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CONSOLIDATED VERSION

INTERNATIONAL STANDARD

colour inside

Energy management system application program interface (EMS-API) – Part 456: Solved power system state profiles

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 456: Solved power system state profiles

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.
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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 61970-456 edition 1.1 contains the first edition (2013-05) [documents 57/1327/FDIS and 57/1342/RVD] and its amendment 1 (2015-09) [documents 57/1591/FDIS and 57/1620/RVD].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 61970-456 has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

IEC 61970-456:2013 is based on IEC 61970-301 Edition 4 (2013). Both are based on the 61970 UML version CIM14. The amendment is based on IEC 61970-301 Edition 5 (2013) and the 61970 UML version CIM15.

For the Topology profile Amendment 1 includes the following changes with respect to the previous edition:

a) The classes Name and NameType classes have been added.
b) The class TopologicalNode has been extended with the role ConnectivityNodeContainer.
c) The attribute IdentifiedObject.description has been removed.

For the StateVariables profile this edition includes the following changes with respect to the previous edition:

a) The role TopologicalIsland.ToplogicalNodes has been replaced by ToplogicalNode.TopologicalIsland.
b) The documentation of attributes SvPowerFlow.p and SvPowerFlow.q has been updated.
c) The attribute SvShuntCompensatorSections.sections has been changed from Integer to Float.
d) The attribute SvShuntCompensatorSections.continuousSections is removed.
e) The attribute SvTapStep.position is changed from Integer to Float.
f) The attribute SvTapStep.continuousPosition is removed.
g) The attribute SvVoltage.angle is changed from radians to degrees.
h) The data types have been elaborated.

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

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

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

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

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

INTRODUCTION

This standard is one of several parts of the IEC 61970 series that defines common information model (CIM) datasets exchanged between application programs in energy management systems (EMS).

The IEC 61970-3xx series of documents specify the common information model (CIM). The CIM is an abstract model that represents the objects in an electric utility enterprise typically needed to model the operational aspects of a utility.

This standard is one of the IEC 61970-4xx series of component interface standards that specify the semantic structure of data exchanged between components (or applications) and/or made publicly available data by a component. This standard describes the payload that would be carried if applications are communicating via a messaging system, but the standard does not include the method of exchange, and therefore is applicable to a variety of exchange implementations. This standard assumes and recommends that the exchanged data is formatted in XML based on the resource description framework (RDF) schema as specified in 61970-552 CIM XML model exchange standard.

IEC 61970-456 specifies the profiles (or subsets) of the CIM required to describe a steady-state solution of a power system case, such as is produced by power flow or state estimation applications. It describes the solution with reference to a power system model that conforms to IEC 61970-452 in this series of related standards. (Thus solution data does not repeat the power system model information.) IEC 61970-456 is made up of several component profiles that describe: topology derived from switch positions, measurement input (in the case of state estimation), and the solution itself.

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

Part 456: Solved power system state profiles

1 Scope

This part of IEC 61970 belongs to the IEC 61970-450 to IEC 61970-499 series that, taken as a whole, defines at an abstract level the content and exchange mechanisms used for data transmitted between control centers and/or control center components.

The purpose of this part of IEC 61970 is to rigorously define the subset of classes, class attributes, and roles from the CIM necessary to describe the result of state estimation, power flow and other similar applications that produce a steady-state solution of a power network, under a set of use cases which are included informatively in this standard.

This standard is intended for two distinct audiences, data producers and data recipients, and may be read from those two perspectives. From the standpoint of model export software used by a data producer, the standard describes how a producer may describe an instance of a network case in order to make it available to some other program. From the standpoint of a consumer, the standard describes what that importing software must be able to interpret in order to consume solution cases.

There are many different use cases for which use of this standard is expected and they differ in the way that the standard will be applied in each case. Implementers should consider what use cases they wish to cover in order to know the extent of different options they must cover. As an example, this standard will be used in some cases to exchange starting conditions rather than solved conditions, so if this is an important use case, it means that a consumer application needs to be able to handle an unsolved state as well as one which has met some solution criteria.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61970-452, *Energy Management System Application Program Interface (EMS-API) – Part 452: CIM Static Transmission Network Model Profiles*[1]

IEC 61970-453, *Energy Management System Application Program Interface (EMS-API) – Part 453: Diagram Layout Profile*

IEC 61970-552, *Energy Management System Application Program Interface (EMS-API) – Part 552: CIM XML Model Exchange Format*[2]

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1 To be published.

2 To be published.

3 Profile information

The profiles defined in this document are based on the UML version ~~CIM14v14~~ CIM15v33.

The profiles are listed in Table 1.

Table 1 – Profiles defined in this document

Name	Version	URI	Revision date
StateVariables	~~1~~ 2	~~http://iec.ch/TC57/61970-456/StateVariables/CIM14/1~~ http://iec.ch/TC57/2011/61970-456/StateVariables/CIM15/2	~~2010-03-24~~ 2011-09-09
Topology	~~1~~ 2	~~http://iec.ch/TC57/61970-456/Topology/CIM14/1~~ http://iec.ch/TC57/2011/61970-456/Topology/CIM15/2	~~2010-03-24~~ 2011-09-09

4 Overview

This document describes an interface standard in which CIM/XML payloads are used to transfer results created during typical steady-state network analysis processes (e.g. state estimation or power flow solutions). Major requirements/objectives driving the design of this standard include:

- Power flow solution algorithms and output are virtually the same whether run in operations or planning contexts. State estimator output shares a common core with power flow. A single standard is desired so as to minimize software development and enable use cases that cross between environments.
- While some users of this standard might only be interested in the output state, the more general situation is that users continue to perform follow-on analyses (e.g. voltage stability) and require both the input on which the solution was based and the output result.
- Real life analytical processes often involve a series of solutions in which most of the input data remains the same from one solution to the next, and the standard must support these processes in a way that does not repeat data unnecessarily.

In order to meet these requirements, this standard depends on modularizing the potentially voluminous overall input and output data into subsets that would each be realized as smaller, separate CIM/XML payloads. An instance of one of these subsets is referred to herein as a 'dataset'.

Two types of partitioning into datasets are utilized. In the first, the data is modularized according to what kind of data is produced (which generally corresponds with what kind of application produces the data). CIM 'profiles' (subsets of the complete CIM) define the classes and attributes that make up of each kind of modularization. The second type of partitioning is by 'model authority set' (MAS), which divides data into sets of object instances according to which utility or entity in an interconnection is responsible for the data. This partitioning occurs at the instance level and produces multiple datasets governed by the same profile that combine to form the complete set of data for that profile. Understanding the partitioning approach is critical to understanding how to use this standard to implement a particular business scenario.

This standard is flexible and designed to satisfy a wide range of analytical scenarios in the planning and operating business environments. We expect that where parties are using it to collaborate in some business process, those parties will often want to create additional business agreements that describe any restrictions and customizations of the standard that are deemed necessary for their process. In most cases, these additional agreements will be local agreements and will not be IEC industry standards.

The CIM/XML formatting of partitioned payloads is defined in IEC 61970-552. This method of formatting has the useful characteristic that valid XML describing a complete model could be achieved simply by concatenating the XML for each partition. Thus ‘merge’ and ‘extract’ of pieces of the modeling require no separate ‘stitching’ instructions and is conceptually a very simple process. IEC 61970-552 also describes how payload headers provide information as to how payloads fit together.

How to read this document:

- Clause 5, "Use cases", gives examples of business problems that this standard is intended to address.
- Clause 6, "Architecture", summarizes how the model partitioning works and describes how the parts described in this document work with parts described in other IEC 61970 series standards.
- Clause 7, "Applying the standard to business problems", describes how to go about applying the standard to your particular business problem.
- Clause 9, "Topology profile" defines the kinds of datasets controlled by this standard. (This section is auto-generated from CIMTool and is where you see the CIM modeling detail.)

5 Use cases

5.1 General

Clause 5 presents some of the business problems that were considered in the design of this standard and discusses how the standard is expected to provide value to the industry.

5.2 EMS state estimation

EMS operations typically run state estimator automatically, usually triggered either by occurrence of certain events or by a time period. Periods of 10 min or more used to be the norm, but currently many state estimator installations are running with much shorter periods approaching 5 s and nearly the same periodicity as SCADA (supervisory control and data acquisition) and consequently rendering event based triggering of state estimator important.

The state estimator’s job is to create the best view of the state of the system, based on the latest available snapshot of the SCADA measurements. The resulting steady state solution of the power system is used as input data for a number of important functions:

- A traditional EMS is usually configured by the EMS vendor with contingency analysis running on the result of the state estimator. While a standard is usually not necessary for applications from the same vendor, there is industry interest in being able to run alternate algorithms for either state estimation or contingency analysis.
- A growing number of other analytical functions that were not originally part of the EMS are also using the state estimator result as the starting point for real-time analysis (e.g. voltage stability).
- Where market systems exist, they normally require real-time exchange of state estimation result from the EMS to the market system, and these systems often are supplied by different vendors.
- Users are interested in being able to connect advanced user interface and situation awareness modules from different vendors into an EMS, and these modules need to acquire state estimator data.
- It is desirable to be able to run historical analysis as well as real-time analysis from state estimator results. This requires estimator results can be archived efficiently, and users shall be able to import results into network planning tool environments that are normally not supplied by the EMS vendor.

All of these situations require an efficient standard method of producing state estimator results and making them available to other applications.

If the complete set of input data and output data were stored for a large interconnection model running on, say, a 10 s period, it would produce a great deal of data and pose a considerable challenge to any real-time exchange. However, there are some obvious characteristics of this problem that may be exploited to reduce the data burden.

- The network model is by far the largest part of the data. It changes infrequently and when it does change, the changes are a small set of data. Only the initialization of the system actually requires a complete large model.
- The topology of the system changes more frequently (when switching devices change position), but still is relatively infrequent and again the changes are small compared to the complete topology.
- Analog measurement input changes completely each run, but in many of the use cases, this data is not required by the consumer. Analog data may also usually be approximated from an analog history if it is not stored.
- Solution state variables change at each run.

What is required of the standard in order for each kind of business exchange to take advantage of these characteristics is that the network model and the topology may be updated only when they change. It is also valuable if updates can be represented in incremental form, rather than by re-transmission of a full model. Consumers of the data then are able to initialize themselves with a full network model and topology when they start, but only receive updates if there were changes. This reduces the data volume problem from Gbytes/solution and Tbytes/day to a more manageable Mbytes/solution and Gbytes/day.

5.3 ENTSO-E[3] Process: Day-ahead congestion forecast

A daily analytical operational process called day ahead congestion forecast (DACF) is currently applied in the ENTSO-E regional group continental Europe. In this process,

- each TSO prepares a power flow case covering exactly its own territory representing each hour of the following day (based on day-ahead market outcomes). These cases are transferred to a central server;
- the full set of submitted cases may be checked for mutual compatibility. (i.e. do the boundary exchange conditions match);
- once all cases are submitted, each TSO downloads from the central server the cases posted by their neighboring TSOs. These are combined with their own models to form a set of study models on which they can analyze the congestion in their region for the next day;
- congestion result cases may be exchanged among TSOs, as the situation warrants.

This work is carried out primarily with planning tools running bus-branch models (although an obvious possible variation on the process would be to generate cases with EMS tools).

Even though the DACF process is not a real-time process like state estimation, it is quite similar in that a sequence of cases is produced representing periodic intervals. The solution values will change at each case, but the network model will change rarely and the topology will change occasionally. Conserving file size is a concern, and that concern is addressed if the standard allows the network model and topology to be exchanged incrementally.

DACF raises another set of requirements, however. Unlike the state estimator scenarios, which feature complete transfer of a solution, the DACF involves a lot of merging and extracting of pieces of solutions. In Figure 1, TSO A runs power flows to develop a picture of

[3] European network of transmission system operator-electricity.

its territory for the following day. This would be done with models that include representations of neighboring TSOs. They shall post, however, only the part of the model representing their own territory, and this shall be a stand-alone solved power flow. (In ENTSO-E, boundaries between TSOs are, by agreement, always at the mid-point of tie-lines, and single TSO cases are formed with equivalent injections at each tie-line mid-point.) At the central site, or at any TSO, submitted internal cases shall be able to be reliably and automatically re-combined to form models with coverage appropriate to whatever task is at hand.

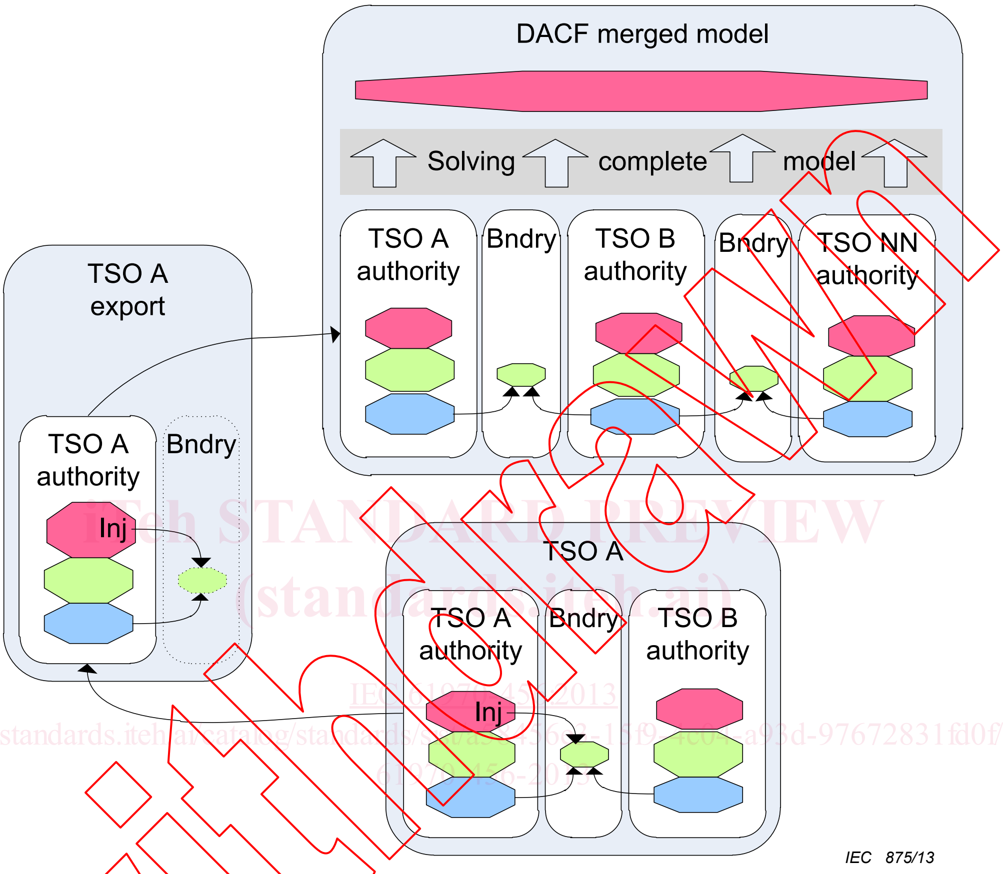

Figure 1 – TSO sends a case to be merged with the overall model

The octagons in Figure 1 represent datasets. The colors of the sets have the following meanings:

- magenta - data described by state variables profile;
- green - data described by the topology profile;
- blue - data described by the equipment profile.

Refer also to Figure 2.

5.4 System planning studies process

There are many synchronous interconnections worldwide (such as ENTSO-E discussed above) that require cooperative construction of future models by its members in order to support planning of the interconnection. Typically, “base cases” are constructed representing future time frames by combining submittals from each interconnection member, a process that closely resembles that depicted in Figure 1 for operational analysis. Instead of day-ahead, a planning case may represent years ahead; instead of daily update, a planning case must be reconstructed as plans change; instead of a known functioning power system, a planning case is not real yet. But in terms of process and in terms of data requirements, the assembly of base cases for planning is the same as in Figure 1, and it is the objective of this standard to