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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMUNICATION NETWORKS AND SYSTEMS
IN SUBSTATIONS –

Part 4: System and project management

FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61850-4 has been prepared by IEC technical committee 57: Power system control and associated communications

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

FDIS	Report on voting
57/558/FDIS	57/573/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annexes A and B are for information only.

IEC 61850 consists of the following parts, under the general title *Communication networks and systems for Power Utility Automation*:

Part 1: Introduction and overview

Part 2: Glossary

Part 3: General requirements

Part 4: System and project management

Part 5: Communication requirements for functions and device models

Part 6: Configuration description language for communication in electrical substations related to IEDs

Part 7-1: Basic communication structure for substation and feeder equipment – Principles and models

Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)

Part 7-3: Basic communication structure for substation and feeder equipment – Common data classes

Part 7-4: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes

Part 8-1: Specific Communication Service Mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3

Part 9-1: Specific Communication Service Mapping (SCSM) – Sampled values over serial unidirectional multidrop point to point link

Part 9-2: Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3

Part 10: Conformance testing

Deleted: IEC 61850 consists of the following parts, under the general title: Communication networks and systems in substations:¶
Part 1: Introduction and overview

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The committee has decided that the contents of this publication will remain unchanged until 2010. At this date, the publication will be

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

Deleted: Part 2: Glossary¹¶
Part 3: General requirements¶
Part 4: System and project management¶
Part 5: Communication requirements for functions and device models¹¶
Part 6: Substation automation system configuration description language¹¶
Part 7-1: Basic communication structure for substation and feeder equipment – Principles and models¹¶
Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)¹¶
Part 7-3: Basic communication structure for substation and feeder equipment – Common data classes¹¶
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Part 8-1: Specific communication service mapping (SCSM) – Mapping to MMS (ISO/IEC 9506 Part 1 and Part 2)¹¶
Part 9-1: Specific communication service mapping (SCSM) – Serial unidirectional multidrop point to point link¹¶
Part 9-2: Specific communication service mapping (SCSM) – Mapping on a IEEE 802.3 based process bus¹¶
Part 10: Conformance testing¹

COMMUNICATION NETWORKS AND SYSTEMS for Power Utility Automation –

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Part 4: System and project management

1 Scope and object

This part of IEC 61850 applies to substation automation systems (SAS). It defines the communication between intelligent electronic devices (IEDs) in the substation and the related system requirements.

The specifications of this part pertain to the system and project management with respect to:

- the engineering process and its supporting tools;
- the life cycle of the overall system and its IEDs;
- the quality assurance beginning with the development stage and ending with discontinuation and decommissioning of the SAS and its IEDs.

The requirements of the system and project management process and of special supporting tools for engineering and testing are described.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61850. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61850 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60848:1988, *Preparation of function charts for control systems*

IEC 61082 (all parts), *Preparation of documents used in the electrotechnology*

IEC 61175:1993, *Designations for signals and connections*

IEC 61346 (all parts), *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations*

ISO 9001:1994, *Quality systems – Model for quality assurance in design, development, production, installation and servicing*

3 Definitions

For the purpose of this part of IEC 61850, the following definitions apply:

3.1

supporting tools

those that support the user in the engineering, the operation and the management of the SAS and its IEDs. The following tasks can be implemented:

- engineering;
- project management;
- parameter change(s);
- diagnostics;
- testing;
- documentation;
- other services.

NOTE The tools are usually part of the SAS.

3.1.1

engineering tools

those tools that support the creation and documentation of the conditions for adapting an SAS to the specific substation and customer requirements. They are divided into project management, parameterization and documentation tools.

3.1.2

System configuration tools

Those tools handling the communication between the IEDs in the system, configuration of issues common for several IEDs, and the connection to the process to be controlled and supervised. See also 'system parameters'.

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3.1.3

IED configuration tools

Those tools handling the specific configuration and download of configuration data to a specific IED of a specific type.

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3.2

expandability

the criteria for the efficient extension of an SAS (hardware and functional) by use of the engineering tools

3.3

flexibility

the criteria for the fast and efficient implementation of functional changes including hardware

3.4

scalability

the criteria for a cost effective SAS while recognizing various functionalities, various IEDs, substation sizes and substation voltage ranges

3.5 parameters

variables which define the behaviour of functions of the SAS and its IEDs within a given range of values

3.5.1 system parameters

data which define the interaction of IEDs in the SAS. They are especially important in the:

- configuration of the SAS;
- communication between IEDs;
- marshalling of data between IEDs;
- processing and visualization of data from other IEDs (for example, at the station level)

3.6

IED-parameter set

all parameter values needed for the definition of the behaviour of the IED and its adaptation to the substation conditions. Where the IED has to operate autonomously, the parameter-set can be generated without system parameters using an IED-specific parameterization tool. Where the IED is a part of the SAS the parameter set may include system parameters, which should be coordinated by a general parameterization tool at the SAS level

3.7

SAS-parameter set

all parameter values needed for the definition of the behaviour of the overall SAS and its adaptation to the substation conditions. The parameter set includes the IED-parameter sets of all participating IEDs

3.8

remote terminal unit (RTU)

typically used as an outstation in a Supervisory Control and Data Acquisition (SCADA) system. An RTU may act as an interface between the communication network and the substation equipment. The function of an RTU may reside in one IED or may be distributed

3.9

SAS product family

different IEDs of one manufacturer with various functionalities and with the ability to perform substation automation systems. The IEDs of a product family are unified in relation to the design, the operational handling, the mounting and wiring conditions and they use common or coordinated supporting tools

3.10

SAS installation

the concrete instance of a substation automation system consisting of multiple interoperable IEDs of one or more manufacturers

3.11

configuration list

an overview of all compatible hardware and software versions of components and IEDs including the software versions of relevant supporting tools operating together in an SAS-product family. Additionally, the configuration list contains the supported transmission protocols for communication with IEDs of other manufacturers

3.12

manufacturer

the producer of IEDs and/or supporting tools. A manufacturer may be able to deliver an SAS solely by use of his own IEDs and supporting tools (SAS product family)

3.13

system integrator

a turnkey deliverer of SAS installations. The responsibility of system integration includes the engineering, the delivery and mounting of all participating IEDs, the factory and site acceptance tests and the trial operation. The quality assurance, the maintenance and spare delivery obligations and the warranty shall be agreed in the contract between the system integrator and the customer

3.14**system life cycle**

the term has two specific meanings:

- a) for the manufacturer, the time period between the start of the production of a newly developed SAS product family and the discontinuation of support for the relevant IEDs;
- b) for the customer, the time period between the commissioning of the SAS-installation mainly based on a SAS product family and the decommissioning of the latest SAS-installation from the same family

3.15**test equipment**

all tools and instruments which simulate and verify the input/outputs of the operating environment of the SAS such as switchgear, transformers, network control centres or connected telecommunication units on the one side, and the communication channels between the IEDs of the SAS on the other

3.16**conformance test**

the check of data flow on communication channels in accordance with the standard conditions concerning access organization, formats and bit sequences, time synchronization, timing, signal form and level, reaction to errors. The conformance test can be carried out and certified for the standard or specially described parts of the standard. The conformance test should be carried out by an ISO 9001 certified organization or system integrator

3.17**system test**

the check of correct behaviour of the IEDs and of the overall SAS under various application conditions. The system test marks the final stage of the development of IEDs as part of a SAS product family

3.18**type test**

the verification of correct behaviour of the IEDs of the SAS by use of the system tested software under the environmental test conditions corresponding with the technical data. This marks the final stage of the hardware development and is the precondition for the start of the production. This test must be carried out with IEDs that have been manufactured through the normal production cycle

3.19**factory acceptance test (FAT)**

customer agreed functional tests of the specifically manufactured SAS-installation or its parts, using the parameter set for the planned application. This test should be carried out in the factory of the system integrator by the use of process simulating test equipment

3.20**site acceptance test (SAT)**

the verification of each data and control point and the correct functionality inside the SAS and between the SAS and its operating environment at the whole installed plant by use of the final parameter set. The SAT is a precondition for the SAS being put into operation

4 Abbreviations

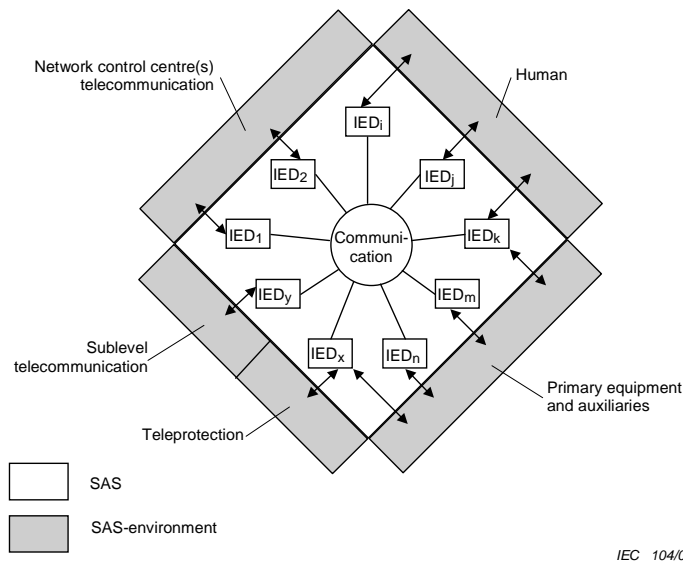
ASDU	-	Application Service Data Unit
CD ROM	-	Compact Disc Read Only Memory
CAD	-	Computer Aided Design
CT	-	Current Transformer
FAT	-	Factory Acceptance Test
HMI	-	Human Machine Interface
IED	-	Intelligent Electronic Device
PE	-	Process Environment
RTU	-	Remote Terminal Unit
SAS	-	Substation Automation System
SAT	-	Site Acceptance Test
SCADA	-	Supervisory Control and Data Acquisition
TE	-	Telecommunication Environment
VT	-	Voltage Transformer

5 Engineering requirements

5.1 Introduction

The engineering of a substation automation system includes:

- the definition of the necessary hardware configuration of the SAS: i.e. the definition of the IEDs and their interfaces with one another and to the environment as shown in figure 1;
- the adaptation of functionality and signal quantities to the specific operational requirements by use of parameters;
- the documentation of all specific definitions (i.e. parameter set, terminal connections, etc.).



IEC 104/02

Figure 1 – Structure of the SAS and its environment

As shown in figure 1, the SAS consists of different IEDs which communicate with each other via communication channels and which execute tasks concerning interactions with the environment of the SAS, such as:

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- telecommunication environment (TE);
 - network control centre(s);
 - subordinate systems;
 - teleprotection.
- the human as a local operator.
- process environment (PE) like switchgear, transformer, auxiliaries.

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Teleprotection is outside the scope of the IEC 61850 series.¶

Typical IEDs may be:

- for the telecommunication environment:
 - gateways;
 - converters;
 - RTUs (telecommunication side);
 - protection relays (teleprotection side).
- for the human machine interface (HMI):
 - gateways;
 - personal computers;
 - workstations;
 - other IEDs with integrated HMIs.
- for the process environment (PE):

- bay control units;
- protection relays;
- RTUs (process side);
- meters;
- autonomous controllers (i.e. voltage controllers);
- transducers;
- digital VTs and CTs.

5.2 Categories and types of parameters

5.2.1 Classification

Parameters are data, which control and support the operation of:

- hardware configuration (composition of IEDs);
- software of IEDs;
- process environment (primary equipment and auxiliaries);
- HMI with different supporting tools; and
- telecommunication environment

in a substation automation system (SAS) and its IEDs in such a way that the operations of the substation and customer specific requirements are fulfilled.

The total set of parameters of an SAS is termed the SAS-parameter set. It consists of the used parts of the parameter sets of all participating IEDs.

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With respect to handling methods and input procedure, the parameters are divided into two categories:

- configuration parameters;
- operating parameters.

With respect to origin and function, the parameters are divided into types:

- system parameters;
- process parameters;
- functional parameters.

In figure 2, the overview of the parameter structure is given.

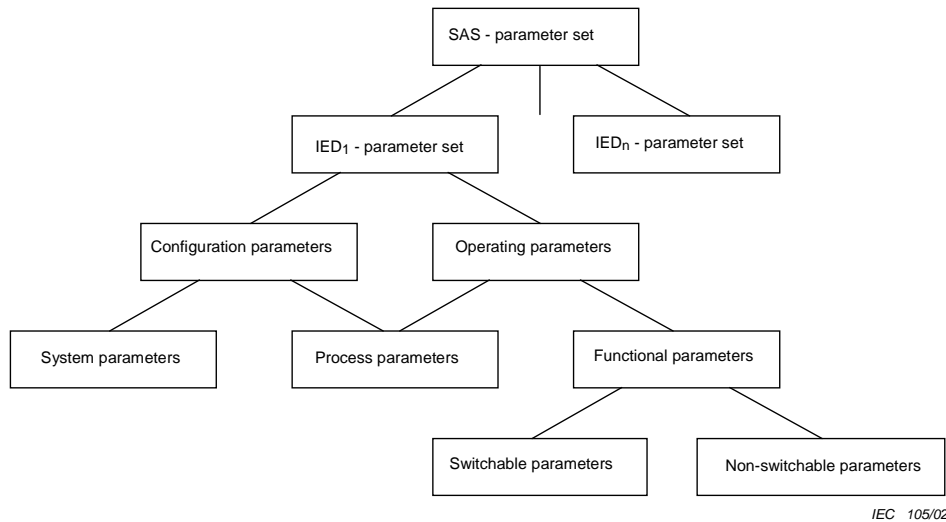


Figure 2 – Structure of SAS and IED parameters

The categories and types of parameters in figure 2 are described below.

5.2.2 Parameter categories

5.2.2.1 Configuration parameters

The configuration parameters define the global behaviour of the whole SAS and its IEDs. As a rule, they are only assigned a value during the initial parameterization, but they should be updated when extending or functionally changing the SAS.

The generation and modification of the configuration parameters should be carried out off-line, i.e. separately from the operation of the SAS. During the input of configuration parameters, a temporary restriction of the SAS operation is allowed.

The configuration parameters usually include system and process parameters.

5.2.2.2 Operating parameters

The operating parameters define the behaviour of partial functions of the SAS. They shall be changeable on-line during the normal operation of the SAS. The modification is allowed without restricting the SAS operation and within a framework of ranges of parameter values. Protection functions, as far as combined in IEDs with other functions, shall not be influenced during the parameterization of these functions.

The range and the basic settings of these parameters are determined at the initial parameterization or at a modification stage, separate from the operation of the SAS. The operating parameters can be put into the on-line SAS via:

- telecommunication interface;
- HMI;
- integrated service interface of the IEDs.

The operating parameters usually include process and functional parameters, for example limit values, target values, command output times, delay times in switching sequences, etc.

5.2.3 Parameter types

5.2.3.1 System parameters

System parameters determine the co-operation of IEDs including the internal structures and procedures of an SAS in relation to its technological limits and available components.

For example, the system parameters determine the configuration of hardware components in the SAS (boards, IEDs), the communication procedure between the IEDs (protocol, baud rate) and the scope of required and available functions in the software of IEDs at the station level.

Additionally, the system parameters describe relations between data from different IEDs, for example interlocking at the station level, visualization of information in the substation single line diagram and others.

Furthermore, the system parameters include the assignment of texts to events at the station level and the determination of data-flows in the SAS, for example to

- HMI (display, event report);
- printer;
- archive;
- telecommunication with network control centre or further substations on a sublevel.

System parameter values should be consistent in all parts of the SAS and its IEDs. The consistency of the system parameter values should be validated by a general parameterisation tool at the SAS level.

5.2.3.2 Process parameters

Process parameters describe all types of information that is exchanged between the PE and the SAS.

The process parameters are responsible for qualitative features at the process interface such as command output times, suppression of transient events (filter time), measured value damping (threshold value), and of the process itself, e.g. switch run times.

Furthermore, the process parameters include the assignment of texts to events for visualization at the IED-level.

5.2.3.3 Functional parameters

Functional parameters describe the qualitative and quantitative features of functionality used by the customer. Normally, the functional parameters are changeable on-line.

For example, the functional parameters determine the target values (set points) of controllers, the starting and tripping conditions of protection relays, automatic sequences such as operations after measurement overflow or commands in relation to specific events. The functional parameters are responsible for algorithms of automatic control, protection, blocking and adjustment.

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For example, process parameters define different relationships such as double point event, double command or the relation of an event input to a command output.

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The functional parameters are divided into switchable and non-switchable parameter value groups.

A set of functional parameter values for a group of functional parameters can be resident in an IED in parallel with other sets of functional parameter values. In this case, only one set of these functional parameter values is active at a time. It shall be possible to switch over between the sets on-line.

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5.3 Engineering tools

5.3.1 Engineering process

The SAS engineering process creates the conditions for designing and configuring a SAS to the specific substation and to the operating philosophy of the customer based on system requirements specification from the customer.

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Within the engineering process we can distinguish three different roles:

- The customer defines what he wants to have and how he wants to operate the system. He sets up the system requirements, and finally accepts the delivered system
- The manufacturer supplies the products from which the system is built
- The system integrator designs the system, based on the customers system requirement specification and the concretely available products from the manufacturers, integrates the products into the designed system, and commissions the system.

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It can be that the same person or organisation has more than one role, e.g. a manufacturer is also system integrator, or a customer does system integration by himself. This influences the packaging and formal organisation, however not the tasks which have principally to be performed.

The concrete engineering process is dependent also on responsibilities for parts of the system, and how they relate together. Even if a system integrator is also manufacturer, he might have to integrate products from other manufacturers. A customer might want to have a system with interfaces to a system of another customer. Across these organisational interfaces a data exchange in a standardized form should be possible.

A typical project will start with the customer (utility) creating a project requirement specification that defines the scope of the project, single line diagrams, device ratings and other required data. The aim is to create a set of technical specifications that can be used for tendering and engineering, irrespective of whether design and installation work will be done in-house or by external parties. Beneath general interfacing requirements his includes also the identification or at least naming rules for primary and secondary equipment, and any communication addresses or addressing schemes needed to interface with other systems of the customer. Further needed redundancy requirements, response times, availability and safety measures have to be stated beneath the environmental, physical and geographical restrictions for the project.

Part 6 of this standard provides a formal means to define the single line diagram with customer's functional names and the intended SA functionality at the equipment identified in the single line description (SSD, System Specification Description). This is based on the hierarchical structure of IEC 61346-1, allows however beneath identifications according to IEC 61346-2 also customer specific naming. It further defines a formal way how to exchange

function and communication related interface descriptions between systems respective system projects (SED, System Exchange Description).

Based on this requirement specification and its knowledge about existing solutions and products, the system integrator selects the fitting products, designs the system inclusive communication system to reach the needed response times and reliability, and produces the specifications for the products to be used. The details form a system design specification, which is typically approved by the customer, and is then used as a base for the product manufacturer to deliver the needed products with the specified configuration. The resulting system specification can be supported by a formal description of IEDs, the functions on them, and their relation to the process functionality as defined in part 6 of this standard (SCD, System Configuration Description). The manufacturer supplied IEDS, before integration into the system, come with a formal description of their functional and communication engineering capability (ICD, IED Capability Description)

The basic engineering process starting with the requirement specification is shown in figure 3:

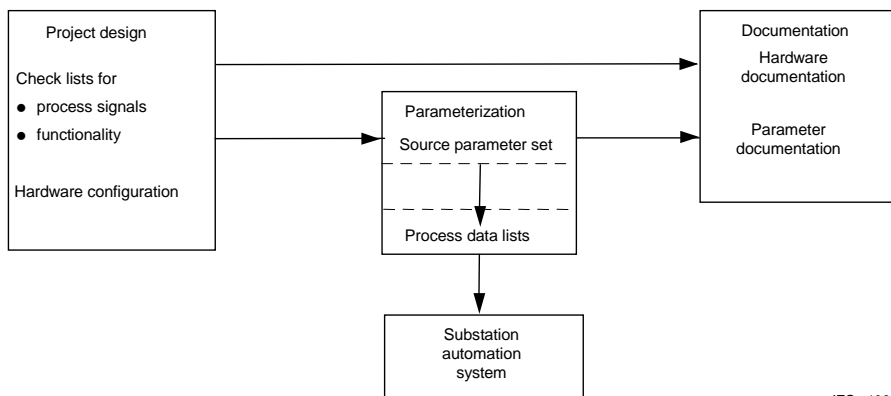


Figure 3 – Engineering tasks and their relationship

Project design is the definition of the technological concept to solve the required SAS tasks including the choice of structure, IED type selection and IED basic configuration as well as the determination of interfaces between the IEDs and the PE. The result is the system design specification.

Parameterization, often called Detail Engineering, is the generation of the parameter set for the SAS.

Documentation is the description of all project and parameterization agreements about the features of the SAS and its link to the PE according to the required standards.

In practice, engineering tools are useful for efficient handling of the engineering tasks. To better support interoperability between tools of different IEDs and different manufacturers, within this standard conceptually two kinds of tools are envisaged:

- System configuration (Project design) tool: allows selection of needed IEDs based on a system (requirements) specification, and defines the communication connections between the IEDs of the system and the logical relations between IED functionality and the primary equipment.

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- IED configuration (parametrization) tool: allows to make the detailed parametrization of an IED based on a system specification beforehand and a system description delivered by the system configuration tool after the system configuration process.

To enable interoperable exchange of engineering data between IED parametrization tools of different manufacturers and the system configuration tool, as well as between different system configuration tools handling different system parts as separate projects, appropriate configuration data exchange formats are defined in part 6 of this standard.

5.3.2 System Configuration tool

The system configuration tool offers the choice of components with functional assignments in the planning stage of an SAS project. Mostly, the tool is based on a database and requires as input as a minimum the required functions and process signals. It provides the first results using, for example, tables and check lists, which have to be agreed upon between system integrator and customer. As a result, the SAS structure and configuration, including the interfaces to the PE, will be defined. In a second step then the communication connections between the IEDs are configured so that the intended system functionality is performed.

The standard language defined in part 6 of this standard allows beneath configuration data exchange between system configuration tool and product parametrization tool as well as between two different system configuration tools / projects also a standardized description of a part of the system requirements specification, and of the functions and communication capabilities of IEDs, which might be used as external inputs to the system configuration tool.

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5.3.3 Parameterization tool

The IED parameterization tool supports the creation of the consistent source parameter set for an IED of a SAS. The parameterization tool can be divided into the general parameterization tool for the management of the system parameters at the SAS-level, handled by the system configuration tool, and IED-specific parameterization tools for the management of the autonomous IED-parameter sets. This second (set of) tool(s) is mostly manufacturer specific, or even IED type specific, while it is the intention of this standard to enable IED type and manufacturer independent implementations of the first type of tools in that sense, that system configuration tasks can be done independent from the used IEDs, and the engineering result transferred to the IED respective IED tool in a standardized form.

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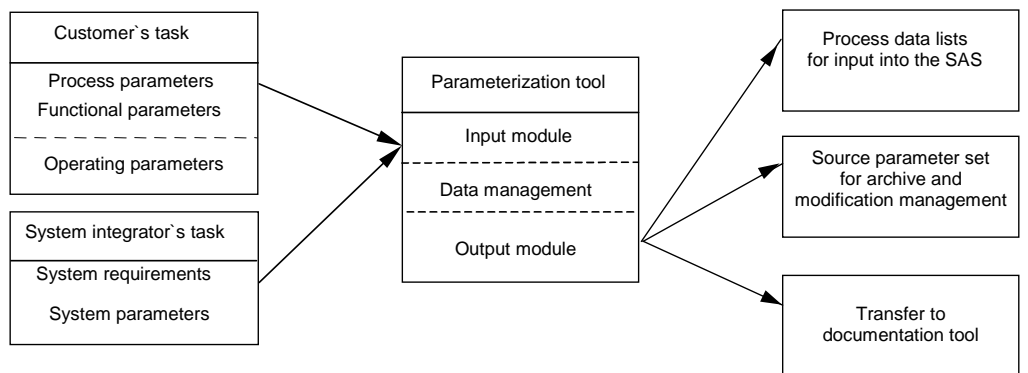
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The main tasks of the parameterization tool are the generation of process data lists based on the source parameter set and the secure management of the process data lists for the SAS and its IEDs. The tool must be capable of reading actual parameter values.

Additionally, the parameterization tool supports the management, archiving and documentation of the source parameter set.

Essential components of the parameterization tool are shown in figure 4.



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Figure 4 – Parameterization process

The input module supports the interactive input of parameters as well as the import of the system description as created by means of the system configuration tool. The structure of input data should be technically oriented towards the substation architecture, i.e. structured according to the hierarchical approach to substation, voltage level, bay, equipment and function.

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The repeated input of similar information should be avoided as much as possible by using for example templates of typical solutions or copy functions (for example, copy of switch, bay, busbar sections, etc.).

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The entry of a parameter should only be necessary once. The assignment of this parameter to other processes should be carried out automatically in order to guarantee parameter consistency at all times.

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The data management module checks the entered parameter values with respect to their consistency and plausibility. Parameters with multiple use will be assigned to the respective processes.

Furthermore, the data management module includes the system information management with respect to the source parameter set. The system information contains a unique identification of the parameter set, including

- substation identification;
- identifier for parameterization state (initialization or modification);
- parameter set version identification
- operator;
- access permission;
- date;
- software releases of the IEDs and the parameterization tool.
- IED instance name in the project

The data management module generates the process data lists, which are the base for the behaviour of the SAS in accordance with the substation and the customer requirements.

The output module is responsible for the transfer of process data lists to an archive (internal or external) or for the direct input into the SAS and its IEDs. Additionally, it provides the service to recall and view the source parameters stored in the archive. The output module must provide the source parameters for the documentation tool.

5.3.4 Documentation tool

The documentation tool generates uniform, project specific, documentation in accordance with the required standards (IEC 61175, IEC 60848, IEC 61346, IEC 61082). The documentation consists of:

- hardware documentation for the representation of all external connections between the SAS components and the PE which are defined in the project design process;
- parameter documentation for the representation of all internal qualitative and quantitative relations, which are agreed in the parameterization process.

The documentation tool should be capable of creating a "revision history", documenting all changes known to the tool itself.

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5.4 Flexibility and expandability

Flexibility and expandability of the SAS requires the expandability of the hardware and software configuration of the SAS. It also depends on the functional and physical architecture and the resulting dependency between functional parts.

The flexible extension of the hardware configuration with additional IEDs or with IEDs of different functionality is the first requirement in order to meet flexibility and expandability of the SAS.

The flexibility and the expandability also depend on the engineering tools. The most essential engineering tool with respect to the behaviour and maintenance of the SAS is the parameterization tool and its handling of different parameter sets in relation to the IED.

Therefore, functionality, compatibility and expandability of the parameterization tool are significant for further functional expansion of the SAS. As a minimum it shall support the compatibility features for different versions of this standard as defined in parts 6 and 7 of this standard.

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The parameterization tool shall be able to run on commercial hardware with a commercial operating system.

The parameterization tool shall be able to support flexible and consistent modification of existing parameter sets with version identification.

The parameterization tool shall provide open interfaces for data exchange with other parameterization tools, for example for dispatching centres and tools from other manufacturers.

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The parameterization tool of a manufacturer shall be backwards compatible, i.e. it shall be possible to parameterize all existing IEDs of the same family supplied by the manufacturer using the most recent parameterization tool.

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5.5 Scalability

The System configuration tool should be able to be used for all typical SAS applications. Generally, the SAS systems are designed in such a manner that they can cover the whole range of applications by using a modular device system with respect to

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- task (transmission or distribution network) and voltage range (medium, high or ultra high voltage) of the substation;
- completion level of the application (simple centralized telecontrol unit or integrated substation control, monitoring and protection with distributed artificial intelligence);
- complexity of the functionality (from simple SCADA up to sophisticated automation tasks);
- telecommunication functions (simple telecommunication to one dispatching centre, node functionality with different telecommunication protocols, master in the common mode with integration of other substations).

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The system configuration tool should permit scalability in such a way that the configuration task for different application levels can be carried out with a minimum of resources and costs. The lowest level, for example, requires only the input of parameters for a simple telecommunication unit, and on the highest level all available options of the SAS must be managed.

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Furthermore, the system configuration tool should support the engineering rationalization by using, for example, templates, macros and copy functions.

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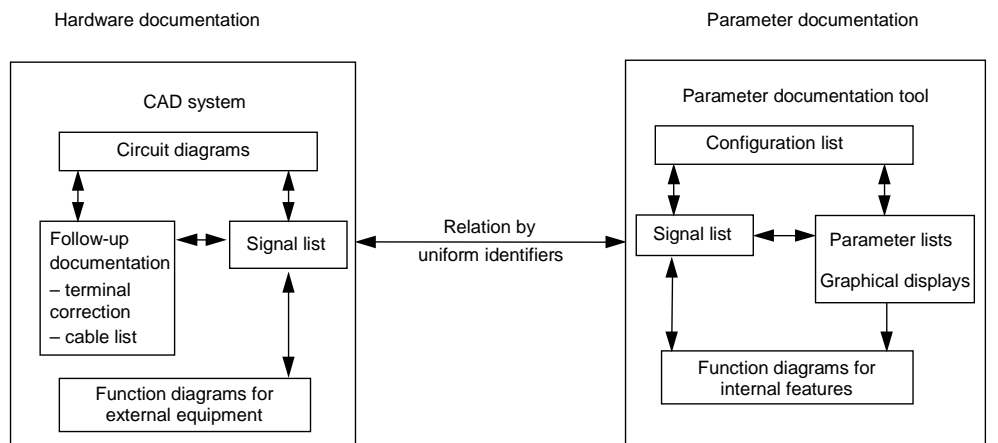
5.6 Automatic project documentation

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The documentation of an SAS consists of two project specific components (see figure 5).



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Figure 5 – Project related documentation of SAS

The hardware documentation consists of:

- circuit diagrams for the link between the SAS components and for their connection with the PE;
- signal connection lists;

- function diagrams for external schemes.
- cubicle layouts and wiring / cabling lists

The parameter documentation consists of:

- the configuration list;
- signal lists;
- parameter lists;
- graphical representation of all displays and operation menu sequences;
- function diagrams for internal features.

The requirement of the engineering tools is that the documentation should be generated as:

- a) hardware documentation with the help of the input values of the planning tool on a CAD (or similar) system;
- b) parameter documentation using the source parameter set from the parameterization tool.

The interfaces between hardware and parameter documentation are the signal lists, which should have uniform and unique signal identifiers in both documents, preferably based on the semantically standardized identifications defined in other parts of this standard.

The generation of documentation, based on the inputs of the planning and parameterization tool, should ensure the consistency between documentation on one hand and the project check lists, the source parameter set and process data lists on the other hand.

5.6.1 Hardware documentation

The hardware documentation of the SAS should be carried out according to the same structure as the documentation of the other substation equipment.

Concerning the identification and the structure of the hardware documentation the use of international standards (for example, IEC 61175, IEC 61346) is recommended.

5.6.2 Parameter documentation

Parameter documentation is typically done in lists and tables, supported by figures showing principle solutions. To get a better overview it is recommended to produce the documentation for typical objects and functions, and then have a higher level list about the object instances of each documented type.

5.6.2.1 Configuration list

The configuration list and the single line diagram of the substation are the starting point for the parameter documentation. The configuration list consists of:

- an overview of IEDs and components of the SAS with identification of the hardware and software releases;
- identification of the software release of the parameterization tool;
- identification of the parameter set according to the requirements in 5.3.3.

The parameter documentation is carried out in different ways for the different parameter types.

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5.6.2.2 System parameter documentation

The system parameters can be taken over as a chosen set from the manufacturer's standard documentation into the project specific documentation.

5.6.2.3 Process parameter documentation

The documentation of process parameters consists of the description of all signals at the system border of the SAS, and details their further management and marshalling inside the SAS. The following description documents are typically included in the process parameter documentation set:

- signal lists are the base for the further process parameter lists. The signal lists give the overview of all analogue and binary signals and their assignment to the inputs and outputs of the IEDs of the SAS and to the specific parts of the documentation;
- telecontrol mapping lists determine the assignment of individual signals to the ASDU addresses of the telecontrol protocol;
- message texts can be defined by the customer and assigned to the binary signals for representation in different reports;
- characteristic curves can be assigned to the analogue values;
- HMI lists describe the presentation features of signals on displays and printers;
- archiving lists cover all information about values of which signals have been archived under which conditions and with which attributes;
- acquisition lists include all information about qualitative attributes of signal acquisition such as filter times of binary inputs or command times.

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5.6.2.4 Functional parameter documentation

The functional parameters should be documented as parameter lists and graphically as function diagrams.

To provide greater clarity, and in accordance with the rules of circuit diagrams, the function diagrams should be structured as follows:

- control (automatic single and double commands, group commands, switching sequences);
- position indication (assignment to commands, parallel work of transformers, voltage definition for busbar section);
- event/alarm indication (group information, automatic operation);
- interlocking;
- measurement linking (overflow, bimetal);
- algorithms for closed loop control.

The operation sequences and the structure and symbols of the overview and detail displays should be documented graphically.

The number and type of report lists and protocols should be documented as a parameter list.

Requirements concerning the design and the structure of the function diagrams are defined in international and national standards (for example, IEC 61082).

5.6.2.5 Operating parameter documentation

The operating parameters should be documented as a parameter list with their ranges of values and basic settings. The values changed by the customer are documented in the operations report.

5.6.3 Requirements of the documentation tool

The input of the documentation tool is the source parameter set, which is created with the parameterization tool. The parameter documentation tool produces the complete parameter documentation as a book with automatic generation of a table of contents.

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The parameter documentation tool should be able to generate partial documentation according to different sorting criteria with practical benefit, for example:

- reference lists for telecontrol information;
- message lists, sorted by IED addresses;
- function diagrams for interlocking.

All changes of parameters must be flagged in the documentation. The parameter documentation tool should be able to support the requirements with respect to such modification services.

5.7 Standard documentation

The standard documentation is the description of the device and the functions of one IED or the SAS product family of a manufacturer which is universally valid and which is not changed for purposes of specific projects.

As a general rule, the standard documentation includes:

- equipment description;
- instruction and maintenance manual;
- system **concept** description;
- description of functions;
- operating instructions;
- instruction for service programs;
- fault detection and maintenance instruction;
- **user manual for the engineering tools.**

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The standard documentation should complete the project specific documentation for each installed SAS.

5.8 System integrator's support

In most cases, the engineering tasks are included in the system integrator's offer for the SAS project.

In all cases, however, the system integrator has to offer customer training for the use of the engineering tools so that the customer may maintain and expand the SAS installation.

The system integrator should support this process with consultative services, training and regular information regarding updates and extended functionality of the SAS installation and the engineering tools.

6 System life cycle

6.1 Requirements of product versions

The life cycles of an SAS and its IEDs are subject to differences of the manufacturer's and the customer's point of view, as shown in figure 6:

- the manufacturer's **product** life cycle contains the period between the start of production and the discontinuation of the SAS product family;
- the customer's **system** life cycle contains the period between the site commissioning of the first SAS installation, mainly based on an SAS product family, and the decommissioning of the latest SAS installation of the same family. The SAS installation may be carried out by a system integrator who is different from the **product** manufacturer.

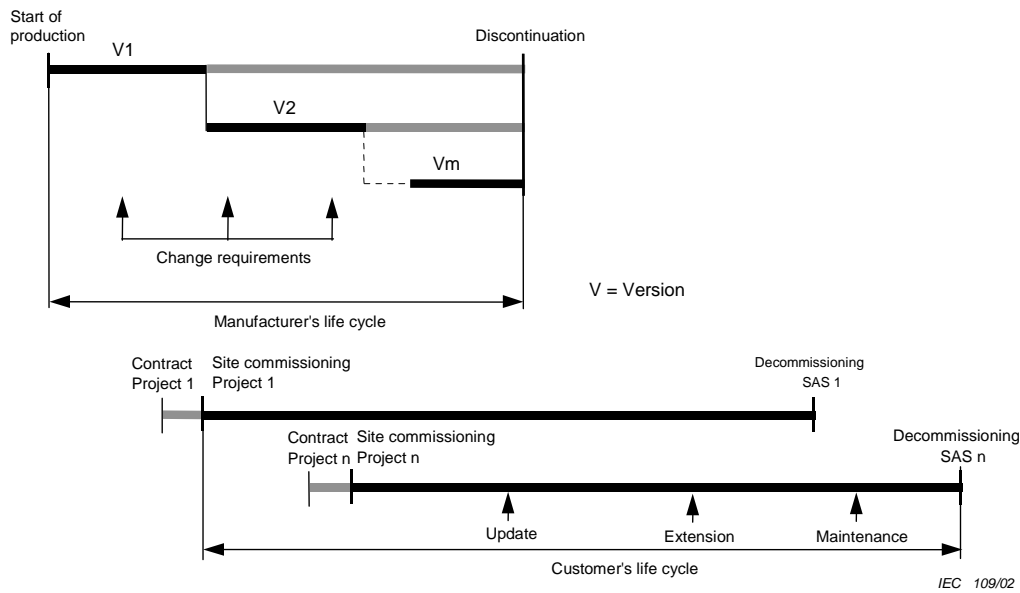


Figure 6 – Two meanings of the SAS life cycle

During the manufacturer's life cycle of the SAS and its IEDs, a number of changes and extensions are required for various reasons:

- functional improvements and extensions;
- technology changes in the hardware;
- correction of recognized problems.

These changes lead to updated IED versions of hardware, software and supporting tools.

A new version of an IED can produce different impacts:

- it influences changes needed to the configuration list of the SAS-product family, in that the new version of the IED requires version changes in other IEDs or in the engineering tool, for example to fulfil new overreaching functions. A system test together with relevant IEDs is necessary and leads to a new configuration list;
- it is independent of other IEDs and compatible with the current configuration list. The system test of the IED has to check the compatibility with the other IEDs in the system. Only the version of the IED will be changed. The configuration list of the SAS version has to be modified.

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The manufacturer is obliged to provide identification of the IED versions:

- in the case of IED software or the supporting tools software, the version information is available in a self identifying manner (for example, on display or PC);
- for the hardware, the version information is available at the board and at the device levels;
- if the functionality has changed or a function has been removed, a new configuration list shall be distributed.

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The co-ordination of the manufacturer's and the customer's life cycles requires that new versions of the IEDs with identical model numbers shall comply with the following rules:

- a) The hardware shall be compatible. All interfaces must perform the same function in the same places. The sizes of the boards and the devices must be identical.
- b) The functional changes from the previous version of the product software should be declared.
- c) The supporting tools shall be downward compatible, which means that the new version of the supporting tool shall serve all existing versions of the same product family.

The manufacturer has to inform the customer about all of the functional changes and extensions that are carried out between the last delivery and a new offer.

6.2 Announcement of product discontinuation

The manufacturer is to inform all customers of the product discontinuation in time to ensure that the customers have the option to order spare products or to prepare extensions.

In the case where the product discontinuation will be carried out without a subsequent functionally compatible product, the required notice shall be published in a defined period in advance.

In the case where a subsequent functionally compatible product will follow, the notice may be published in a shorter period in advance. An overlap for delivery of both products for a minimum period is required (an example is given in annex A).

6.3 Support after discontinuation

During the customer's life cycle of an SAS and its IEDs, a number of changes, extensions and maintenance issues will occur. The manufacturer is obliged to support this process after the discontinuation of the SAS product family and its compatible IEDs according to the agreement between system integrator respective customer and manufacturer. The following examples could be used for such agreements:

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- special customer agreement for further supply with a minimum annual order with special agreed prices and delivery conditions in an agreed time period;
- supply of the same or compatible IEDs (from the point of view of functionality, mounting and wiring) for extensions under specific delivery conditions for an agreed time period;
- supply of spare parts and repair service under specific delivery conditions for an extended time period;
- administration, maintenance and delivery of all supplied versions of the IED software and the service tool software in accordance with the agreed delivery conditions by the manufacturer. The maintenance of parameter sets is the responsibility of the customers;
- support in the integration of new products using adaptive interfaces.

An example for the corresponding time conditions is shown in annex B.

The above requirements concerning the "system life cycle" exclude the use of commercially available computing products (for example, PCs, CD ROMs).

In the case where the manufacturer and the system integrator are different, the support after discontinuation shall be agreed in relevant contracts.

7 Quality assurance

7.1 Division of responsibility

The quality assurance is a common task of the system integrator/manufacturer and of the customer of the SAS with different areas of responsibility. If two or more parties are involved, then the responsibilities of each party shall be defined at the time of procurement.

7.1.1 Responsibility of the manufacturer and system integrator

7.1.1.1 Quality system

The manufacturer and the system integrator should establish and maintain a quality system in accordance with ISO 9001.

The stages of quality assurance as a responsibility of the manufacturer and system integrator are shown in figure 7.

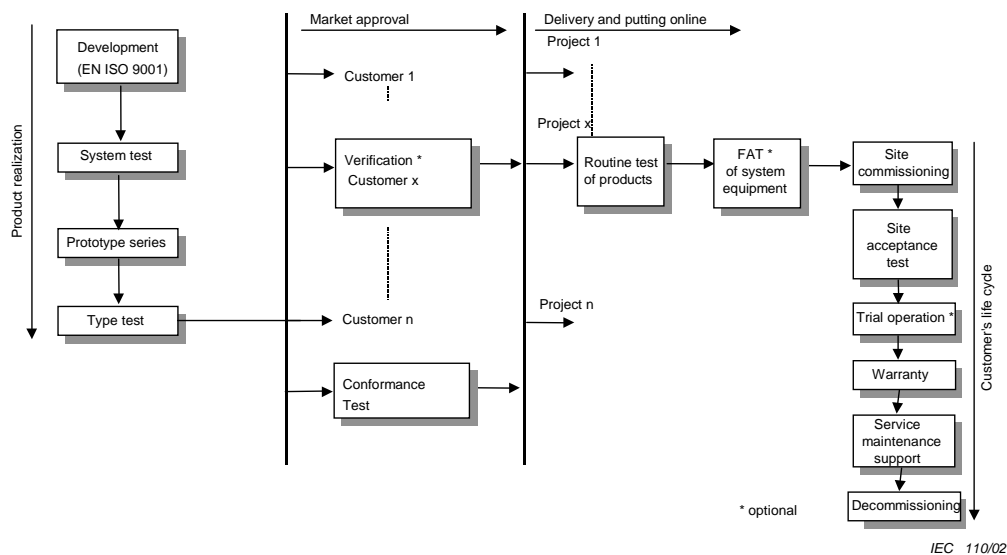


Figure 7 – Stages of quality assurance – Responsibility of manufacturer and system integrator

7.1.1.2 Test responsibilities

The manufacturer is responsible for the correct handling of type tests and system tests of his individual products. Type tests and system tests are preconditions for starting the regular delivery.

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All IEDs have to pass device specific routine tests defined by the manufacturer to ensure quality before the products are handed over for delivery.

Customer specific verifications and approvals may be required according to the customer's philosophy and shall be negotiated between the system integrator and the customer.

The system integrator is obliged to prepare and carry out these special investigations with individual products and the overall SAS. Furthermore, the system integrator is obliged to prove the fulfillment of the technical requirements, including performance criteria.

When introducing an SAS, the system integrator is responsible for ensuring that all functions are jointly tested by the representatives of the system integrator and the customer during the optional factory acceptance test (FAT) and the mandatory site acceptance test (SAT) with the specific configuration and parameter set of the customer. The successful finishing of the FAT (if required) is the precondition for the equipment delivery and the further site acceptance test at the customer's premises. FAT and SAT, as well as their contents, shall be negotiated between the customer and the system integrator.

The commissioning of the SAS on site is normally the responsibility of the system integrator. Commissioning is followed by a trial operation phase (for example, one month). The length of this phase and the conditions to be met should be negotiated between the customer and the system integrator.

7.1.1.3 Warranty and after sales service

After the site commissioning, the warranty begins in accordance with the agreed conditions for

- the hardware,
- the engineering,
- the software.

After the warranty, the system integrator or the manufacturer should provide after sales service:

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- the supply of spare parts for an agreed period;
- the support in diagnosing failures;
- the mandatory provision of urgent information to the customers about malfunctions;
- the correction of detected software errors and hardware defects;
- the offer and introduction of software updates.

7.1.1.4 Diagnostic

The manufacturer should develop and offer special diagnostic tools for

- failure definition inside or outside the SAS;
- failure localization inside the SAS and the individual IED's.

The diagnostic tools should be designed to be used remotely, if appropriate.

The technical documentation of the SAS and its individual products shall include the recommended preventive maintenance (for example, for batteries, capacitors).

7.1.2 Responsibility of the customer

The customer is responsible for ensuring that the relevant environmental and operating conditions of the SAS satisfy the conditions described in the technical documentation of the SAS and its individual products.

The customer has to carry out preventive maintenance for service or exchange of maintainable parts in accordance with the instructions of the manufacturer.

The inspection and regular check of individual products and their inter-related function (for example, protection – circuit breaker) will be necessary from time to time in accordance with the recommendations of the manufacturer or the customer's standards organization (IEE, VDEW, IEEE, etc.).

Corrective maintenance has to be carried out immediately after detection of defects.

7.2 Test equipment

The test equipment includes all equipment that is required for the acceptance test and commissioning. The test equipment is used to provide the verification of all inputs and outputs of the primary equipment, the communication with the network control centre and the functionality of the individual IEDs of the SAS (for example, protection).

Additionally, the test equipment is necessary to prove the behaviour and the performance characteristics of the SAS. With respect to the functionality and performance requirements, the test equipment is divided into three categories:

- normal process simulation;
- transient and fault process simulation;
- communication check and simulation.

7.2.1 Normal process test equipment

This test equipment, in its simplest form, must be able to provide all alarms and position indications for the substation control system, enable the simulation of measured values (including overrange) and be able to display all commands from the SAS.

More complex test equipment must be able to simulate reactions of the switchgear in real time. Such test equipment can be used to check dynamic processes such as switching sequences or synchronization. There is a need to be able to generate various conditions for the reactions, for example to produce intermediate positions of switchgear or to simulate an earth fault on one busbar section during a switching sequence.

Test equipment should also be capable of generating a large quantity of data traffic in a short time or intermittent data traffic on a regular basis.

7.2.2 Transient and fault test equipment

This test equipment should be capable of injecting programmable transients of voltages and currents in a three-phase power system, simulating many kinds of faults or other abnormal processes such as power swing, saturation of current transformers and others. The test equipment should be capable of producing simulated faults, thus producing disturbance records.

7.2.3 Communication test equipment

This test equipment is used for performing tests at all communication channels for:

- internal links of the SAS;
- telecommunication.

The communication test system should be a convenient and efficient tool which enables the performance of the following functions at all required levels (network control centre, substation, bay and process level):

- simulation of a server, simulation of a client, monitoring of the data traffic;
- quality analysis of the data traffic (for example, the quality of electrical signals, time breaks, etc.).

7.3 Classification of quality tests

7.3.1 Basic test requirements

The manufacturer should provide a test concept that covers all activities beginning with prototype functional tests in the development state to the final type and system tests. The scope and object of tests, the test procedures and the passing criteria must be specified.

All tests shall be documented in such a way that the results are reproducible, if required.

All tests should be performed by an internal part of the manufacturer's organization that is qualified for performing the tests and has the organizational independence to state whether a product has passed the tests or not.

7.3.2 System test

The system test is the proof of correct functionality and the performance of each IED under different application conditions (different configuration and parameters) and in co-operation with other IEDs of the overall SAS product family including all tools, for example for parameterization, diagnostic (figure 8).

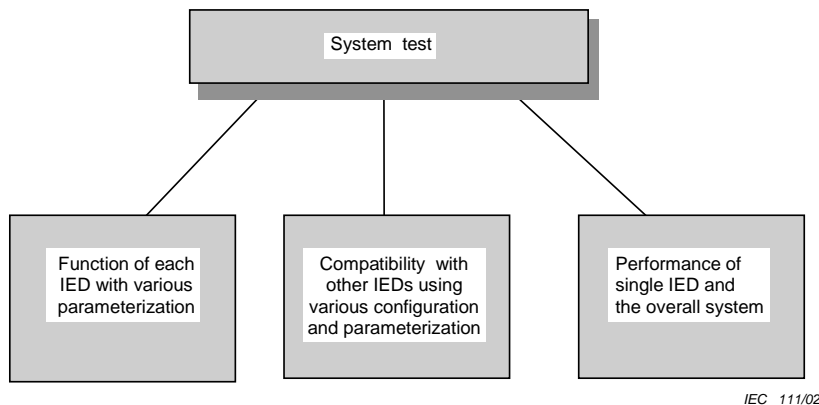


Figure 8 – Contents of system test

A successful finished system test is the precondition for starting the type test.

7.3.3 Type test

The “fitness for use” of a newly designed product shall be proven by a type test. The type test shall be performed using samples from the manufacturing process. The type test is the verification of the product against the technical data (figure 9) which are specified, such as:

- mechanical withstandability;
- electromagnetic compatibility;
- climatic influences;
- functional correctness and completeness.

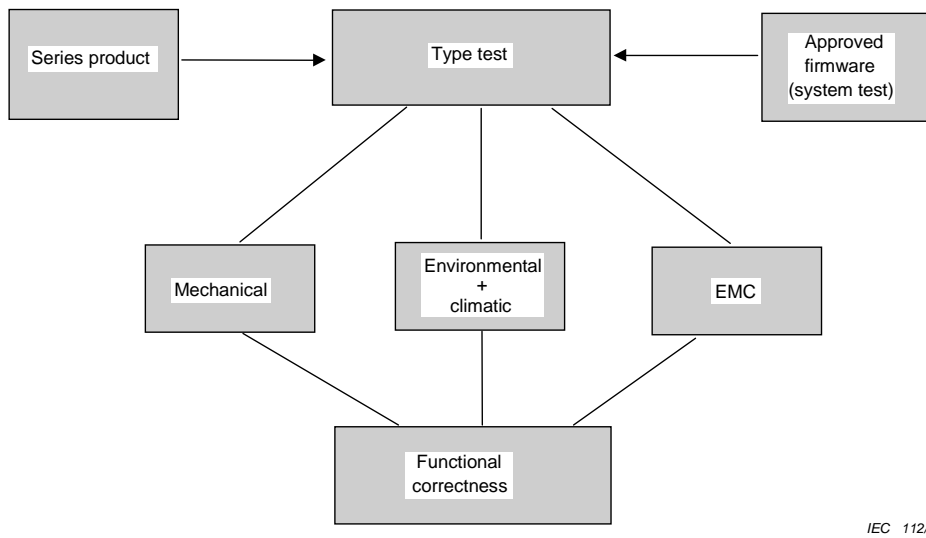


Figure 9 – Contents of type test

The type test shall be carried out by the use of system tested software.

The type test shall be passed before regular production delivery can be started.

7.3.4 Routine test

The routine test consists of special hardware and functionality tests as shown in figure 10.

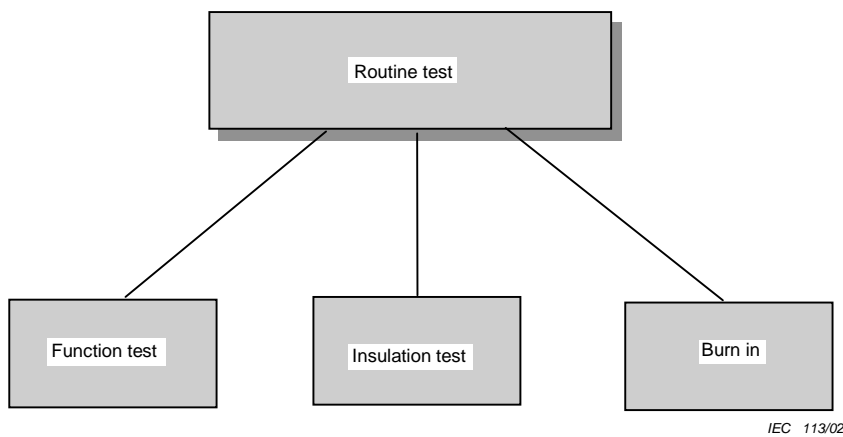


Figure 10 – Contents of routine test

The routine tests should be carried out for each product before leaving the manufacturer.

7.3.5 Conformance test

The conformance tests are performed on the communication channels of IEDs and include the verification of the communication procedure in accordance with the standard or its parts (see IEC 61850-10).

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7.3.6 FAT and SAT

The factory acceptance test (FAT) serves to validate and verify a system from the customer's point of view. The factory acceptance test is optional.

The scope and object of the FAT have to be discussed and agreed between system integrator and customer and should be documented in checklists.

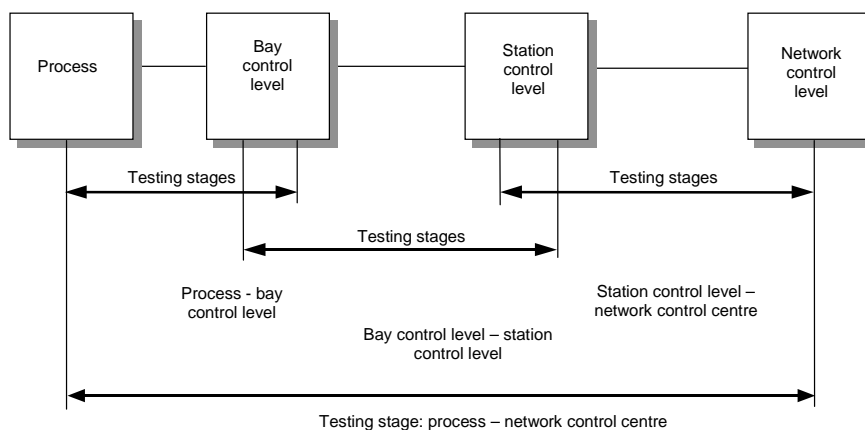
The checklists are part of the contract.

The result of the FAT should be documented and signed by both the manufacturer and the customer.

The focus of a FAT is to test typical solutions and their behaviour in normal and abnormal situations. A process simulation allows to make also tests for abnormal process conditions and process failure situations.

The main purpose of the acceptance test of the SAS on site (SAT) is to show the correct installation and connection of all system components. It shall be carried out on the completely installed equipment in individual steps (figure 11).

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NOTE This is not a communication structure.

Figure 11 – Testing stages for site acceptance test

Figure 11 shows four stages of SAT:

- process – bay control level;
- bay control level – station control level;
- station control level – network control centre(s);
- process – network control centre(s).

The stages are carried out according to a commissioning plan, which must cover the verification of all information exchanges and functions.

The SAT procedure has to document the results of each step and summarizes the customer's acceptance for putting the SAT into operation.

Annex A (informative)

Announcement of discontinuation (example)

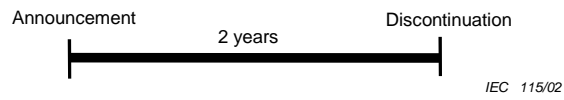


Figure A.1.a) – Without subsequent functionally compatible product

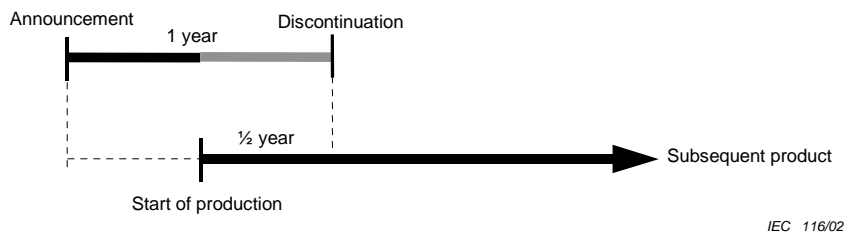


Figure A.1.b) – Functionally compatible product follows

Figure A.1 – Announcement conditions

Annex B (informative)

Delivery obligations after discontinuation (example)

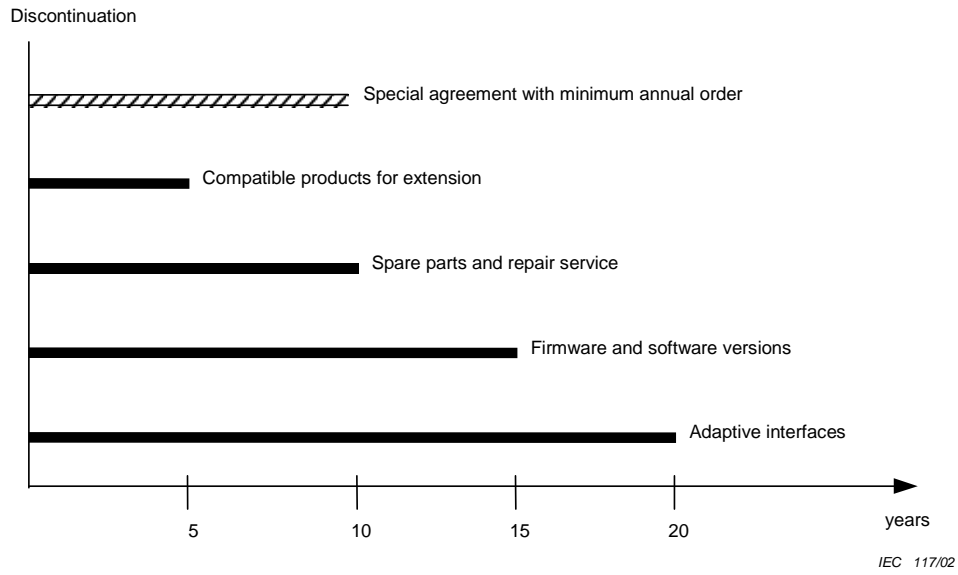


Figure B.1 – Periods for delivery obligations

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