

# TECHNICAL REPORT



---

## Power systems management and associated information exchange – Part 1: Reference architecture

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

---

ICS 33.200

ISBN 978-2-8322-3764-9

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

## CONTENTS

FOREWORD .....	7
1 Scope .....	9
2 Normative references .....	9
3 Terms, definitions and abbreviated terms .....	10
3.1 Terms .....	10
3.2 Abbreviated terms .....	12
4 Drivers and objectives for Reference Architecture .....	13
5 Overview .....	15
5.1 Standardisation context .....	15
5.2 Relevant business domains .....	16
5.3 Intended audience .....	19
5.3.1 General .....	19
5.3.2 Implementing actors .....	19
5.3.3 Standardization actors .....	20
5.4 Reference to relevant sources .....	20
6 Reference Architecture .....	21
6.1 Underlying methodology .....	21
6.1.1 General .....	21
6.1.2 The Smart Grids architectural methodology .....	22
6.1.3 SGAM levels of abstraction .....	24
6.1.4 The use case methodology .....	25
6.1.5 Data modelling .....	27
6.1.6 Profiling methodology .....	28
6.2 Reference Architecture overview .....	29
6.3 Elements of Reference Architecture .....	30
6.3.1 General .....	30
6.3.2 Elements as Interface Reference Model abstract components .....	31
6.3.3 Elements as some typical Smart Grids Systems .....	33
6.3.4 Elements as 61850 Intelligent Electronic Devices .....	34
6.4 Relationships of Reference Architecture .....	35
6.4.1 General .....	35
6.4.2 Communication inside substation .....	37
6.4.3 Communication between substations .....	38
6.4.4 Communication to support distributed automation along the feeder .....	39
6.4.5 Communication between substation and control centres and between control centres .....	39
6.4.6 Communication at the enterprise level .....	42
6.4.7 Communication to connect DERs (see Figure 26) .....	43
6.4.8 Communication to or within power plants (hydro, gas, thermal, wind) (see Figure 27) .....	44
6.5 Security standard landscape for Reference Architecture .....	45
6.5.1 General .....	45
6.5.2 Evolving security requirements for power system management .....	47
6.5.3 Resilience and security measures for power system operations .....	48
6.5.4 Overview and correlations of IEC 62351 security standards .....	50
6.6 Relationships applied to telecommunication .....	52

6.6.1	General .....	52
6.6.2	Applicability statement of communication technologies to the Smart Grids sub-networks .....	54
6.7	Interoperability .....	56
7	Use of Reference Architecture .....	56
7.1	General.....	56
7.2	Development of Enterprise Architecture .....	56
7.2.1	General .....	56
7.2.2	Model Driven Architecture.....	57
7.2.3	The Open Group Architecture Framework .....	57
7.3	How to evolve from a Present User Architecture to Reference Architecture .....	58
7.4	Example: how to map a use case using Reference Architecture .....	58
7.5	Development of information exchange specification .....	67
7.6	Integrating security in Reference Architecture .....	68
7.6.1	General .....	68
7.6.2	Identification of security requirements.....	69
7.6.3	Mapping of security to power system domains .....	70
7.6.4	Security controls.....	71
8	Main areas of future standardisation work.....	73
8.1	General.....	73
8.2	Increase standard usage efficiency through digitalisation .....	73
8.3	Harmonise data modelling.....	73
8.4	Other future topics .....	74
9	Conclusion .....	74
	Annex A (informative) SGAM Layer description.....	75
	Annex B (informative) Elements examples .....	76
B.1	Example of control centre distribution systems.....	76
B.2	Example of a system, the case of network model management system .....	76
B.3	Example of a power flow component .....	77
	Annex C (informative) Relationship examples .....	79
C.1	General.....	79
C.2	Data transformation via gateways and adapters .....	79
C.3	Example of a Message Exchange .....	80
	Annex D (informative) TC 57 standards descriptions and roadmaps.....	84
D.1	TC 57 Working Group 03 .....	84
D.2	TC 57 Working Group 10 .....	85
D.2.1	General .....	85
D.2.2	IEC 61850 standard overview .....	85
D.3	TC 57 Working Group 13 .....	87
D.3.1	General .....	87
D.3.2	IEC 61970 standard overview .....	87
D.4	TC 57 Working Group 14 .....	89
D.4.1	General .....	89
D.4.2	IEC 61968 standard overview .....	89
D.5	TC 57 Working Group 15 .....	91
D.5.1	General .....	91
D.5.2	IEC 62351 standard overview .....	91
D.6	TC 57 Working Group 16 .....	100

D.6.1	General .....	100
D.6.2	IEC 62325 standard overview .....	100
D.7	TC 57 Working Group 17 .....	105
D.8	TC 57 Working Group 18 .....	105
D.9	TC 57 Working Group 19 .....	106
D.9.1	General .....	106
D.9.2	IEC 62357 and IEC 62361 related standard overview .....	106
D.10	TC 57 Working Group 20 .....	107
D.11	TC 57 Working Group 21 .....	108
D.11.1	General .....	108
D.11.2	IEC 62746 related standard overview .....	108
D.12	Supplemental standards developed by the IEC and other bodies .....	109
Bibliography.....		110
Figure 1	– Core domain of Reference Architecture.....	16
Figure 2	– IEC TS 62913 conceptual model .....	17
Figure 3	– Two infrastructures (OT/IT) must be designed, operated, and secured .....	18
Figure 4	– Relevant sources for IEC TR 62357-1:2016 .....	21
Figure 5	– SGAM plane.....	22
Figure 6	– SGAM Model.....	23
Figure 7	– SGAM levels of abstraction .....	24
Figure 8	– Interactions between the Business and Function layers.....	27
Figure 9	– Data modelling and harmonization work mapping .....	28
Figure 10	– Information Models, Profiles and Messages .....	29
Figure 11	– Reference Architecture.....	30
Figure 12	– Power systems information related standards.....	31
Figure 13	– Distribution IRM Model .....	32
Figure 14	– Flexibility for assignment of element “Volt/Var Control” to SGAM segments (M490 C-Reference Architecture).....	33
Figure 15	– SGCG/M490 Smart Grids systems on SGAM Plane .....	34
Figure 16	– IEC 61850 Data Modelling.....	35
Figure 17	– Functions of a substation automation system allocated logically on three different levels (station, bay/unit, or process).....	36
Figure 18	– IEC 61850 related standards .....	37
Figure 19	– Communication inside substation .....	38
Figure 20	– Communication between substations.....	38
Figure 21	– IEC 61850 Telecontrol and control equipment and systems related standards.....	40
Figure 22	– Communication between substation and control centres.....	41
Figure 23	– Communication between control centre .....	41
Figure 24	– CIM Communication layer standards .....	42
Figure 25	– Communication from control centre / trading system to a market place.....	43
Figure 26	– Communication to connect DER .....	44
Figure 27	– Communication to/or within power plants .....	44
Figure 28	– Generic security architecture.....	45

Figure 29 – Architecture of key power system management security standards and guidelines .....	46
Figure 30 – Typical cyber security requirements, threats, and possible attack techniques .....	48
Figure 31 – Interrelationships between IEC communication standards and IEC 62351 security standards.....	51
Figure 32 – Mapping of communication networks on SGAM .....	54
Figure 33 – Use of Reference Architecture in TOGAF .....	58
Figure 34 – CIM circuit breaker application view .....	59
Figure 35 – Real world devices .....	61
Figure 36 – Operate a circuit breaker with IEC 61850 .....	62
Figure 37 – SCL for LNs .....	63
Figure 38 – SCL POS attribute.....	64
Figure 39 – ACSI service example .....	65
Figure 40 – Mapping of an ACSI service .....	66
Figure 41 – Hierarchical model for a circuit breaker .....	66
Figure 42 – SGAM analysis for the function “Monitoring inside the distribution grid”.....	67
Figure 43 – IEC mapping tool.....	68
Figure 44 – Security assessment types supporting Security Architecture design .....	69
Figure 45 – Security requirements and tasks per SGAM Layer depending on the abstraction layer .....	71
Figure 46 – Security Controls.....	72
Figure 47 – Addressing security requirements with security means of different strength.....	72
Figure 48 – RA through time .....	73
Figure A.1 – SGAM layer description .....	75
Figure B.1 – Example of control centre distribution system and relationships with other typical distribution systems .....	76
Figure B.2 – Network Model Management and other involved systems.....	77
Figure B.3 – Parts of a CIM network case .....	78
Figure C.1 – SCADA data interfaces .....	80
Figure C.2 – IEC 61968 associated communication technologies .....	81
Figure C.3 – XMPP architecture concept.....	82
Figure C.4 – Use of XMPP example .....	83
Figure D.1 – IEC 61850 standard series .....	85
Figure D.2 – IEC 61970 standard series .....	88
Figure D.3 – IEC 61968 standard series .....	90
Figure D.4 – NSM object models.....	94
Figure D.5 – RBAC concepts in IEC TS 62351-8.....	95
Figure D.6 – Architecture of IEC information exchange standards.....	96
Figure D.7 – Hierarchical architecture of DER system operations.....	98
Figure D.8 – IEC 62325 standard series .....	101
Figure D.9 – MADES overview .....	102
Figure D.10 – MADES scope .....	102
Figure D.11 – Interface Reference Model or the North American Style ISO/RTO market operations.....	104

Figure D.12 – IEC 62361, IEC 62357 standard series .....	107
Figure D.13 – IEC 62746 standard series.....	109
Table 1 – Business and System Use Case .....	26
Table 2 – Standards Guidelines .....	47
Table 3 – Overview of IEC 62351 standards .....	50
Table 4 – Technologies covered by SDOs in function of SGAM Communications Sub- Networks .....	55
Table 5 – Message types .....	60
Table 6 – Information assets and their relation to system security.....	70

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**POWER SYSTEMS MANAGEMENT AND  
ASSOCIATED INFORMATION EXCHANGE –****Part 1: Reference architecture**

## FOREWORD

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

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 62357-1, which is a technical report, has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

This new edition cancels and replaces the first edition published in 2012 and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) The new edition provides updates and defines layered Reference Architecture to help direct longer term goals and activities, specifically to ensure compatibility of all new

standards developed in the IEC by benefitting from lessons learned during development of the current standards and their application to actual utility projects as well as through application of other internationally recognized architecture standards.

- b) This edition reflects the progress recently achieved with the international Smart Grids (SG) initiatives and the CIGRE D2.24 large system architecture vision. It also leverages the work done by NIST-SGIP, CEN-CELELEC-ETSI SGCG M490, IEC SG3 Smart Grids Roadmap, and IEC SyC Smart Energy working groups.

The edition also reflects the most recent editions of the IEC standards relating to power systems management and associated information exchange, including the IEC 61850 series and the IEC 61968, IEC 61970 and IEC 62325 Common Information Model (CIM) standards.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
57/1688/DTR	57/1745/RVC

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

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

In this technical report, the following print types are used:

- *obligations: in italic underlined type.*

A list of all parts in the IEC 62357 series, published under the general title *Power systems management and associated information exchange*, can be found on the IEC website.

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

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

A bilingual version of this publication may be issued at a later date.

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



# POWER SYSTEMS MANAGEMENT AND ASSOCIATED INFORMATION EXCHANGE –

## Part 1: Reference architecture

### 1 Scope

Electricity grids from generation to consumers, including transmission and distribution, as well as energy markets are facing many new challenges while integrating an increasing variety of digital computing and communication technologies, electrical architectures, associated processes and services. The new challenges lead very often to support an increasing level of interaction between involved actors, components and systems.

Thus, it is key for the IEC to propose a clear and comprehensive map of all standards which are contributing to support these interactions, in an open and interoperable way.

The purpose of this document is to provide such a map (as available in 2016), but also to bring the vision of the path which will be followed by the concerned IEC technical committees and working groups in the coming years, to improve the global efficiency, market relevancy and coverage of this series of standards.

### 2 Normative references

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

IEC 60870-5 (all parts), *Telecontrol equipment and systems – Part 5: Transmission protocols*

IEC 60870-6 (all parts), *Telecontrol equipment and systems – Part 6: Telecontrol protocols compatible with ISO standards and ITU-T recommendations*

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

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

IEC 61970 (all parts), *Energy Management System Application Program Interface (EMS-API)*

IEC 62325 (all parts), *Framework for energy market communications*

IEC 62351 (all parts), *Power systems management and associated information exchange – Data and communications security*

IEC TR 62357-200, *Power systems management and associated information exchange – Part 200: Guidelines for migration from Internet Protocol version 4 (IPv4) to Internet Protocol version 6 (IPv6)*

IEC 62361 (all parts), *Power systems management and associated information exchange – Interoperability in the long term*

IEC 62746 (all parts), *Systems interface between customer energy management system and the power management system*