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Edition 2.0 2018-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

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

Interface de programmation d'application pour système de gestion d'énergie (EMS-API) – Partie 456: Profils d'état de réseaux électriques résolus

IEC 61970-456:2018-03(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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

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

This second edition cancels and replaces the first edition published in 2013 and Amendment 1:2015. This edition constitutes a technical revision. It is based on the IEC 61970 UML CIM16 version 33.

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

a) The Steady State Hypothesis (SSH) profile has been added in new Subclause 8.2.
b) Clause 5 "Overview" has been extended to better describe the relation between different profiles and aligned with the current nomenclature used with profiles, e.g. "data set" and "network part".

c) The former Clause 6 "Architecture" has been shrunk and merged with Clause 6 "Use cases".

d) The former Clause 7 "Applying the standard to business problems" has been split and merged with Clause 6 "Use cases" and Clause 7 "Data model with CIMXML examples".

e) Clause 6 "Use cases" description of the use cases has been extended.

f) The former Clause 8 "Data model with CIMXML examples" has become section 7 "Data model with CIMXML examples".

g) The CIMXML document examples in Clause 7 "Data model with CIMXML examples" has been updated to match with IEC 61970-552:2016.

h) Clause 8 "Profiles" describe the actual profile data.

i) Subclause 8.1 "Comments and notes" gives additional information on the use some profile data.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
57/1951/FDIS	57/1963/RVD

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

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

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

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

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

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INTRODUCTION

This document 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 61970-300 series specifies 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 document is one of the IEC 61970-400 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 document 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 document assumes and recommends that the exchanged data is formatted in XML based on the resource description framework (RDF) schema as specified in IEC 61970-552 CIM XML model exchange standard.

IEC 61970-456 specifies three profiles:

- The Steady State Hypothesis (SSH) profile that describe power flow application input variables such as voltage set points, switch statuses etc..
- The topology profile that describe a bus-branch model. A topology model may be created by a network model builder from a node-breaker model and SSH inputs or by a tool where a user interactively builds a topology model. A topology model is input to power flow applications.
- State variables solution from a power system case such as is produced by power flow or state estimation applications.

IEC 61970-456 describes the dynamic value inputs and solutions with reference to a power system model that conforms to IEC 61970-452 in this series of related standards. The separation of information into profiles also enables separation of data into documents corresponding to the profiles. In this way the profiles defined in this document generate small data documents compared with traditional bus-branch or node-breaker formats that include the network, the initial conditions and the result.

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, define at an abstract level the content and exchange mechanisms used for data transmitted between power system analyses applications, control centers and/or control center components.

The purpose of this document 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 document 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 document 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 document describes what that importing software must be able to interpret in order to consume power flow cases.

There are many different use cases for which use of this document is expected and they differ in the way that the document will be applied in each case. Implementers are expected to consider what use cases they wish to cover in order to know the extent of different options they must cover. As an example, this document 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 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 61970-452:2017, *Energy management system application program interface (EMS-API) – Part 452: CIM static transmission network model profiles*

IEC 61970-453:2014, *Energy management system application program interface (EMS-API) – Part 453: Diagram layout profile*

IEC 61970-552:2016, *Energy management system application program interface (EMS-API) – Part 552: CIMXML Model exchange format*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Profile information

The profiles defined in this document are based on the UML version CIM16v33.

The profiles are listed in Table 1.

Table 1 – Profiles defined in this document

Name	Version	URI
SteadyStateHypothesis (SSH)	1	http://iec.ch/TC57/2013/61970-456/SteadyStateHypothesis/1
Topology (TP)	4	http://iec.ch/TC57/2013/61970-456/Topology/4
StateVariables (SV)	4	http://iec.ch/TC57/2013/61970-456/StateVariables/4

5 Overview

This document describes an interface standard in which XML payloads are used to transfer initial conditions and 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 document include:

- Power flow solution algorithms and outputs 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. security analysis, 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.
- Power flow solutions tend to drift if the result from a power flow run is used as input to a subsequent power flow run. By preserving the initial conditions between power flow runs the solutions do not drift.

In order to meet these requirements, this document depends on modularizing the potentially voluminous overall input and output data into subsets that would each be realized as smaller, XML payloads. An instance of one of these subsets is referred to herein as a ‘dataset’. Data set payloads are typically compressed to a zip archive.

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 network parts, which divides data into sets of instances according to which utility or entity in an interconnection is responsible for the data. The party responsible for data is called the Model Authority of the data and the network parts are defined by Model Authority Sets (MAS). This partitioning occurs at the instance level and produces multiple datasets governed by a profile and network part. Datasets from different MAS combine to form the complete set of data for that profile, Figure 1 illustrates this.

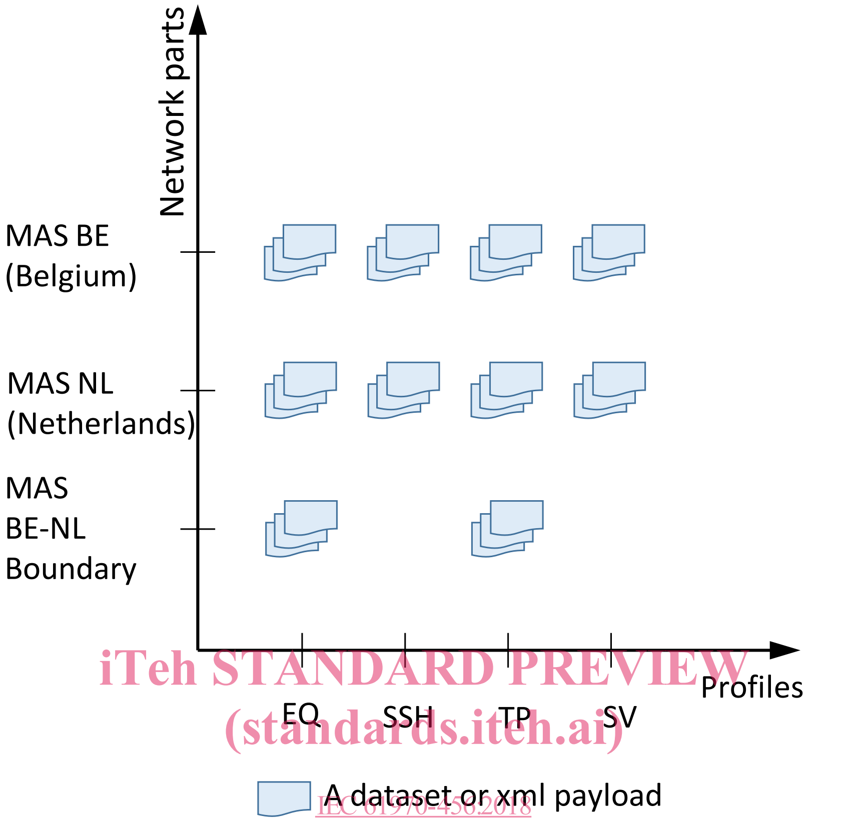

Figure 1 – Relations between MAS, profile and dataset

Different IEC 61970 profiles are listed along the horizontal axis:

- EQ for equipment as described in IEC 61970-452.
- SSH for power flow initial data as described in this document.
- TP for topology data as described in this document.
- SV for state variables data as described in this document.

A few example Model Authority Sets are listed along the vertical axis:

- MAS BE represent a regional Model Authority Set for Belgium that is a network part defined by a Model Authority BE, e.g. the Belgian TSO.
- MAS NL represent a regional Model Authority Set for Netherlands that is a network part defined by another Model Authority NL, e.g. the Netherlands TSO.
- MAS BE-NL Boundary represent a Model Authority Set that is a network part for the boundary between MAS BE and MAS NL. The boundary network part is typically agreed mutually between Model Authority BE and NL.

The document symbol in Figure 1 describe a dataset packaged as a payload, e.g. a CIMXML document as described in IEC 61970-552.

The Model Authority Sets along the vertical axis in Figure 1 define parts of a network. Datasets belong to a Model Authority Set and this is indicated in Figure 1 by the horizontally aligned datasets at each MAS.

The profiles along the horizontal axis in Figure 1 describe a subset of the CIM canonical data used for a particular purpose. A dataset Figure 1 contain data for a specific profile and this is indicated in Figure 1 by the vertically aligned datasets at each profile.

At each crossing point between a Model Authority Set and profile there is a stack of datasets meaning that for this particular Model Authority Set and profile there may be many datasets e.g. representing different points in time or different study cases. The ways datasets can be created and combined is dependent on the use case. Specifications that better support use cases on how to combine datasets an explicit CIM model for Model Authority Sets is being developed and will be released in the future..

This document 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 document that are deemed necessary for their process. In most cases, these additional agreements will be local agreements and will not be IEC industry standards.

This document does not specify a serialization format on its own but does so in companion with specification for CIMXML payloads is defined in IEC 61970-552. This method of serialization has the several useful characteristic

- The serialization format for a profile is defined by rules in IEC 61970-552 that describe the format based on the semantic model from the profile.
- Valid XML describing a complete model could be achieved simply by concatenating the CIMXML documents for each partial or profile document. 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.

Figure 2 shows some of the profiles that are covered by the IEC 61970-450 to IEC 61970-499 series and depicts the relationships between them. The profiles are defined in different IEC 61970-450 specifications where each specification defines a group of profiles:

- Static network model profiles defined in IEC 61970-452
  - Equipment profile. The static modelling information describing power system physical elements and their electrical connections;
  - Measurement profile that defines the existence of measurements and their relations to power system equipment.
- Schematic display layout exchange profiles defined in IEC 61970-453
  - Schematic layout exchange profile. Describe the elements of schematic or geographic displays that typically shall be amended when new elements are added to a network model.
- Initial and solved power system state profiles defined in IEC 61970-456 (this document)
  - Steady State Hypothesis profile that provide the initial conditions to power flow. This profile have numerous sources, e.g. State Estimator or cases set up in a study;
  - Topology profile. The topology result as is produced by a network model builder;
  - State Variables profile. The result of a power flow calculation.

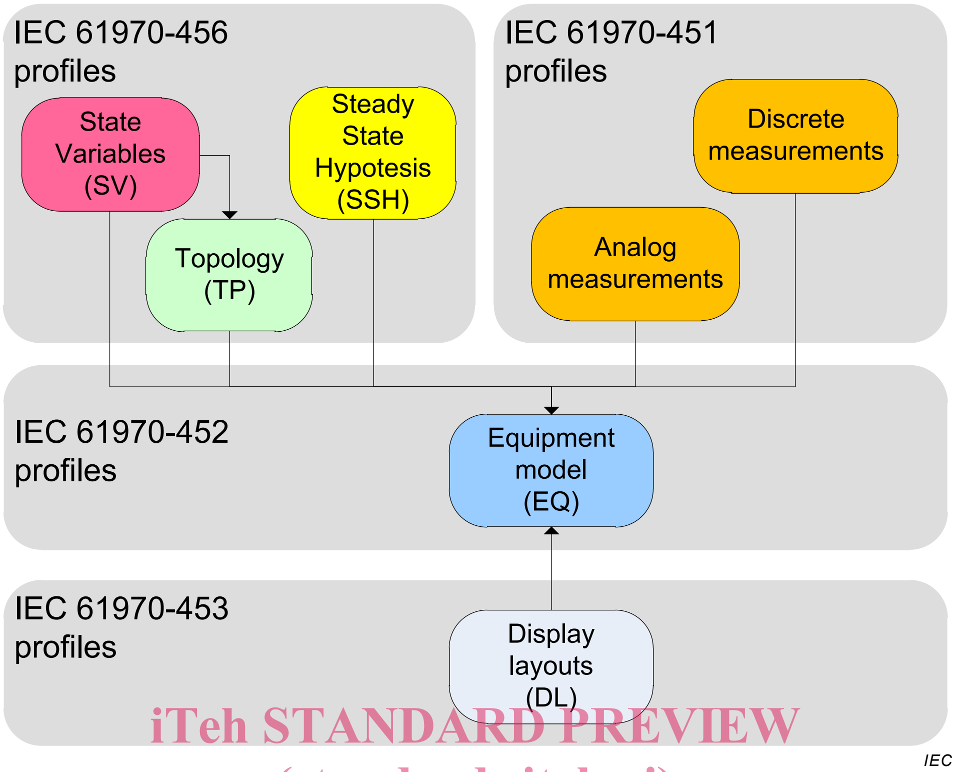

Figure 2 – Profile relationships

These modules satisfy the needs of network analysis business processes used in operations, in planning studies, as well as for transfers between operations and planning. The IEC 61970-451 profiles that support transfer of SCADA measurements to EMS applications do not yet exist and is planned work.

Network models used in operations include detailed descriptions of measurements and their location in the network and switching devices, such models are called node-breaker models. Network models used in planning may not have this level of detail and typically exclude measurements and switching devices. Instead of computing the power flow buses (TopologicalNodes) from switching device statuses the power flow buses are maintained manually.

It assumed that node-breaker and bus-branch models will be combined in the future to enable sharing of the same models between operations and planning.

In Figure 2, an arrow between profiles indicates that there are relationships defined between classes in the two profiles. The directionality indicates that classes in the “from” profile depend on classes in the “to” profile. For data this means that “from” class data refers to or depends on “to” class data. Example: a dataset of an equipment model may have many Topology, State Variable and Steady State Hypothesis datasets that refer to it.

In IT-systems, datasets corresponding to the profiles in Figure 2, are exchanged between functions and/or applications. Some examples of applications and their dataset exchange are described in Clauses 6 and 7.

The equipment model has equipment connectivity described by the ConnectivityNode and Terminal classes, refer to Figure 3. The Terminal class is central in that it support Equipment, Topology, State Variables, Steady State Hypothesis and Diagram Layout profiles. Within the Equipment profile the Terminal associate ConnectivityNodes with ConductingEquipment and provide multi Terminal equipment (e.g. Switches, ACLinesegments etc.) with well-defined equipment “sides”.

The Equipment and Steady State Hypothesis profiles are the basis for network model building and power flow calculation. The Topology profile describe power flow busses, TopologicalNodes that are used as input by a power flow calculation. TopologicalNodes are created in a step preceding the actual power flow solution and can be the result of a network model builder using ConnectivityNodes as input or by manual editing in a bus-branch model editor. The state variables profile describes the result of a power flow application, refer to Figure 3.

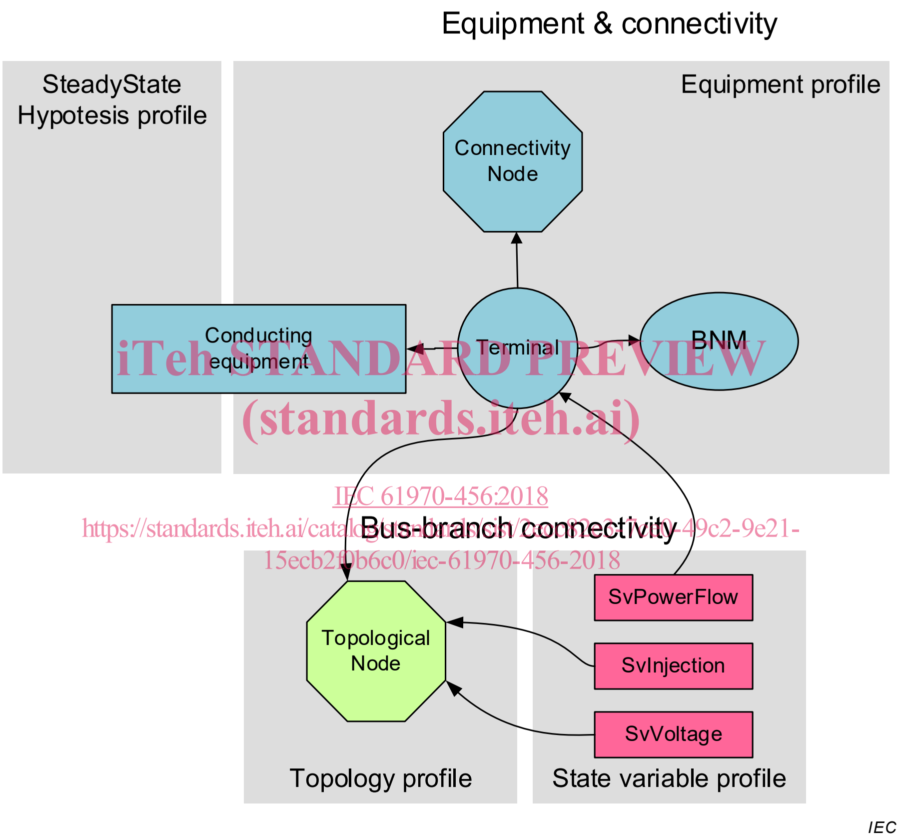

Figure 3 – Connectivity model example

The arrows in Figure 3 describe references between the CIM objects. For a node-breaker model the TopologicalNodes are computed from switching devices connecting ConnectivityNodes and for a bus-branch model the TopologicalNodes are manually maintained.

A node-breaker model use ConnectivityNodes to describe how conducting equipment are connected. In topology processing all conducting equipment connected with each other through closed Switches are identified and conducting equipment Terminals are assigned to a TopologicalNode.

A bus-branch model use TopologicalNodes to describe how conducting equipment are connected. In this case the TopologicalNodes are manually maintained and the assignment of conducting equipment Terminals to TopologicalNodes is also manually maintained. The manually maintained TopologicalNodes have well known identifiers or “Bus numbers” that enables comparison of different studies on the same network.

In the case of a node-breaker models the TopologicalNodes are created by topology processing. BusNameMarkers (BNM) are used to avoid an arbitrary naming of TopologicalNodes resulting from topology processing, as described in 7.1.1. The TopologicalNodes in a bus-branch model imply that the Switches in a corresponding node-breaker model have specified Switch statuses (Switch.open). By creating BusNameMarkers for one or more such sets of Switch statuses and use the BusNameMarker names to name the TopologicalNodes generated by topology processing it is possible to preserve the TopologicalNode names. Variations in Switch statuses is managed by adding as many BusNameMarkers as needed to support the wanted variations.

This use of BusNameMarkers preserve TopologicalNode names but not the mRID (the rdf:ID/rdf:about in IEC 61970-552). Hence TopologicalNode mRIDs will vary between different topology processing runs. In version 17 of the canonical UML the information model has been modified to support preserving the TopologicalNode mRIDs (this version of the profile is based on version 16 of the canonical UML).

An equipment model using ConnectivityNodes may not necessarily have any switches. A simplified equipment model can initially be created without switches similar to a bus-branch model. This enables mixing detailed node-breaker models having switches with simplified bus-branch style models without switches as both describe connectivity using ConnectivityNodes. This is useful when operational models are to be combined with planning models to verify that the planned extensions work with existing operational models.

6 Use cases

6.1 Overview

This clause describes how the standard should be applied in business problems and gives examples of some scenarios.

Network applications use a bus-branch model in the basic power flow calculation where the branches are non-zero impedance elements. Real power systems have measurements and switching devices that are not described in bus-branch models but in node-breaker-models. So, to run network calculations on a node-breaker model a bus-branch model where all zero impedance elements have been removed is created. In many study situations, it is impractical to deal with all the details in a node-breaker model, hence studies often use a bus-branch model for building study cases. The Steady State Hypothesis profile describes the data, e.g. switch statuses, needed to transform a node-barker model into a bus-branch model.

A large interconnected power network is typically divided into regions with a system operator that is responsible for operating the power network within a region. With increased and stronger interconnections between the regions the mutual dependency between the regions increases. A consequence is that a power flow set up for a particular region must also include a substantial part of the neighboring regions including both EQ and SSH data. Figure 4 shows an example from Europe.