX gives an example of inconsistent terms for data attribute classes.

Table 2-XXX: Inconsistent terms for data attribute classes

IEC 61850	IEC 62350	IEC 61400-25
Common LN information	Configuration settings	General information
Controls	Controls	Control information
Status information	Status information	State information
Measured values	Measured values	Analogue information
Setting	Control settings	Setpoint information
-	-	Configuration information

Table 2-XXXI demonstrates an example of the different names of the logical node “converter”, its common information properties, its control and its measurement values in all three standards. A recommendation how to harmonise the names according to IEC 61850 (where the definitions are partially allocated in the logical nodes for three phase measurements MMXU and single phase measurements (MMXN) is added in the first row.

Unfortunately, such inconsistencies are present in all data definitions of the new standards. IEC 61400-25 is still far away from consistency and a common approach. Furthermore, this standard is focused on synchronous machines only and the specifics of the widely used doubly fed induction machines are not considered.

Table 2-XXXI: Comparison of data models over different IEC standards

Attribute	recommendation*	61850	62350 →	61850-7-420	61400-25
Logical Node:	**ZCON**	**ZCON**	**DINV**	**YINV**	**WCNV**
<u>Common LN information</u>					
Owner/Operator	--	--	DEROwn	--	--
GPS location of Device	--	--	DERLoc	--	--
Type of commutation	not clear	--	Commute	CmutTyp	--
Type of Isolation	not clear	--	Isolation	IsoTyp	--
Switching Frequency	--	--	SwitchFreq	SwPer	--
Switch Type	--	--	SwitchType	SwTyp	--
Operating mode	OpMod	--	OperMode	Loc	--
Grid connect mode	GrMod	--	GridMode	GriMod	--
PQV-Limiting Curve	--	--	PQVLimit	PQVLim	--
Operation time	OpTmh	OpTmh	OperTim	OpTmh	OpTmRs
External equipment health	EEHealth	EEHealth	--	EEHealth	--
External equipment name	EEName	EEName	--	EEName	--
Maximum power output	MaxW				

Attribute	recommendation*	61850	62350 →	61850-7-420	61400-25
<u>Controls</u>					
Reset energy meter	RsTotWh	--	--	--	--
Set operating mode	SetOpMod	--	SetOperMode	--	--
Output Power setpoint	SetW	--	OutWLvl	OutWset	(LN WAPC)
Output reactive power	Setvar	--	OutVarLvl	OutVArSet	(LN WRPC)
Power factor setpoint	SetPF	--	PFLvl	OutPFSet	(LN WRPC)
Frequency setpoint	SetHz	--	FrqLvl	OutHzSet	--
Fan speed setting	SetFan	--		FanSpdSet	--
<u>Status information:</u>					
Actual Operation mode	Op	--	StatOperMode	--	CnvOpMod
On/Off status	Pos	--	Status	InvSt	--
Operation time of meter	MTROpTm	--	--	--	--
Status of cooling system	ClMod	--	CLSt	--	--
Alarm heat sink temperature	AlmThm	(PTTR: AlmThm)	HeatSinkTemp	MV	--
Enclosure temperature	--	--	EnclTemp	↓ MV	--
Ambient outside temperature	--	--	AmbAirTemp	↓ MV	--
Fan speed setting	--	--	FanSpeed	↓ C	--
Measured fan speed	--	--	MeasFanSpeed	↑ MV ↓	--

Attribute	recommendation*	61850	62350 →	61850-7-420	61400-25
Measured Values					
Actual frequency	Hz	(LN MMXU: Hz)	OutHr	MMXU	Hz
AC Voltage	PPV, PhV	(LN MMXU: PPV, PhV)	OutV	MMXU	GriPPV,GriPhV
AC Current	A	(LN MMXU: A)	OutAmp	MMXU	GriA
DCVoltage	Vol	(LN MMXN: Vol)	InpV	MMDC	Dc/V
DC Current	Amp	LN MMXN: Amp)	InpA	MMDC	DC/A
Active power	TotW, W	(LN MMXU: TotW, W)	OutW	MMXU	--
Reactive Power	TotVAr, VAr	(LN MMXU: TotVAr, VAr)	OutVar	MMXU	--
Apparent Power	TotVA, VA	(LN MMXU: TotVA, VA)	--	MMXU	--
Power Factor	TotPF, PF	(LN MMXU: TotPF, PF)	OutPF	MMXU	--
Inside temperature	ITmp	(PTTR: Tmp)	--	--	CnvTempDclink
Grid side temperature	ETmp	(PTTR: Tmp)	--	--	CnvTempGri
Metered output	SupWh	(LN MMTR: SupWh)	--	MMMTR	--
Metered consumption	DmdWh	(LN MMTR: DmdWh)	--	MMMTR	--
Heat sink Temperature				HeatSinkTmp	
Fan speed				FanSpdVal	
Ambient outside air				AmbAirTmp	

*Recommendations in consistency with IEC 61850 if applicable or with its building rules in case of extensions

Data models for the same equipment are different depending of the data source – e. g. substation transformer (IEC 61850) or wind plant transformer (IEC 61400-25). In this case, the acceptance of power automation industry and utilities for applying the new standards will be very low.

The migration from IEC 62350 to IEC 61850-7-420 was executed after receiving a first comment from the “German network for energy and communication” lead by B. Buchholz, Siemens AG, in November 2005. This is the right way to

- keep consistency of data models on all levels of the power system,
- use the existing data models and extend only for further needs,
- apply the common building rules.

2.8.4. Current IEC Activities and New Proposals

New activities have been started to integrate the data models of IEC 61850 into the older but widely distributed standards IEC 60870-5-101/104. Figure 2-28 demonstrates the current status of communication standards on the different levels of the power system communication hierarchy.

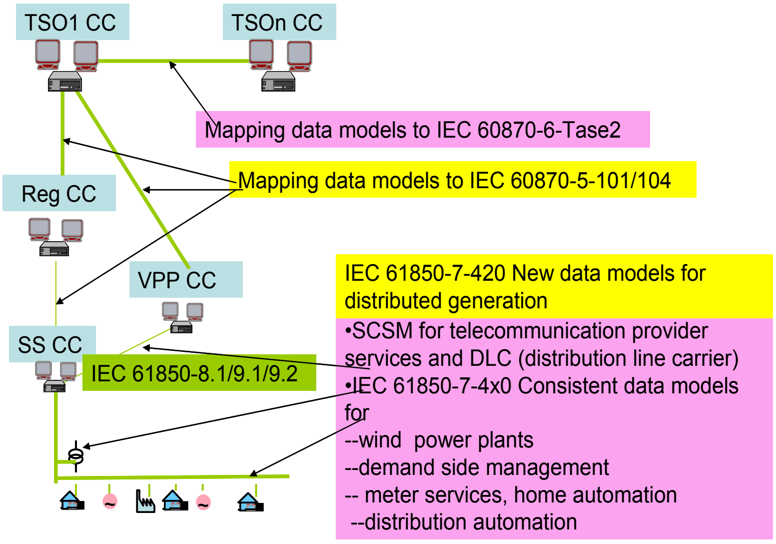


Figure 2-28: Existing standard (green), current activities (yellow) and further needs (red) for IEC communication standards to reach common data models on all communication levels

Parts 1-10 of IEC 61850 became official standard between 2002 and 2004. Since then, IEC 61850 has been used in some hundred projects of substation automation. The substation communication level is fully covered by this standard (marked in green colour in Figure 2 28. The statements marked in yellow belong to the following activities:

- IEC 61850-7-420 - generic data models for all kinds of distributed and renewable energy sources
- Generic data models of IEC 61850 to be mapped into IEC 60870-5-101 and 104

Additional needs for standardisation occur on the highest and lowest levels:

- The communication between the control centres on the transmission level using IEC60870-5-Tase2 needs the same approach as it is applied for IEC 60870-5-101/104.
- The mapping of the IEC60850 ACSI to other physical and link layers needed for the communication in the distribution level shall be standardised.
- New consistent data models shall be developed following the building rules of IEC 61850 for
  - wind power plants (synchronous machines with converter and all kinds of induction machines),
  - storage technologies and further industrial processes which can be used for storage purposes,

- demand side management with switching of load groups
- metering services from data collection, tariff information up to special functions of home automation,
- distribution automation including, e.g., reading of short circuit indicators, remote control of isolators, condition information of assets, etc.

These complex tasks require a coordinated work of experts representing different technologies and skills. It may be successful only if an overlaying responsibility for data model consistency is assigned. Furthermore, it is quite important that the standards will be kept “lean” in the sense that only those data models will be described which are required for communication based network operation.

2.8.5. Conclusions

Further work on communication standards should only be performed in the responsibility of IEC TC 57 (the move from IEC 62350 to IEC 61850-7-420 is the right step) in order to:

- Keep consistency of data models on all levels of the power system
- Use the existing data models of IEC 61850 and extend only for further needs
- Apply the common building rules of IEC 61850 for all supplement data models

The standardized mapping of the ACSI to different physical and link layers is an issue to be solved for an efficient application of existing infrastructure in the distribution level.

New work item proposals (IEC 61850-7-4x) are required to cover the data for

- Distribution automation
- Metering services
- Demand side management.

3. Standards for Electricity Market participation

The standardization of commercial data structures and communication protocols faces similar problems to those introduced in the area of technical standards regarding the promoting body, the presence of competitive alternatives and the general acceptance but derived from a slightly different source.

The unbundling of European electricity markets has been introduced in the European countries with more or less liberalization and distinct specific implementation details to consider the background sector details. In brief, all open markets operate with bilateral contracts, day-ahead market and intraday market but the concrete timing, data models, business processes and ancillary services are managed with diverse schemes.

In a recent European Commission Conference “Energy Sector Inquiry – Public Presentation of the Preliminary Findings” (see [www-5]), Ms N. Kroes stated that:

> “The third problem is the lack of market integration in Europe.
>
> Both gas and electricity markets are still largely national. Incumbents remain both largely national and largely dominant. They often seem to have limited interest in going out and competing on their neighbours’ territory.
>
> [...]
>
> For electricity, the inquiry shows an overall lack of interconnector capacity. Moreover, the capacity that is there is not fully available to new entrants. Again the main reasons are long-term historic capacity reservations and inefficient congestion management mechanisms. In addition there are important differences in the market rules applicable to each area. Finally, a lack of adequate incentives to invest in additional capacity completes the worrying picture.”

It is advisable that distributed energy resources and renewable sources are treated in an almost unique way at each country. The required minimum or maximum sizes, the possibility to aggregate third party resources into one single bid offer, penetration degrees affect the market design.

The taken approach has consisted in reviewing the existent commercial standards for conventional electricity markets under the assumption that DER and µGrid technology will be tackled similarly. Therefore, data structures, communication protocols, business processes will be shared among all actors. The future European Electricity Market and the complementary Local/Regional Electricity Markets should establish the rules and lead towards the standardization, at least at European level in a top bottom approach.

An alternative path would consist on µGrid technology succeeding and including a set of proprietary solutions addressing some kind of local low voltage market to deliver an optimization of installed devices. If an average µGrid device is hidden behind a MV/LV transformer and sized around a few kWs or tens of kWs, it is quite unlikely that this small size player could play any role at the whole sale market. Several competitive µGrid internal arrangements would be in use and any of them would be required to implement the standardised protocol to the main grid; this coexistence could be meaningful for the µGrid size, about the MV/LV TF in the range of 1,000 kW, and to the distribution grid.

3.1. IEC 62325

3.1.1. Summary

3.1.1.1. Description

The IEC 62325 series defines a framework for energy market communications. It includes the business operation view with profiles of technical e-business communication architectures together with migration scenarios. The first edition of the IEC series does not include the processes and information models neither the abstract service model but them may be added in the future. Published documents do not define standards: only references (other available standards) and provide the general framework.

The set of standards is aimed to support the communication aspects of all e-business applications in deregulated energy markets with emphasis on system operators but the real-time communication of energy systems is beyond the scope of the IEC 62325 series.

It is important to note that energy markets still evolve from the previous vertically integrated business model to the open market approach imposed by the de-regulation. Consequently, the IEC 62325 series specifies no “content”: the specific content modelling of regional markets is subject of regional projects and may be candidate for future standardisation extending the IEC 62325 series.

3.1.1.2. Status

Nowadays, the IEC 62325 series consists of the following documents:

Table 3-I: IEC – Search > Publications & Work in progress > Reference IEC62325

Part	Date	Description	Status[11]
-101	2005-02	General guidelines	TR
-102	2005-02	Energy market model example	TR
-501	2005-02	General guidelines for use of ebXML	TR
-502	2005-02	Profile of ebXML	TS

However, this work is in progress and it is expected to be completed with other publications. As a result, the IEC 62325 series will be composed of the parts that can be seen in the following table:

[11] IEC Stage Codes, see http://www.iec.ch/ or Annex A: IEC Stage Codes

Table 3-II: IEC 62325 – Future parts

Part	Description
-101	General guidelines
-102	Energy market model example
-201	Glossary
-3xx	(Titles are still to be determined)
-401	Abstract service model
-501	General guidelines for use of ebXML
-502	Profile of ebXML
-503	Abstract service mapping to ebXML
-601	General guidelines for use of web services
-602	Profile of Web Services
-603	Abstract service mapping to web services

IEC TC57 WG16 is currently working on these issues. Concretely, its activity is focused on the areas described below:

- CIM market extensions to support models and objects required for energy market communications.
- Platform Independent Service Model.
- Platform Specific Model for Web Services.

A parallel effort aimed to similar objectives has been running leaded by ETSO. The WG16 has identify the multiplicity of efforts and started a shared collaboration framework where the advanced situation of ETSO is recognised as well as its participation in the European Energy Market design while the advantageous position of IEC regarding ICTs and standardization is admitted. The agreement defines a twofold coherent target based on focussing individual efforts in their expertise: IEC on Information Technologies and ETSO on business processes.

3.1.1.3. Support

The IEC 62325 series is not supported at all. It has to be taken into account that it is not a proper standard but a general report describing the overall methodology that should be used to define the standards. Besides, it specifies no content because energy markets depend on local regulation. In brief, at the moment it is only a definition: desirable recommendations regarding energy market communications and consequently, there are not any available implementations yet.

3.1.2. Overview

The IEC 62325 series as defined so far is a framework for energy market communications.

Part 101 gives general guidelines for e-business in energy markets based on Internet technologies. For this purpose, it provides a description of the:

- Energy market specific environment.
- Energy market requirements for e-business.
- Energy market structure.
- Modelling methodology.
- Network configuration examples.
- Communication security.

Part 102 defines an example business model of the electricity market following the Open-EDI reference model ISO/IEC 14662.

Part 501 provides general guidelines of how to use the "Electronic business eXtensible Markup Language (ebXML)" together with migration scenarios and an implementation example.

Finally, part 502 specifies an energy market specific messaging profile based on the ISO 15000 series that is intended to provide the basis for system configuration.

Next, an overview of the main concepts defined in the mentioned documents is presented.

3.1.2.1. The Open-EDI architecture

The e-business architecture and the IEC 62325 series follow the Open-EDI reference model ISO/IEC 14662.

This model divides the business transactions into two views:

- Business Operational View (BOV): a perspective of business transactions limited to those aspects regarding the making of business decisions and commitments among organizations, which are needed for the description of a business transaction.
- Functional Service View (FSV): a perspective of business transactions limited to those information technology interoperability aspects of IT systems to support the execution of Open-EDI transactions.

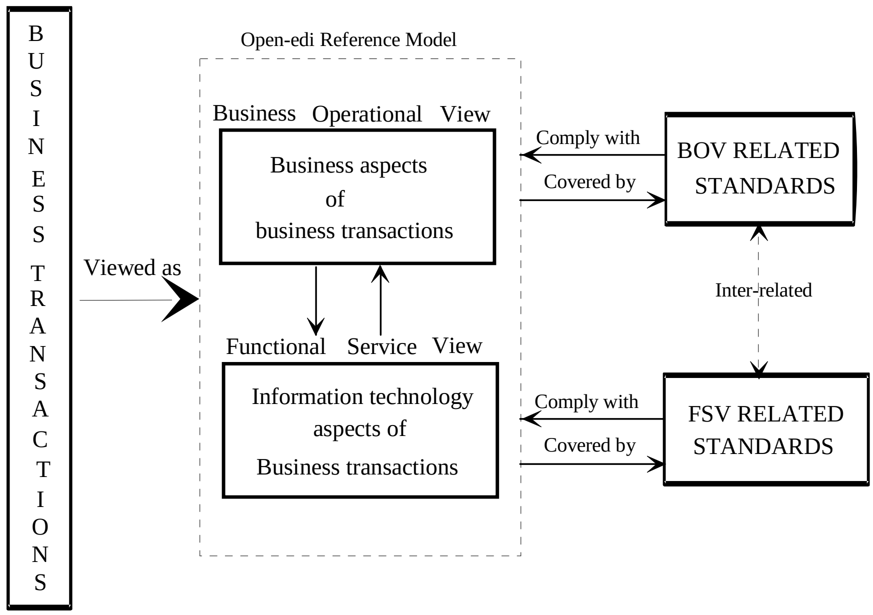


Figure 3-1: The Open-EDI reference model

3.1.2.2. Modelling methodology

The energy market has its own legal, commercial and technical requirements. These requirements may be different for different markets and even for different regions. The introduction of e-business in energy markets requires having a common shared understanding amongst all market participants. This understanding is represented using a formalised e-business modelling methodology. This will allow mapping the model onto different e-business communication technologies.

The IEC 62325 series recommends using the UN/CEFACT Modelling Methodology (UMM) to describe the BOV.

Table 3-III shows an overview of the UMM workflow while Table 3-IV provides an example applied the workflow associated to a change of supplier.

Table 3-III: UMM workflow

Workflow	Main focus for e-business	View	UML and XML artefacts
Business modelling	Business context, business area, process area	BOM (Business Operations Map)	Use case diagrams, scenario descriptions
Requirements	Business processes and collaborations	BVR (Business Requirements View)	Detailed use case diagrams, Activity diagrams
Analysis	Transactions, identification of business documents	BTV (Business Transaction View)	Sequence diagrams, collaboration diagrams
Design	Business documents, Business service interface	BSV (Business Service View)	Class diagrams, XML-messages, interaction parameters

Table 3-IV: Example workflow for supplier change

Workflow	Focus	Example
Business modelling	Business domain	Electricity market
	Business area	Supply
	Process area	Change of supplier
Requirements	Business processes and collaborations	Network access registration, etc…
Analysis	Transaction	Request of contract data of new customer
	Identification of documents	Contract data request document, etc…

3.1.2.3. Security

The IEC 62325 assumes that the communication between the different market participants is performed making use of Internet. Due to the characteristics of Internet, it will be necessary to employ different measures in order to guarantee the reliability and the security on the transference but not specific technology is recommended.

The countermeasures to security risks are based on three fundamental measures:

- Encryption: it provides privacy.
- Digital signatures: they provide message integrity and request authentication.
- Trusted certification of public key pairs within a public key infrastructure (PKI).

3.1.2.4. Typical network configurations

Different network configurations are identified as feasible for use in e-business:

- Peer to peer: this configuration allows any market participant to directly communicate with any other participant over the Internet using a B2B (Business to Business) gateway. It requires that all market participants be always on-line.

- Portal: in this configuration one organisation is responsible of managing and operating all market participants using the hub.
- Enterprise Application Integration (EAI): it allows the different applications and systems of an organisation to communicate with each other seamlessly.
- Business Process Management Systems (BPMS): the general idea of the BPMS is to separate the business logic from the application in order to make the business processes better manageable.

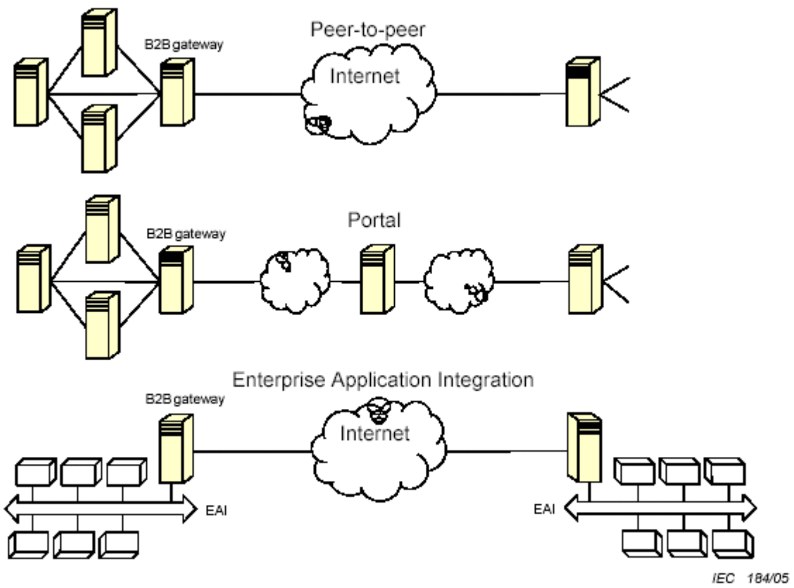


Figure 3-2: Alternative network configurations

3.2. ETSO-EDI

3.2.1. Summary

The European Transmission System Operators (ETSO) is in charge, sharing the responsibility with the European Commission, of implementing the future European Electricity Market. Two task forces were created for this purpose:

- TF6 “Information Systems” has produced an “Electronic Highway” for the communications among TSOs.
- TF14 “EDI (Electronic Data Interchange)” aims electronic document interchange standards

Task Force 14 addresses the establishment of a uniform methodology and data structures targeting the future European Energy Market. ETSO F14 has identified the need of solving the technical and commercial gaps in a deregulated energy market and recognised the existent lack of standardisation.

3.2.1.1. Description

The work of ETSO TF14 started following the direction of EDIFACT as a well known standard methodology already in place that enabled the electronic information exchange among distinct participants in diverse environments successfully. The irruption of XML introduced some changes leading to new arrangements in the role played by several groups (UN/CEFACT and OASIS) related to the standard.

TF14 chosen approach is based on open standards philosophy, focusing on the business processes, leaving the pure ICT implementation details out of the scope of the group and providing keys as to maintain the relation to the available and relevant external standardization efforts; In line with this strategy, documents are published allowing any type of use under the unique requisite to keep the copyright note and the attached disclaimer to facilitate its adoption.

In brief, an UML based methodology is used to describe the relations between stakeholders taking part in several business processes related to energy markets and XML is employed as encapsulation method for data holding during the information exchange.

3.2.1.2. Status

The set of documents for describing the future European Electricity Market is currently composed by the following elements:

- ETSO Modelling Methodology for the Automation of Data Interchange of Business Processes (EMM)
- ETSO Electricity Role Model
- ETSO Core components & Code List
- ETSO Energy Identification Coding Scheme

Additionally, several implementation guides are provided as reference for the analysed business processes related to energy trading:

- ETSO Scheduling System (ESS)
- ETSO Settlement Process (ESP)
- ETSO Reserve Resource Planning (ERRP)
- ETSO Capacity Allocation and Nomination System (ECAN)
- ETSO Acknowledgement Document
- ETSO Status Request

These documents are actively being maintained into providing revisions and new releases on as needed basis demonstrating the long term view applied by the TF14.

3.2.1.3. Support

The TF14 is still far from covering the complete range of business processes in the energy market and therefore, the partial solution can not be applied for any market although some implementations are already in practice such as ESS in several European countries (Austria, Germany, Switzerland, Luxembourg, Hungary…).

In any case, the recognition by the IEC WG16 that ETSO should lead the technical design of the market from the power system point of view while the IEC would cover those fields related to the technical implementation and ICT related issues clarifies the role of each contributor and should promote consolidation and applicability of the resulting standards.

3.2.2. Overview

The work of ETSO TF14 focuses on the data exchanges performed between TSO and other involved partners (TSO, DSO and market participants) paying attention to UCTE role.

The ETSO Modelling Methodology centres on the basic framework defining the guidelines that are applied uniformly.

The ETSO Electricity Role Model (Figure 3-3) provides coverage of involved parties defining common nomenclature and definitions, roles and associated actors and domain specification.

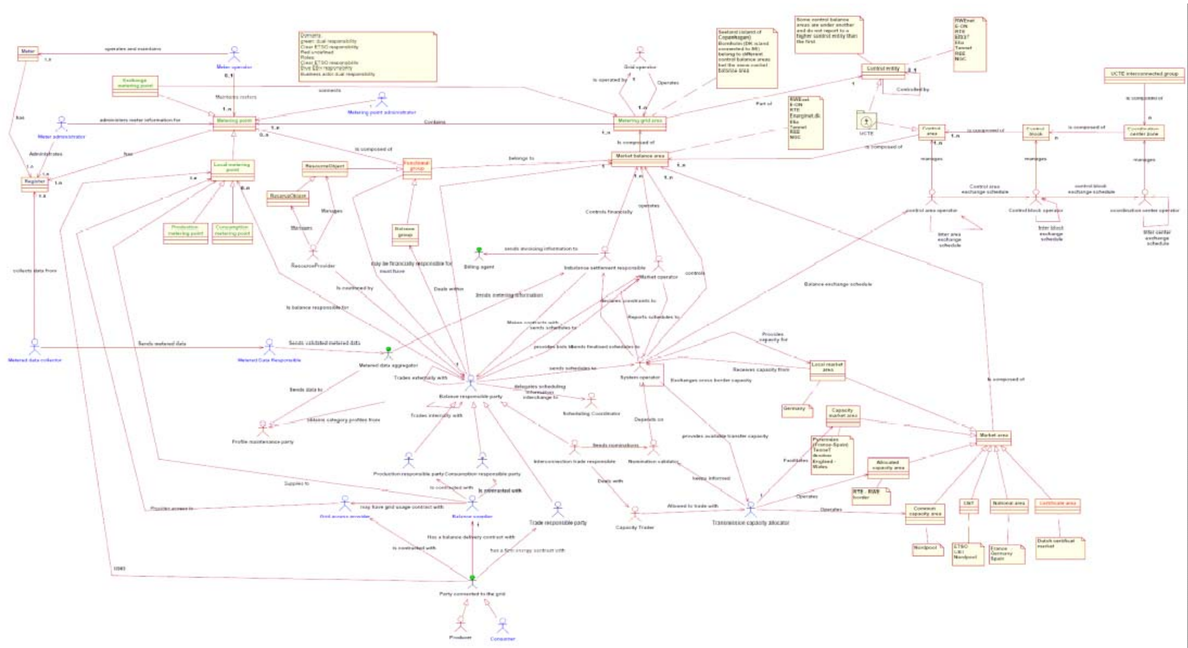


Figure 3-3: ETSO Role Model V4R0

The identified roles correspond to the information flow within the context of electricity market processes. These itemized roles take into consideration that a given electricity market actor could be playing several roles at the same time but also allowing an actor to play any set of roles a flexible manner.

The ETSO Core components & Code List provides an implicit set of conventions defining codes (where the full range of possibilities is depicted), names and descriptions for the several processes considered so far, as shown at Table 3-V and Table 3-VI.

Table 3-V: Business type (UID ET0017)

Code	Business Type	Business Type
A01	Production	The nature of the business being described is production details
A02	Internal trade	The nature of the business being described is internal trade details
A03	External trade explicit capacity	The nature of the business being described is external trade details between two areas with limited capacity requiring a capacity agreement identification
…	…	…
A10	Tertiary control	A time series concerning tertiary reserve requirements.
A11	Primary control	A time series concerning primary reserve requirements
A12	Secondary control	A time series concerning secondary reserve requirements
…	…	…

Table 3-VI: Energy Product (UID ET0008)

Code	Product Name	Description
8716867000016	Active power	The product of voltage and the in-phase component of alternating current measured in units of watts and standard multiples thereof.
8716867000023	Reactive power	The product of voltage and current and the sine of the phase angle between them, measured in units of voltamperes reactive and standard multiples thereof. (not used for planned schedules).
8716867000030	Active energy	The electrical energy produced, flowing or supplied by an electrical circuit during a time interval, being the integral with respect to time of instantaneous active power, measured in units of watt-hours, or standard multiples thereof.
8716867000047	Reactive energy	The integral with respect to time of reactive power. (not used for planned schedules)
8716867000139	Capacitive Reactive energy	Refer to the ETSO document "Energy product types Active - Reactive - Inductive - Capacitive"
8716867000146	Inductive Reactive energy	Refer to the ETSO document "Energy product types Active - Reactive - Inductive - Capacitive

The ETSO Energy Identification Coding Scheme is a unique identification system where each participant receives a code for the participation in the European energy market substituting the previously issued and used national codes.

These documents constitute the base for the different implementation guides already available. Each one of the implementation guides are supported by means of a UML document providing the required information regarding the involved business process in form, use cases view, activity diagrams, sequence diagrams, class diagrams, etc.

The general objective of providing implementation guides is to allow third party software vendors to develop a commercial product supporting the targeted business process to energy market actors.

Taking as reference ETSO Scheduling System (ESS) the document set includes:

- ESS Implementation Guide
- ESS UML Diagrams
- ESS Document DTDs
- ESS Document Schemas
- ESS Schema Models
- ESS Document XSL Style sheets
- ESS Document XML Example

The overall energy balancing process is divided into three separate processes: planning, operation and settlement. The first one constitutes the scope for ESS where the day ahead schedule is targeted.

The business process is based in a UML diagram and it is completely described in the implementation guide. The remaining documents are provided for convenience such as the XML example files and associated XML information and annexes (schemas, DTDs, etc.)

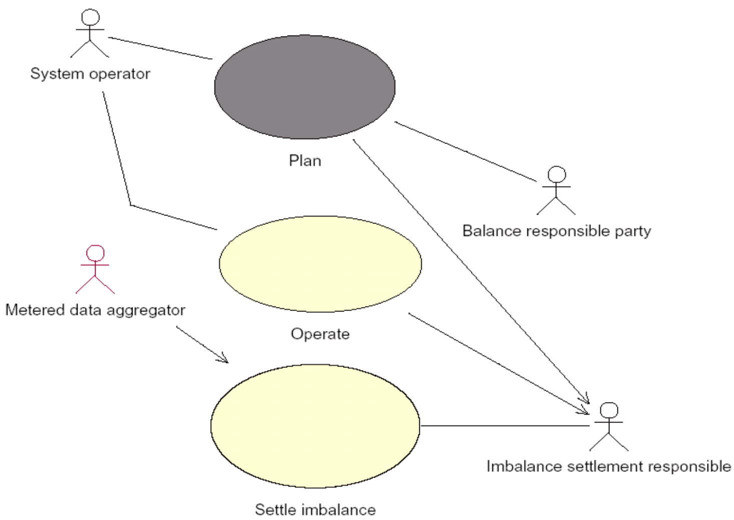


Figure 3-4: ETSO ESS V3R0 Use Case View: Balancing process perspective

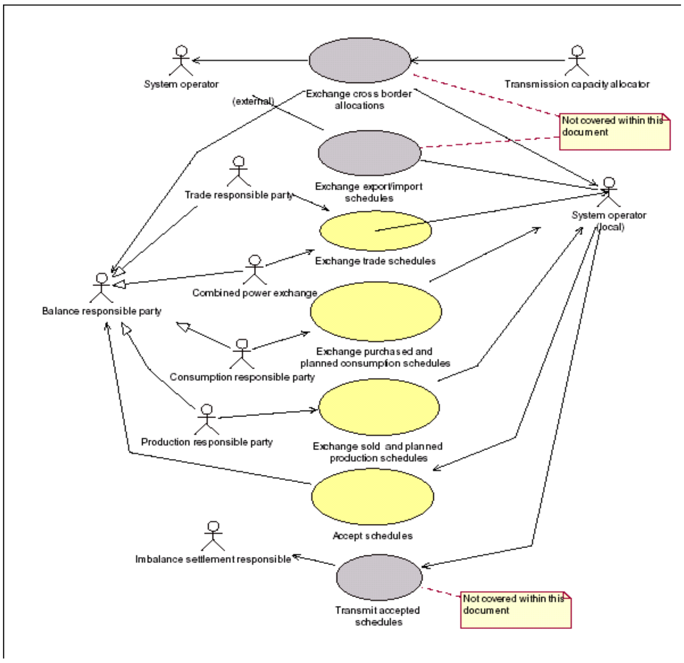


Figure 3-5: ETSO ESS V3R0: Use Case View: Transmit planned schedule information

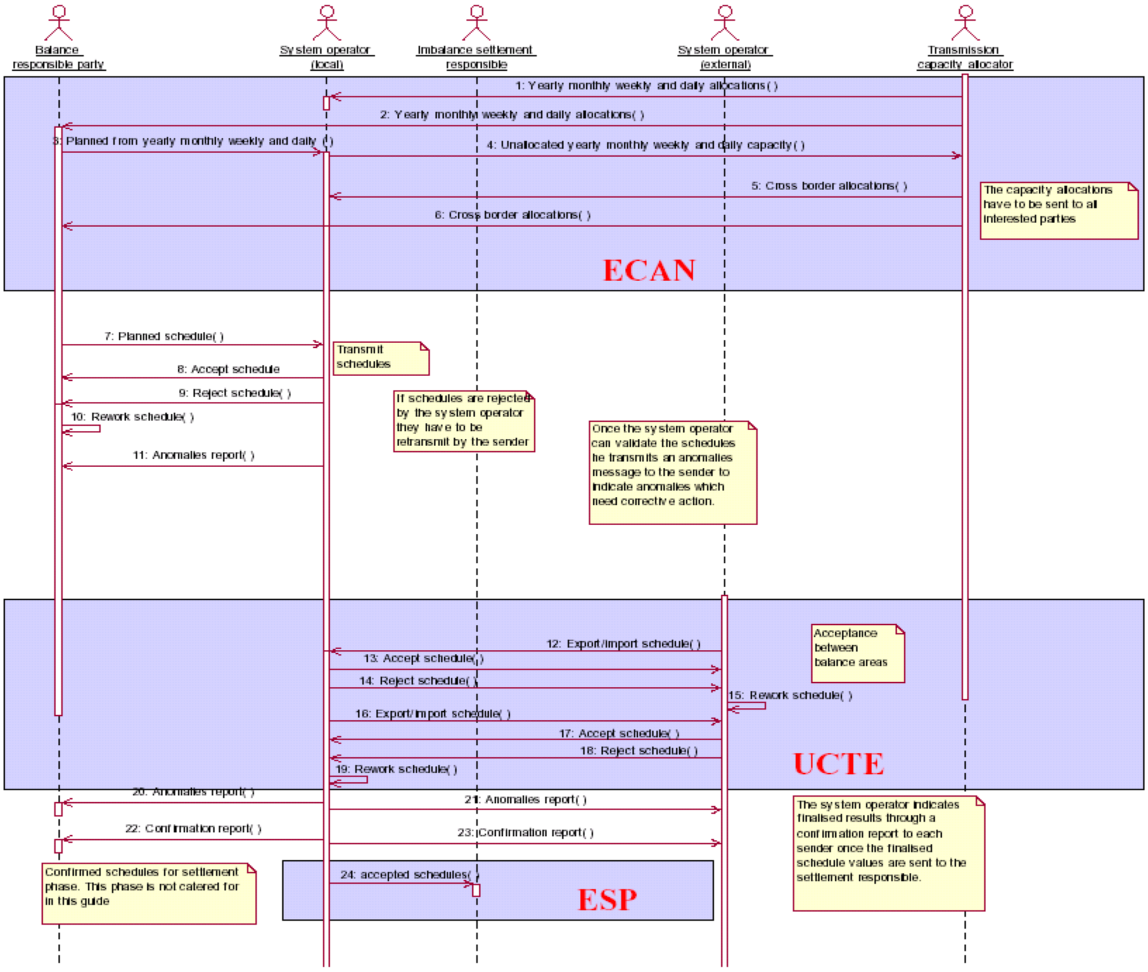


Figure 3-6: ETSO ESS V3R0: Sequence Diagram: Transmit planned schedule information

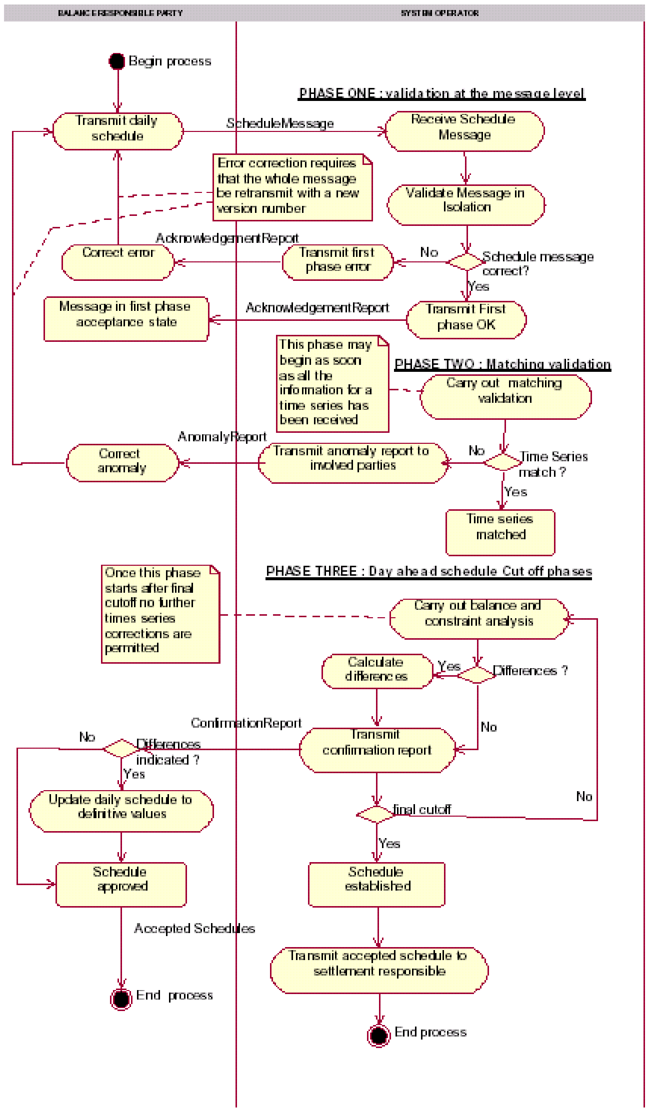


Figure 3-7: ETSO ESS V3R0: Activity Diagram: Transmit planned schedule information

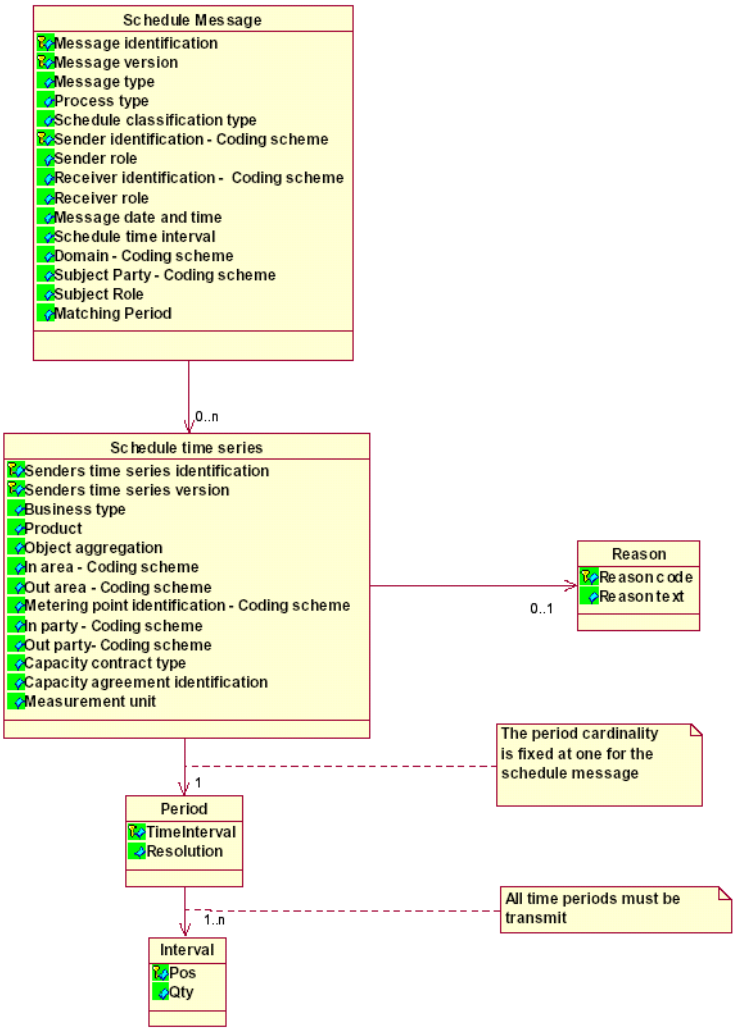


Figure 3-8: ETSO ESS V3R0: Class Diagram: Planned schedule

The remaining processes described so far follow the same approach in terms of modelling methodology and intended audience.

3.2.3. Review

In general it is clear that ETSO TF14 will define a common European Energy Market from the point of view of the TSO activities. The work started in 2001 and, even when a significant effort has been done, the complete design is not finished.

It is unlikely, after de deregulation experience, ETSO work will be implemented across all European countries in a regular form without national or even technical (lack of interconnection capacity compromising the own market) interests raising barriers against its deployment.

A second concern is related to the TSO perspective assumed in the work that may leave out of consideration DSO needs and the expected participation of distributed generation in power system operation.

4. Grid Code Requirements

Grid code documents set the requirements for users of the low, medium and high voltage networks. These have evolved to suit conventional generation and substantial modifications are required to apply them to new forms of micro-generation. Such modifications have been produced or are in the process of being developed in many European countries. Grid code requirements should be optimised to allow the best possible generation mix rather than to give preference to one particular technology. As the development and implementation of a European Grid Code is discussed, the requirements should be set according to a consistent and clear approach (e.g. technology-, size-, and network-specific rules).

Grid codes deal with the connection of generating stations at all voltage levels, from LV to EHV. In the context of this report, distribution network codes are more relevant, since μGrids are currently envisaged at the LV or MV level.

Grid code connection requirements mainly deal with:

- Power quality and reliability. In Europe and elsewhere, several cases have been reported where the levels of power quality have been improved by decentralized generation. However, under certain conditions, connection of DG may lead to power quality problems. Such situations can be avoided by developing standards which ensure that system voltage, harmonics, flicker and power factor are kept within acceptable limits.
- Safety matters regarding the general public and utility personnel. Island operation is one of the safety concerns e.g. for the utility personnel sent on-site to check and repair damages following faults.
- Protection of equipment owned by the distribution company and its customers
- Faults or short circuits. Fault response of a distributed generator must be in synchronization with the utility's protection systems.
- Islanding. Islanding is an issue for security of supply and safety. Utilities need also to consider whether it is possible to control an island created by an independent distributed generator.

During the last years, the objectives and general requirements of the various national codes have gradually converged to a certain extent, an outcome of better understanding of the issues associated with the connection and operation of DG and the accumulation of significant experience. Yet, there still remain important differences with respect to the evaluation methodologies, the limits accepted and several other technical issues. A few examples of such issues, where dispute and divergent views are still observed, are the following:

- *Point of common coupling versus point of connection*: At which of the two physical points connection standards should apply. In general the point of common coupling is preferred at the MV level, but the point of connection is also used in HV and LV networks.
- *Emergency generators*: Temporary emergency generators can become an issue for the utility, when they may operate in parallel with the grid. The concerns are similar as for island operation and faults.
- *Utility interface disconnection switch*: A visible disconnection associated with each potential source of electric power is required by some utilities for safety or contractual reasons. Furthermore, open or closed status of disconnection switch must be clearly indicated and the disconnection need to be a lockable, accessible and load-break switch.
- *Effect on protection*: The ratio of the fault contribution from the decentralised generator to the fault contribution of the system influences the power system under short-circuit conditions. To avoid problems, the contribution of the power system should be much higher than the contribution of the decentralized generator. If the decentralised generator’s contribution dominates, it may interfere with the existing protection and modifications are required to avoid any damage to utility personnel and equipment.
- *Harmonics*: The limits and evaluation methodologies in the various national codes are far from common. High frequency harmonics, in particular, i.e. harmonics beyond the 40^{th} or 50^{th} order, are an issue with modern DG equipment, operating at high switching frequencies.
- *Direct current off-set*: Micro-generation schemes utilise DC/AC converters, which should inject only alternating current (AC) into the power system. Yet under certain conditions a direct current (DC) offset may also be present. Several national regulations apply restrictions to DC current injection, but widely different limits are adopted.

4.1. IEEE 1547

4.1.1. Summary

4.1.1.1. Description

The conventional utility electric power systems (EPS) were not designed to accommodate the active generation and storage at the distribution level. The IEEE Std 1547TM consists of a series of standards, which describes the recommendations to properly integrate distributed resources (DR) into the existing EPS. It is being developed by Standards Coordinating Committee 21 (SCC21) on Fuel Cells, Photovoltaics, Dispersed Generation and Energy Storage concerning distributed resources interconnection with Electric Power Systems.

The 1547 standard focuses on the technical specifications for, and the testing of, the interconnection itself. It provides requirements relevant to the performance, operation, testing, safety, and maintenance of the interconnection. It includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for design, production, installation evaluation, commissioning, and periodic tests. The stated requirements are universally needed for the interconnection of distributed resources (DR), including synchronous machines, induction machines, and power inverters/converters and will be sufficient for most installations [Ref-6].

The requirements are applicable to all DR technologies with aggregate capacity of 10 MVA or less at the point of common coupling interconnected with EPSs at typical primary and/or secondary distribution voltages. Installation of DR on radial primary and secondary distribution systems is the main emphasis of the 1547 standard, although installation of DR on primary and secondary network distribution systems is also considered [Ref-6].

4.1.1.2. Status

The **IEEE Std 1547^{TM}** was approved by the IEEE Standards Board in June 2003. As an American National Standard it was approved in October 2003.

The **IEEE Std 1547.1^{TM} (2005)** was published in 2005.

The work group on the **P1547.2** draft meets 2-3 times per year and discusses the topics relevant for each section of this draft. The changes that have been accepted will be resumed in the new version of draft. Actually the latest version of the draft is the **P1547.2** Draft 5 July 21, 2006.

The work group on the **P1547.3** draft meets 2-3 times per year and discusses the topics relevant for each section of this draft. The changes that have been accepted will be resumed in the new version of draft. Actually the latest version of the draft is the **P1547.3** Draft 5 April 27, 2006.

The work group on the **P1547.4** draft meets 2-3 times per year and discusses the topics relevant for each section of this draft. The changes that have been accepted will be resumed in the new version of draft. The next meeting of P1547.4 is Feb 1 – 2, 2007 in Atlanta GA. DR Islanding Systems will be discussed.

2007 Target for the **IEEE P1547.5**: Establish ballot-ready draft and conduct intra-SCC 21 pre-ballot reviews.

At the February 2006 meeting on the **IEEE P1547.6** the participants agreed that power electronics equipment development and validation will be instrumental and those networks and planned island interconnection system characterisation and operational field testing are missing today to establish the requirements in the new standard. Work continuing. 2007 Target: Draft standard for review.

4.1.1.3. Support

The support for the IEEE Std 1547 development facility was great from the members, industry, utilities, and general-interest groups and individuals. The development of 1547 included arduous debate and scrutiny by hundreds of dedicated and experienced individuals. The names of 444 work- and ballot-group individuals appear in the front of the standard [www-6].

4.1.2. Overview

The IEEE 1547 series of standards focuses on the technical specifications for, and testing of, the interconnection itself, and not on types of the DR technologies. These standards aim to be technology neutral.

This 1547 series directly provides requirements for DR interconnected to utility power networks and are relevant to the performance, operation, testing, safety considerations, maintenance of the interconnection and shall be met at the point of common coupling (PCC). These requirements are universally needed for interconnection of DR, including synchronous machines, induction machines, or power inverters/converters.

The topics dealt in the standard are:

- General Requirements
  - Voltage Regulation
  - Integration with Area EPS Grounding
  - Synchronisation
  - Secondary and Spot Networks
  - Inadvertent Energising of the Area EPS
  - Monitoring
  - Isolation Devices
- Response to AREA EPS Abnormal Conditions
  - Voltage Disturbances
  - Frequency Disturbances
  - Disconnection for Faults
  - Loss of Synchronism
  - Feeder Reclosing Coordination
- Power Quality
  - Limitation of DC Injection
  - Limitation of Voltage Flicker induced by the DR
  - Immunity Protection
  - Harmonics
  - Surge Capability
- Islanding

This IEEE Std 1547 has some limitations like e.g. the largest aggregate capacity of 10 MVA or less to all distributed resource technologies at the PCC. The considered frequency is the 60 Hz only.

Furthermore this Standard includes specific requirements for DR interconnected with secondary spot networks.

Figure 4-1shows the structure of this standard with the additional documents in that series.

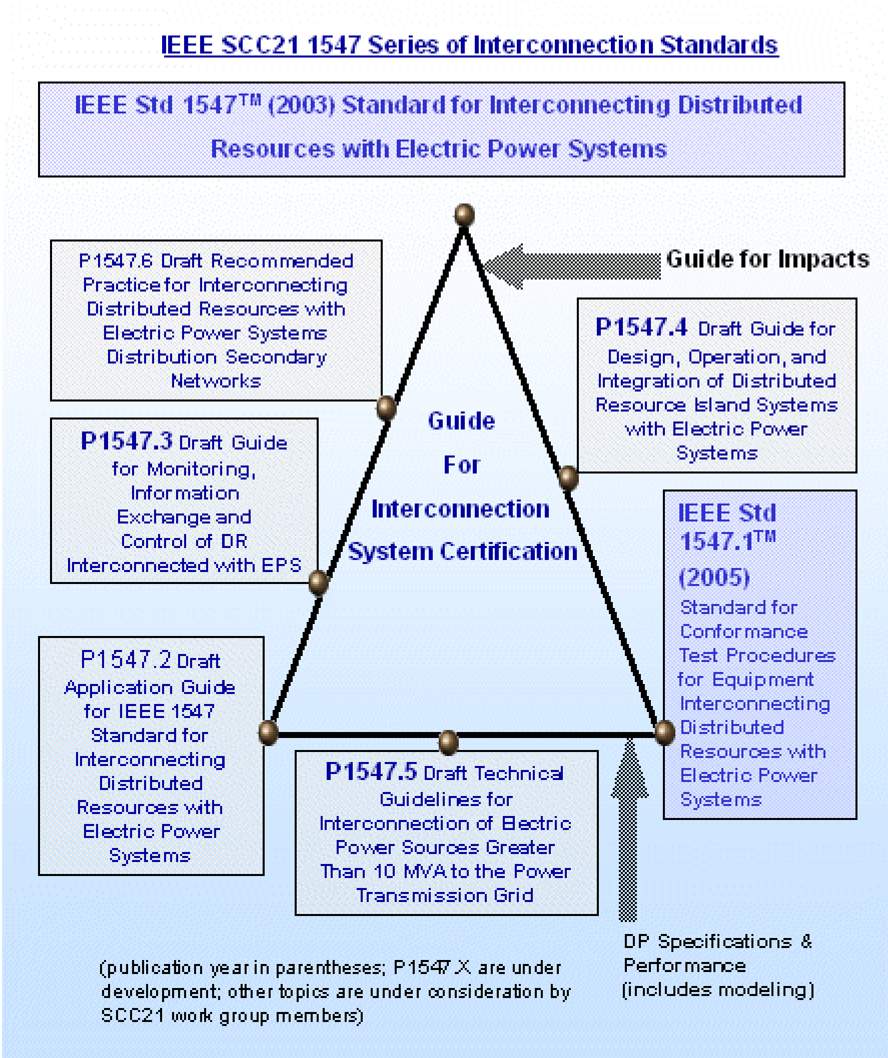


Figure 4-1: IEEE 1547 Series of Interconnection Standards [www-7]

The IEEE Std P1547.1 Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with EPS specifies the tests to demonstrate that interconnection functions and equipment of a DR conform to IEEE Std 1547. These test procedures must provide both repeatable results, independent of test location, and flexibility to accommodate the variety of DR technologies. The Interconnection equipment that connects DR to an EPS must meet the requirements specified in IEEE 1547 [www-7].

The IEEE Std P1547.2 Draft Application Guide for IEEE Standard 1547 for Interconnecting Distributed Resources with EPS facilitates the use of IEEE 1547 by characterising the various forms of distributed resource technologies and the associated interconnection issues. Additionally, the background and rationale of the technical requirements are discussed in terms of the operation of the distributed resource interconnection with the electric power system. The technical descriptions and schematics, applications guidance and interconnection examples presented in the P1547.2 document enhance the use of IEEE Std 1547 [www-7].

The IEEE Std P1547.3 Draft Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with EPS facilitates the interoperability of one or more distributed resources interconnected with electric power systems. It describes functionality, parameters and methodologies for monitoring, information exchange and control for the interconnected distributed resources with, or associated with, electric power systems. Distributed resources include systems in the areas of fuel cells, photovoltaic's, wind turbines, micro turbines, other distributed generators, and, distributed energy storage systems [www-7].

The IEEE Std P1547.4 Draft Guide for Design, Operation, and Integration of Distributed Resource Island Systems with EPS – This document provides alternative approaches and good practices for the design, operation, and integration of distributed resource (DR) island systems with electric power systems (EPS). This includes the ability to separate from and reconnect to part of the area EPS while providing power to the islanded local EPSs. This guide includes the distributed resources, interconnection systems, and participating electric power systems. This guide is intended to be used by EPS designers, operators, system integrators, and equipment manufacturers. The document is intended to provide an introduction, overview and address engineering concerns of DR island systems. It is relevant to the design, operation, and integration of DR island systems. Implementation of this guide will expand the benefits of using DR by targeting improved electric power system reliability and build upon the interconnection requirements of IEEE 1547 [www-7].

The IEEE Std P1547.5 Draft Technical Guidelines for Interconnection of EPS greater then 10 MVA to the Power Transmission Grid provides guidelines regarding the technical requirements, including design, construction, commissioning acceptance testing and maintenance/performance requirements, for interconnecting dispatchable electric power sources with a capacity of more than 10 MVA to a bulk power transmission grid with purpose to provide technical information and guidance to all parties involved in the interconnection of dispatchable electric power sources to a transmission grid about the various considerations needed to be evaluated for establishing acceptable parameters such that the interconnection is technically correct [www-7].

The IEEE Std P1547.6 Draft Recommended Practice for Interconnecting Distributed Resources with EPS Distribution Secondary Networks – this standard builds upon IEEE Standard 1547 for the interconnection of distributed resources (DR) to distribution secondary network systems. This standard establishes recommended criteria, requirements and tests, and provides guidance for interconnection of distribution secondary network system types of area electric power systems (Area EPS) with distributed resources (DR) providing electric power generation in local electric power systems (Local EPS). This standard focuses on the technical issues associated with the interconnection of Area EPS distribution secondary networks with a Local EPS having DR generation. The standard provides recommendations relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. In this standard consideration is given to the needs of the Local EPS to be able to provide enhanced service to the DR owner loads as well as to other loads served by the network. Equally, the standard addresses the technical concerns and issues of the Area EPS. Further, this standard identifies communication and control recommendations and provides guidance on considerations that will have to be addressed for such DR interconnections [www-7].

4.2. European grid codes

4.2.1. Summary

Several countries in Europe are described and considered:

- France
- Spain
- Portugal
- Austria
- Netherlands
- United Kingdom
- Germany
- Greece
- Belgium
- Norway, Denmark, Sweden (not in detail)
- Italy

4.2.1.1. Description

The grid connection regulation is different in several European countries. It is either done by law, by a regulator, by the Transmission System Operator, by the Distribution System Operator or by national standards. To give an overview the different countries are assigned to the type of regulation which are listed in Table 4-I.

Table 4-I: Overview about the classification of European countries regarding the type of regulation

Regulated by	Countries
Law	France, Spain, Portugal
Regulator	Austria, The Netherland, United Kingdom
TSO/DSO	Germany, Greece, Belgium Norway, Denmark, Sweden
National standard	Italy

4.2.1.2. Status

The phenomenon of renewable energy sources and distributed generation is relatively new and regulation is continuously adapting as new issues appear. It is advisable to notice some cases such as fault-ride-capability at wind power plants being promoted nowadays by means of tariff incentives by the Spanish legislation when the previous normative scenario was requiring exactly the opposite.

Obviously, the initial normative framework was not though for a wide implantation of this technology but the current figure demonstrates that installed wind power is one and a half times the nuclear capacity (roughly 12 GW against 8GW). Recently the wind power production has even equalled the nuclear power generation for a few hours.

The real impact of DG and RES is still to be discovered because the price mechanisms, incentives, emission targets, fuel prices and so on are directly related to the installation plans.

4.2.1.3. Support

National level legislation is completely fulfilled by DG as it is compulsory for obtaining technical and administrative permissions.

The relatively large number of ‘old’ equipment is dominant and therefore last regulatory updates are deployed depending on the new tariff scheme and payback periods. It is unlikely that already commissioned DG would be modified to the most recent regulation.

4.2.2. Overview

In the next paragraphs the terms of grid connection regulation are described for some of the countries listed in Table 4-I.

- France: In 2003 a government degree about “the connection of installation to the distribution and transmission network” was enacted. Because of the formulation is very general three ministerial orders were decreed about generation plants. They are not very detailed so that a reference guide from the system operator and the contract between the producer and the network operator is going to complete the ministerial orders regarding technical issues.
- Spain: Distributed generation is acquired by the “Special Regime”. The regulatory documents for the distribution network are in detail: the OM September, 12th 1985, the RD 436/2004 and the RD 1663/2000.
- Austria: The E-Control GmbH has got the coordination of the national grid code. The name of the grid code is “Technical and organisational rules for operators and users of transmission and distribution networks (TOR)”. It is part of the “market rules” which have a de facto status of a law since they are implemented in the ElWOG law (“*Elektrizitätswirtschafts- und organisationsgesetz*”).

- The Netherlands: The needed technical rules can be found in the National Code. It consists of a Grid Code, a System Code and a Metering Code.
- United Kingdom: The Distribution Code of Great Britain specifies among other things the connection to DNO networks and certain requirements for the control and protection of DG. The Distribution Code has been set up by the DNOs.
- Germany: The VDN (*Verband der Netzbetreiber – VDN e.V. beim VDEW*) is an organisation of grid operators. Guidelines for the connection of DG units to the grid are given by this organisation. The Distribution Code specifies the standards for DSO-owned networks. The Technical Connection Conditions ("*Technische Anschlußbedingungen*") issued by each DSO based on the VDN – guidelines describe in detail the connection of DG to the grid. They almost have the status of regulations.
- Greece: The Public Power Cooperation (PPC) launched in 2004 the "Technical Requirements for the connection of independent generation to the grid". This should ensure that the installation does not affect the proper operation of the grid. The criteria are power quality, fault level contribution and interconnection protection.
- Belgium: In Belgium the federal and regional authorities have got responsibility for "Energy". Four regulator bodies were founded (CREG, VREG, Vwape, BIM) who implemented the Directive 96/92/CE according to their respective competence.
- Italy: The Italian standard CEI 11-20: "Electrical energy production system and uninterruptible power systems connected to I and II class network." Describes the connection of generating units. But a specific and complete framework for DG connection to the grid has not developed yet.

The approach of connecting DG units to the distribution grid by these four different groups has got advantages (+), disadvantages (-) and open questions (?). They are listed in Table 4-II using [Ref-7]

Table 4-II: Advantages, disadvantages and open questions of the different groups of regulation

	Regulation by law	Regulation by regulator	Regulation by TSO/DSO	Regulation by National standard
Technical expertise	?	?	+	+
Integration of all parties in working process	-	?	-	+
Update cause of new developments	?	?	?	?
Clearness of situation	-	?	+	+
Implementation	+	+	?	?

	Regulation by law	Regulation by regulator	Regulation by TSO/DSO	Regulation by National standard
Acceptability		+	+	

A summary of the most important issues of the grid connection standards are given in tabular form. Only LV levels are considered. The data can also be found in [Ref-8] and [Ref-9]. The considering issues and there shortcuts used in the following tables are listed in Table 4-III.

Table 4-III: issues and shortcuts

Acronym	Description	Acronym	Description
ST	System Type		maximum DG power limits
VL	Voltage Levels		operating power factor
NT	Network Topologies		power quality constraints protection
NES	Neutral Earthing Scheme		other requirements
DFL	Design Fault Level	DC-Inj.	DC Injection
Min. Ind.	Minimum inductance	LVRT	Low Voltage Ride Through
Min. Cap.	Minimum capacitance	SG syn.	SG synchronization
SVC	Short voltage changes	MV/LV TR group	MV/LV transformer group
FVC	Fast voltage changes	AD	Accessible Disconnect
H&I	Harmonics & Inter-harmonics		
MS	Mains signaling		

Table 4-IV, Table 4-V, Table 4-VI and Table 4-VII summarize some of the current grid connection issues across different European Countries.

Table 4-IV: Summary of the Grid Codes of France, Spain and Portugal in tabular form

		France	Spain	Portugal
ST		Interconnected	Interconnected	Interconnected
		Isolated (island)	Extra peninsular systems	isolated
VL	**LV**	230 V / 400 V	230 V / 400 V	230 V / 400 V
NT	**LV**	Radial, 3 Ph + N	Radial, 3 Ph + N	Radial, 3 Ph + N
NES	**LV**	TT	TN	Neutral of DG and LV connect
DFL	**LV**	24 kA	20 kA	-
Max. DG Power Limits	**LV, 1Ph**	18 kVA (1phase)	< 50 % of transformer power	5 kVA
	LV, 3Ph	250 kVA (3phase)	100 kVA and less than 50 % of transformer power	150 kVA
Operating Power Factor	**Min Ind.**	Constant reactive power control	Asyn.: pf > 0.86; Gen.: pf >0.8	0.8
	Min Cap		1	0.8
Power Quality	**SVC**	Δ U between +6% and -10%	IEC 50160, IEC 61000 series	

		France	Spain	Portugal
Constraints	**FVC**	Δ U < 5 %	IEC 50160, IEC 61000 series	Hydro and thermal unit < 5 %, Wind generators < 2%
	Flicker	Limited such that DNO can meet its commitments in terms of power quality	IEC 50160, IEC 61000 series	EN 50160
	H&I	Emissions should be limited	IEC 50160, IEC 61000 series	EN 50160, the compatibility level for interharmonics is 0.2% U_n,per IEC 1000-2-2:1900; THD < 8 %
	MS	f = 175 Hz; DG must not affect mains signalling	IEC 50160, IEC 61000 series	Remote control signal, high frequencies
	DC-Inj.		IEC 50160, IEC 61000 series	
Protection	**LV anti-islanding**	Decoupling protection with U>, U<, f> and f< relays	3 undervoltage relay at 0.85U_n 1 overvoltage relay at 1.1 Un, Underfrequncy relay at 49 Hz Overfrequency relay at 51 Hz	Under study
Other requirements	**LVRT**	Interconnect → DG must not disconnect before decoupling protection Islands → DG must stay connected for voltages of 0.3 U_n for 600 ms and 0.7 U_n for 2.5 s	Necessary	To be applied for new wind generation
	SG syn.	Δ U < ± 10 % Δ f < ± 0.1 Hz Δ φ < ± 10 %	Synchronous .generator: Δ U = ± 10 %, Δ f = ± 2 Hz Δ φ = ± 20 %; Asynchronous generator. s < 10 % when P ≤ 1000 kVA s < 5 % when P > 1000 kVA Wind generation connection cannot produce voltage drops > 2% of rated value and may be only less than three connections per minute	S_n < 500 kVA: 0.9 – 1.1 pu (V); Frequency deviation: ± 0.3 Hz; Phase angle ± 20 ° S_n > 500 kVA: 0.92 – 1.08 pu (V) Frequency deviation ± 0,2 Hz, phase angle ± 10°
	MV/LV TR group		Dyn	Dyn
	AD		Yes	Yes

Table 4-V: Summary of the Grid Codes of Austria, Netherlands and UK in tabular form

		Austria	The Netherlands	United Kingdom (UK)
ST		Interconnected	Interconnected	interconnected
		-	Only one or two small islands	
VL	**LV**	230 V / 400 V	230 V / 400 V	230 V / 400 V
NT	**LV**	Radial, 3 Ph + N	Radial, sometimes meshed, 3 Ph	
NES	**LV**	TN-C	TT or TN	
DFL	**LV**	25 MVA	NA	See G59/1 or G83/1
Max. DG Power Limits	**LV, 1Ph**	4.6 kVA (1phase)	1 Ph @ 40 A = 10 kVA	
	LV, 3Ph	Not defined	3 Ph @ 250 A = 173 kVA	
Operating	**Min Ind.**	Not defined	0.9	

		Austria	The Netherlands	United Kingdom (UK)
Power Factor	Min Cap	Not defined	0.9	
Power Quality Constraints	SVC	Δ U = 3 % of U_n	During one week 95 % of time between ± 10 %, always between + 10 % and – 15 %	EN 50160
	FVC	Δ U = 3 % if repeat rate r < 0.1 min^{-1} and in some cases (r < 0.01 min^{-1}) → Δ U = 6 %	Max. 10 %	Δ U = 3 %
	Flicker	P_{lt} = 0.46 p.u.	During one week 95 % of time P_{lt} < 1, always P_{lt} < 5	Engineering Recommendation P28; P_{st} = 1; P_{lt} = 0.8
	H&I	Individual calculated when inverters are used	IEC 50160 for individual harmonics; during one week THD < 8 % for 95 % of time; during one week THD < 12% for 99,5 % of the time	Planning level: THD = 5 % More in G5/4, Stage 1
	MS	DG must not negatively impact mains signalling	Ripple control at various frequencies between 200 Hz and 1600 Hz, DG must not negatively impact ripple control, otherwise measures are requires	
	DC-Inj.	Recommendation for PV	No specific requirements	
Protection	LV anti-islanding	PV: ENS or non-islanding inverter Generally: U>, U<, f>, f<	Undervoltage, Overvoltage, Frequency deviation, Connection delay after tripping	Undervoltage + 10 % Overvoltage – 10 % Overfrequency + 1 % Underfrequency – 6 %
Other requirements	LVRT	Not required	None	
	SG syn.	Δ U < ± 10 % Δ f < ± 1 Hz Δ φ < ± 10 %	Considered responsibility of generator operator, no specific requirements by grid company	
	MV/LV TR group	Dyn	-	
	AD	Yes, not required when ENS/non-islanding inverters are being used	no	yes

Table 4-VI: Summary of the Grid Codes of Germany, Greece and Belgium in tabular form

		Germany	Greece	Belgium
ST		Interconnected	Interconnected	interconnected
		-	Isolated	
VL	LV	230 V / 400 V	230 V / 400 V	230 V / 400 V
NT	LV	Radial, 3Ph+N	Radial, 3Ph+N	Radial, 3 Ph + N, (some older grids have 3x230V)
NES	LV	-	TN-C	TN-C in industrial systems, TN-S in others (is promoted), occasional IT

		Germany	Greece	Belgium
DFL	**LV**	Must be limited if it is too high for the grid	24 kA	16 MVA
Max. DG Power Limits	**LV, 1Ph**	4,6 kVA	5 kVA	< transformer MV/LV
	LV, 3Ph	Depends on grid	100 kVA	< transformer MV/LV
Operating Power Factor	**Min Ind.**	-	0.95	No specific limits
	Min Cap		0.95	No specific limits
Power Quality Constraints	**SVC**		< ± 3 % of U_n	< ± 3 % between on-off switching; EN 50160
	FVC		~ 5 %	P_{st} < 1; EN 50160
	Flicker	EN 61000-3-3; EN 61000-3-11	Per IEC 61000 (3-3, 3-5, 3-6)	IEC/EN 61000-3-3 for DG ≤ 16 A IEC/TR2 61000-3-5 for DG > 16 A
	H&I	EN 61000-3-2 or EN 61000-3-12	Per IEC 61000 (3-2, 3-4, 3-6) U_h < 0.2 %, h non-integer or h > 40	IEC/EN 61000-3-2 for DG ≤ 16 A IEC/TS 61000-3-4 for DG > 16 A
	MS		f_{ms} = 175 Hz, U_{ms} = 2 %, specific restriction apply	f = 175/180/217/315/1347 Hz Δ U = 2 %
	DC-Inj.	Max. 1 A for 0.2 s	Under consideration: < 1 %	DC current < 1 % of rated current; if higher trip after 0.2 s
Protection	**LV anti-islanding**	Undervoltage U < 0.7 U_n Overvoltage U > 1.15 U_n Underfrequency f < 47 Hz Overfrequency f > 52 Hz	PVs: Per VDE 0126 (ENS) Generally: U>, U<, f>, f<	U > 1.06 p.u. instantly, U < 0.5 – 0.85, delay 1.5s f: 49.5, 50.5, instantly; DG must be disconnected with one phase fault
Other requirements	**LVRT**		None for interconnected system Under consideration for islands	None
	SG syn.	Automatic synchronisation preferred	Δ U < ± 10 % Δ f < ± 0.5 Hz Δ φ < ± 10 %	Δ U, Δ f, Δ φ must be such that they do not cause an sudden variation >6 % in voltage
	MV/LV TR group		Dyn	Often Yd + earthing transformer direct to earth
	AD	MSD (german: ENS) or AD; MSD/ENS: U < 0.8 U_n U > 1.15 U_n f < 49,8 Hz or f > 50,2 Hz	Yes	Yes

Table 4-VII: Summary of the Grid Codes of Italy in tabular form

		Italy		
ST		Interconnected		
		Only small islands		
VL	**LV**	230 V / 400 V		
NT	**LV**	Radial, 3Ph+N		
NES	**LV**	TT (TN or IT only in specific cases)		
DFL	**LV**	16 kA		

		Italy		
Max. DG Power Limits	**LV, 1Ph**	5 kVA		
	LV, 3Ph	50 kW		
Operating Power Factor	**Min Ind.**	-		
	Min Cap	-		
Power Quality Constraints	**SVC**	IEC 50160, IEC 61000 series		
	FVC	IEC 50160, IEC 61000 series		
	Flicker	IEC 50160, IEC 61000 series		
	H&I	IEC 50160, IEC 61000 series		
	MS	-		
	DC-Inj.	IEC 50160, IEC 61000 series		
Protection	**LV anti-islanding**	Generally: U>, U<, f>, f<		
Other requirements	**LVRT**	-		
	SG syn.	-		
	MV/LV TR group	Dyn		
	AD			

4.3. Ancillary services

4.3.1. Definitions

According to the Electricity Directive (2003/54/EC), ancillary services are all services necessary for the operation of a transmission or distribution system. It comprises compensation for energy losses, frequency control, voltage and power flow control (reactive power and active power), restoration of supply (black start, temporary island operation) and balancing.

The liberalisation of the energy market has led to the establishment of separate balancing and ancillary service markets. The objective of these markets is to keep the power system running at any time.

4.3.2. Current situation and future requirements

The actual power flows and the network situation differ from the schedules defined in the wholesale market based on forecasts and plans. The balancing and ancillary service market provides TSO with resources for maintaining the instantaneous balance in the network within given network constraints.

Balancing markets comprise contracts for primary, secondary and minute reserves with different time scales. Due to minimum trading sizes for provision of the balancing power the market is mainly limited to large players such as aggregators, large power producers or large consumers. Ancillary services are provided by generators and the system operators to guarantee system reliability and power quality.

Currently, the TSO is the single buyer on the balancing market. DSOs are responsible only for the services compensation for energy losses and voltage control. In 2015, it is assumed that also DSOs are to some extent responsible for balancing and ancillary services that can be provided by Microgrid structures (Figure 4-2). Some ancillary services can be offered by DG operators directly to the DSO.

System Services

F - Frequency stability: - Primary control power <30s (FP)
- Secondary control power <5 min (FS)
- Minute reserve power 7-15 min (FM)

P - Power Balance: - Scheduling and Generation dispatch (PD)

V - Voltage stability: - Tap changer control (VT)
- Reactive power control (VQ)

R – Restoration of supply: - Black start capability (RB)
- Island operation (RI)

S – System management: - Power quality assurance (SQ)
- Operation management (SO)

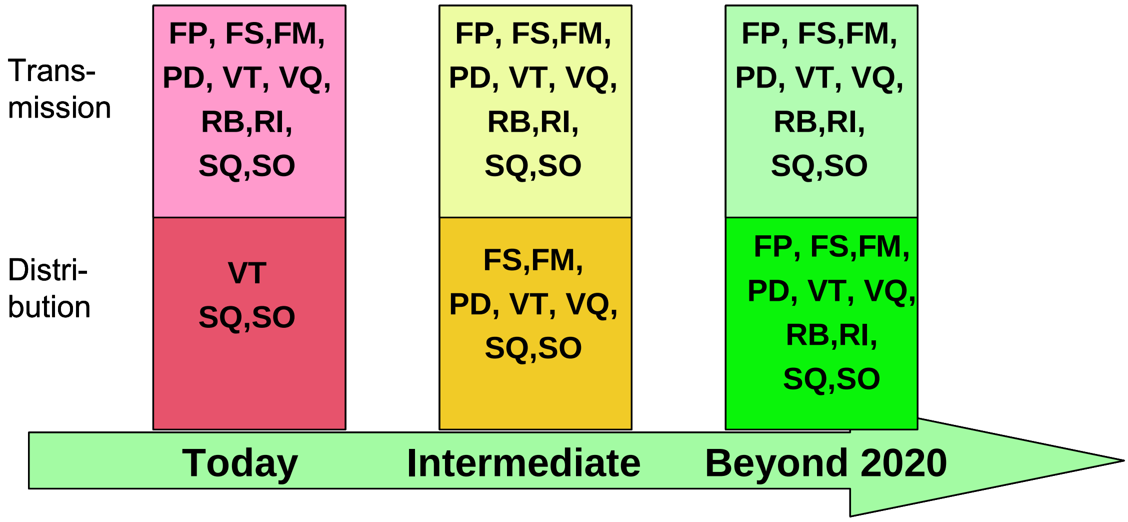


Figure 4-2: Present and future system services in T&D networks

4.4. Applicability and consistency of grid codes

Currently all grid codes include provisions to prevent islanding, i.e. to force the disconnection of the unit in case it starts feeding a part of the network, separated from the main grid. For this purpose, specific protection is installed which trips the DG unit in a very short time (ranging from a few tenths of a sec up to a few sec), once the voltage or frequency deviate significantly from their nominal values. The time delay is typically fast enough to allow disconnection prior to the shortest re-closing times found in protective relays on the network. It should also prevent re-closure into an out of phase DG unit, as well as allow the fault arc to deionise prior to re-closure. Once a DG unit has disconnected from the network, it should not reconnect into a de-energized system.

Anti-islanding protection is realized via either passive protection or active protection. Passive anti-islanding protection typically utilizes voltage and frequency relays to measure electrical variables at the DG installation terminals and determine whether island conditions have been formed. On the other hand, several inverter manufacturers have added an additional “active” anti-islanding capability. Active anti-islanding is more robust than passive, but even it cannot guarantee that an island will not develop under certain special operating conditions.

When the formation of a running island is possible, conditions in the island must be evaluated to assess the maximum level of expected overvoltages and how fast the interconnection protective relaying will respond to them. As regards neutral instability in an island, this can be avoided by suitable transformer connections or by using a properly sized grounding transformer on the primary circuit.

Most grid codes allow the intentional islanding of customer facilities, to increase the reliability of supply. This can be accomplished if the user installation includes suitable DG resources and the interconnection is designed to provide “backup islands” during network outages. This approach requires reliable DG units and careful coordination of utility sectionalizing and protection equipment. During upstream faults, the disconnection switch must open and the generator must be able to carry the load on the islanded section, maintaining suitable voltage and frequency levels at all islanded loads. This scheme may result in a momentary interruption to the island, since the DG might trip during the voltage disturbance caused by the upstream fault, unless. A DG assigned to carry the island must be able to restart and pick up the island load after the switch has opened. Suitable paralleling equipment is also needed for returning to grid-connected mode of operation. To ensure that proper voltage regulation is maintained and to establish that the DG can handle inrush during "starting" of the island, power flow analysis of island scenarios must be performed. Fault, protection and stability studies are also needed for island conditions.

In general, however, it must be emphasized that current grid codes do not favour the formation of islands within the distribution system, permitting it only within user premises, i.e. involving the separation of a specific installation but no parts of the outside ("public") network. On the other hand, the adopted view towards DG at the distribution level tends to ensure their timely disconnection, once abnormal conditions occur in the network.

Such an approach is compatible to the concept of μGrids, which relies on the intentional islanding and controlled reconnection of larger parts of the network, comprising several independent users. To this end, several modifications would have to take place in all network codes applied today, to form a legal, technical and economic framework suitable for the development and proliferation of μGrids. Specific issues to be addressed include indicatively the following:

- Modified connection requirements, to reflect the fact that the μSources will operate in a much more confined network, during islanding.
- Modified interconnection protection requirements, which will discriminate between unintentional (and potentially harmful) islanding and deliberate separation from the main grid.
- Control specifications for distributed generation and storage devices, intended to operate within μGrids.
- Communication requirements, for the μGeneration and storage facilities, as well as for load management.
- Revised metering and tariff policies, for single DG units and for overall μGrid entities.

5. References

[Ref-1] Utility Communications Architecture® (UCA) – Object Models for Distributed Energy Resources (UCA-DER); Available online at http://www.epri-intelligrid.com/intelligrid/

[Ref-2] Technical and System Requirements for Advanced Distribution Automation, EPRI, Palo Alto, CA: 2004. 1010915.

[Ref-3] Growth of decentralised power production: a challenge for the electrical grid? The Dutch experience; COGEN, March 2001; (http://www.cogen.org/)

[Ref-4] Application Guide for Distributed Generation Interconnection: 2003 Update, The NRECA Guide to IEEE 1547; Available at http://www.nreca.org/

[Ref-5] Utility Communications Architecture (UCA®), Object Models for Distributed Energy Resources (UCA-DER); Electricity Innovation Institute and Electric Power Research Institute, Inc, December 2004; Available at http://www.epri-intelligrid.com/

[Ref-6] T. Basso, R. DeBlasio: IEEE 1547 Series of Standards: Interconnection Issues, Preprint, National Renewable Energy Laboratory, September 2003, NREL/JA-560-34882, http://www.nrel.gov/docs/fy03osti/34882.pdf

[Ref-7] *Normen, Regulierungen im DG-Bereich in Europa und Österreich; Roland Bründlinger*; Arsenal Research

[Ref-8] Connection criteria at the distribution network for distributed generation; CIGRE Task Force C6.04.01;

[Ref-9] International standard situation concerning components of distributed power systems and recommendations of supplements; Project DISPOWER; Deliverable D2.1.

[Ref-10] International standard IEC 61850: *Communication networks and systems in substations – Parts 1-10*.

6. Web Sites

[www-1] http://www.iec.ch/
International Electrotechnical Commission – IEC

[www-2] http ://www.cimuser.org/
CIM User Site

[www-3] http://sharepoint.ucausersgroup.org/CIM/
CIM Users Group

[www-4] http ://www.iberdrola.es/wcorp/gc/en/corporativos/funcionamiento.html
CORE Description. CORE stands for *Centro de Operación de Renovables* (Renewable Operation Centre)

[www-5] http://europa.eu/
European Commission Conference, Energy Sector Inquiry – Public Presentation of the Preliminary Findings, Brussels, Thursday 16th February 2006: Ms. Neelie Kroes (Member of the European Commission in charge of Competition Policy): "Towards an Efficient and Integrated European Energy Market – First Findings and Next Steps"

[www-6] http://www.gradingandexcavation.com/de_0311_ieee.html

[www-7] http://grouper.ieee.org/groups/scc21/dr_shared/

[www-8] http://www.edi.etso-net.org/

7. Glossary

Term	Stands for	Notes
ADA	Advanced Distribution Automation	EPRI IntelliGrid terminology
APCI	Application Protocol Control Information	IEC 60870 terminology
APDU	Application Protocol Data Unit	IEC 60870 terminology
ASDU	Application Service Data Unit	IEC 60870 terminology
CCAPI	Control Centre Application Programming Interface	EPRI project
CDC	Common Data Classes	IEC 61850 terminology
CIM	Common Information Model	IEC standard 61970-301
CIS	Component Interface Specification	IEC 61970 component
CIS-DA	Custom Interface Specification – Data Access	OPC standard
CIS-AE	Custom Interface Specification – Alarms and Events	OPC standard
CIS-HAD	Custom Interface Specification – Historical Data Access	OPC standard
CORBA	Common Object Request Broker Architecture	OMG standard
DAF	Data Access Facility	OMG standard
DAIS	Data Acquisition for Industrial Systems	OMG standard
DER	Distributed Energy Resources	
DG	Distributed Generation	
DMS	Distribution Management System	
DNP3	Distributed Network Protocol v3	(see http://www.dnp.org/)
DO	Data Object	IEC 61850 terminology
DSO	Distribution System Operator	
EPA	Enhanced Performance Architecture	IEC 60870 terminology
ebXML	electronic business XML	(see http://www.ebxml.org/)
EDI	Electronic Data Interchange	
EMS	Energy Management Systems	
EPS	Electrical Power System	
ERP	Enterprise Resource Planning	
ETSO	European Transmission System Operators	
FSK	Frequency Shift Keying	Type of modulation for communications
HDAIS	Historical Data Access for Industrial Systems	OMG standard
HMI	Human Machine Interface	
HSDA	High Speed Data Access	IEC 61970 component
HV	High Voltage	
GDA	Generic Data Access	IEC 61970 component
GES	Generic Eventing and Subscription	IEC 61970 component
GID	Generic Interface Definition	(EPRI project)
GOOSE	Generic Object Oriented Substation Event	UCA definition for relay-relay messages
GSSE	Generic Substation Status Event	Same as GOOSE in IEC 61850 terms
ICCP	Inter Control Centre Communication	IEC 60870 component
ICT	Information and Communication Technologies	

Term	Stands for	Notes
IEC	International Electrotechnical Commission	(see http://www.iec.ch/)
IED	Intelligent Electronic Device	
IEEE	Institute of Electrical and Electronics Engineers	
IRM	Interface Reference Model	
ISO	Independent System Operator	
LAN	Local Area Network	
LD	Logical Device	IEC 61850 terminology
LPCI	Link Protocol Control Information	IEC 60870 terminology
LPCU	Link Protocol Control Unit	IEC 60870 terminology
LN	Logical Node	IEC 61850 terminology
LV	Low Voltage	
MDA	Model Driven Architecture	OMG Standard
MMS	Manufacturer Message Specification	ISO Standard 9506-1, 9506-2
MV	Medium Voltage	
OAG	Open Applications Group	(see http://openapplications.org/)
OMG	Open management Group	(see http://www.omg.org/)
OPC	Ole for Process Control	(see http://www.opcfoundation.org/)
PICOM	Piece of Information for COMmunications	CIGRE WG34.04 terminology
RDF	Resource Description Framework	(see http://www.w3c.org/)
RTU	Remote Terminal Unit	
SCADA	Supervisory Control And Data Acquisition	
SCL	Substation Configuration Language	IEC 61850 terminology
TASE	Telecontrol Application Service Element	IEC 60870 component
TCP/IP	Transmission Control Protocol / Internet Protocol	(see http://www.ietf.org/)
TSDA	Time Series Data Access	IEC 61970 component
TSO	Transmission System Operator	
UCA	Utility Communications Architecture	(see http://www.ucausersgroup.org/)
UML	Unified Modelling Language	(see http://www.uml.org/)
UN/CEFACT	United Nations Centre for Trade facilitation and Electronic Business	(see http://www.unece.org/cefact/)
UN/EDIFACT	United Nations Directories for Electronic Data Interchange for Administration, Commerce and Transport	(see http://www.unece.org/cefact/)
XML	eXtensible Mark-up Language	(see http://www.w3c.org/)
WAN	Wide Area Network	

8. Annexes

8.1. Annex A: IEC Stage Codes[12]

Code	Description
1CD	1st Committee Draft
2CD	2nd Committee Draft
3CD	3rd Committee Draft
4CD	4th Committee Draft
5CD	5th Committee Draft
6CD	6th Committee Draft
7CD	7th Committee Draft
8CD	8th Committee Draft
9CD	9th Committee Draft
A2CD	Approved for 2nd Committee Draft
A3CD	Approved for 3rd Committee Draft
A4CD	Approved for 4th Committee Draft
A5CD	Approved for 5th Committee Draft
A6CD	Approved for 6th Committee Draft
A7CD	Approved for 7th Committee Draft
A8CD	Approved for 8th Committee Draft
A9CD	Approved for 9th Committee Draft
ACDV	Draft approved for Committee Draft with Vote
ADIS	Approved for FDIS circulation
ADISSB	FDIS manuscript subcontracted to CO
AMW	Approved Maintenance Work
ANW	Approved New Work
APUB	Draft approved for publication
APUBSB	PUB manuscript subcontracted to CO
BPUB	Publication being printed
BWG	Draft returned to Working Group
CAN	Draft cancelled
CCDV	Draft circulated as Committee Draft with Vote
CDIS	Draft circulated as FDIS
CDM	Committee Draft to be discussed at Meeting
CDPAS	Circulated Draft for Publicly Available Spec.
CDTR	Circulated Draft Technical Report
CDTS	Circulated Draft Technical Specification
CDVM	Committee draft with vote for meeting
DEC	Draft at Editing Check
DEL	Deleted items
DELPUB	Deleted Publication
DREJ	Draft rejected
MERGED	Merged project
NADIS	FDIS not approved
NCD	CCDV not approved
PNW	Proposed New Work
PPUB	Publication issued
PWI	Potential new work item
RDIS	Text for FDIS received and registered
SPE	Special Handling
SRP	Publication under Systematic Review
WPUB	Publication withdrawn

[12] Source: http://www.iec.ch/cgi-bin/procgi.pl/www/iecwww.p?wwwlang=e&wwwprog=stages.p&progdb=db1#PWI