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Key Technologies of Information Exchange in Electric Utility Based on IEC 61968

***Abstract**. The research on interoperability testing and implementation methodology of IEC 61968 has been carried out for many years. But there are still many problems to be solved. This paper proposes a practical architecture for information exchange based on IEC 61968 to bridge the gaps between theory and practice. Some novel and original implementation technologies are elaborated covering model, profile, metadata and verification aspects. Finally the feeder data integration case for local utility business demonstrates the feasibility and effectiveness of the proposed architecture.*

***Streszczenie.** W artykule przedstawiono praktyczną budowę struktury wymiany informacji opartą na standardzie IEC 61968. Opisano nowatorskie sposoby implementacji modelu, profilu, meta danych oraz przykład wykorzystania, weryfikujący wykonalność i efektywność proponowanej struktury. (**Technologie wymiany informacji o elementach sieci w standardzie IEC 61968**)*

Keywords: IEC 61968, information integration, common information model (CIM), profile.
Słowa kluczowe: IEC 61968, integracja informacji, Common Information Model (CMI), profil

Introduction

The integration of electric power system and its information systems is the key foundation to achieve smart gird. Smart grid relies on valuable and reliable information extracted from integrated data to promote grid operating performance and utility management efficiency and eventually provide high quality electric power services. However, these large amounts of complex data, such as network structures, operating indexes, equipment status, measurement parameters and geographic information, are scattered in different systems deployed at different places to be used for various business applications. Due to their diverse vendors, running environments and application domains, most of these heterogeneous systems are working independently with relatively self-maintained data and isolated management modes. Without unified model and integration mechanism, it is hard to establish effective data exchange within and between utilities for information sharing and interaction.

Common information model (CIM) initially is sponsored by Electric Power Research Institute (EPRI) and mainly focuses on transmission system for Energy Management System (EMS), which is accepted as the international standard by International Electrotechnical Commission Technical Committee 57 Working Group 13 (IEC TC57 WG13) [1]. Meanwhile, IEC TC57 WG14 takes CIM ongoing extensions to distribution system and utility management as standard interfaces for utility information exchange [2]. CIM has been widely recognized as the generic model for smart grid information integration.

With the everlasting development of power system and utility business, CIM is updated continuously to adapt to smart grid requirements [3], including model extension [4]-[6], amendment [7], [8] and harmonization with other different models [9]. As the gradually increasing demands of data exchange among systems, a series of utility business abstract components and their corresponding contextual models or CIM profiles [2] for message exchange are designed in IEC 61968 standards on the basis of CIM. IEC 61968 is oriented to inter-system integration on event-drive basis in loosely coupled and heterogeneous environments with middleware services and interface adapters to achieve non-real time data message transactions [2] compared to the intra-application real-time information interaction pattern. IEC 61968 is implemented on SOA-based enterprise service bus (ESB) that linearizes interface numbers compared to traditional point-to-point architecture and facilitates cost reduction for development and maintenance. The guidelines for naming and design rules are also recommended in IEC 61968-100 [10].

Although many IEC 61968 interoperability tests [11] and some specific application-oriented CIM information exchange demonstrations [12]-[14] have been carried out, the existing methodology and tools [15], as well as ongoing standards, are still immature and merely focus on specific points alone, which do not comprehensively cover all the situations and problems faced in engineering processes. This paper proposes a complete and practical architecture of information exchange based on IEC 61968, in which key technologies and solutions to every aspect of model management, business profile, message pattern, verification tool and metadata management are discussed in detail. Moreover, taking the feeder management business as a case study, the feeder static and dynamic modeling, profile scenario design and verification progress are studied to demonstrate the feasibility and effectiveness of the proposed architecture.

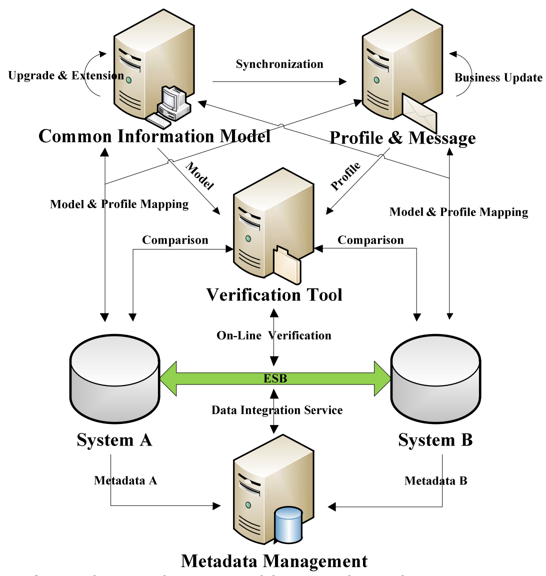


Fig.1. Information Exchange Architecture based on IEC 61968

Architecture of Information Exchange

The promotion of operation and management towards higher levels for utilities in smart grid needs data from all aspects of systems integrated which is the necessary condition to dig out valuable information. By means of certain interface adapters, each system, such as distribution management system (DMS), geographic information system (GIS), outage management system (OMS) and customer information system (CIS), offers standard services to public and has accesses to services provided by other systems on ESB. However, it is not enough to establish the loosely coupled integration without an effective and flexible architecture with modularized and coordinated components on top level. In practice, the data sharing relies on the model mutual recognition, profile structure conformability, exchange pattern agreement and data correlation matching. Consequently, the architecture, shown in Figure 1, requires providing necessary integration-level functions, such as the synchronization between model and CIM profile, the semantic mapping between models, verification for every part and metadata management.

CIM and its necessary local extensions are considered as the global unified model. The extension does not require completely covering all the private models in each system, only the parts for external exchange services are needed. If private models for the same object are different, the reasonable extensions should also take these diversities into consideration to meet global compatibility and ontology uniformity. Furthermore, model need periodically updates and release to all integrated systems according to CIM standard evolutions and local exchange data changes.

CIM Profile, or contextual model, is the subset of model with properly adjustments of cardinality and other limit according to the specific business data exchange scenario requirement. Once the global model and local business change, sets of profiles should synchronize to the updated version. At the same time, all related system adapters and their service interfaces also require having the ability to auto-transform to new profiles in order to send and receive data message correctly. Apart from the effects of changes in message structure, namely XML schema (XSD) definition, the message pattern ought to redesign because of the profile or system function adjustments. Message pattern design includes determination of message flow direction and its transmission protocol or mechanism. Although IEC 61968 has defined the core part of integration prototype, the extensive analyses and customization to local utility business requirements are premises of practical implementation.

The verification takes place in all aspects of information integration process to ensure the conformity of information. The verification tool contains standard model and profiles which are periodically sent to verification tool from model and profile management servers. It guarantees the model and profile synchronization, profile and message compliance and consistence between the system interfaces and profiles. The verification process can be divided into two aspects as Figure 1 shows. One is off-line check, i.e. in the stage of system development and preliminary test, and the other is the on-line verification, namely by on-line detecting, tracing the message by XSD or RDF and recording service execution progress according to the business scenario definition.

Unified metadata management is indispensable to accomplish CIM-based logical connections among sets of discrete data as soon as ontology reaches agreement. Because of the diverse data sources and coding styles, it is critical to merge multi-set of data from various systems through establishing model semantic agreement and data mapping table to form the complete model. Metadata management maintains the tables and provides the search service.

The following sections elaborate the each part of the architecture in detail respectively.

Model Mapping and Its Extension

CIM and its local extensions, as the global model on ESB in utility, do not require the internal data models of integrated systems to conform to it. But external data models for exchange through services and interfaces have to possess unified structure and semantic. It is vital to establish model mappings and to design the reasonable custom extensions to meet local utility business and system integration requirements.

(1) Harmonization between Different Models

Most of electric power control and application systems use dedicated designed application-based information models to express their specific data logical relationships and storage form in order to achieve high performance. For example, there are customized dynamic data model for power system safety analysis, planning information model for calculating optimal distributed energy resource (DER) access point, equipment management model for asset lifecycle application and weather data model for short-term load forecasting, etc.

When required original data and analysis results come from or provide to other systems, different models need to map to global unified model. These mappings aim to identify the difference among the models that can be harmonized and used together to realize the very part of data format transforming. But they do not seek to change the system internal model usage and combine all models together. All the mappings are not only on class level but also include the attribute and relationship by textual table or some ontology software.

1) Direct Mapping

Many legacy system models simply place all relevant and needed attributes of certain object into the same class without classification. These models are similar with simple database table structures and use some attributes like foreign key to set up class relationships with each other. However, CIM is based on the object-oriented abstraction modeling method. By means of Unified Modeling Language (UML), CIM establishes logical hierarchy between classes using generalization, aggregation and association relationships. The public parts are extracted to form root classes and the rests are classified into proper concrete classes. Major electric power system objects are comprehensively and meticulously modeled in CIM according to their physical and electrical characters.

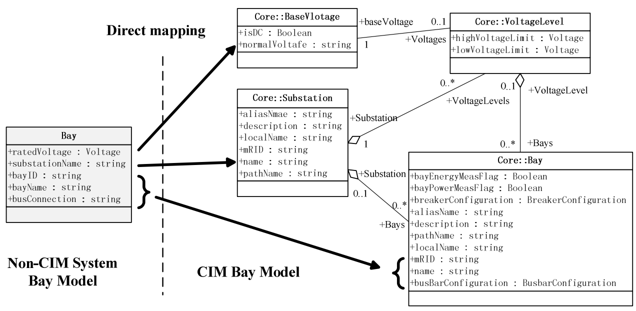


Fig. 2. Direct mapping for bay model

Figure 2 shows a typical direct mapping between non-CIM model and CIM. On the left is the non-CIM bay model used in a substation management system (SMS). There are five attributes defined to describe bay, including identification (bayID and bayName), substation the bay belongs to (substationName), operating voltage level (ratedVoltage) and bus type (busConnection). Although there is the class called Bay in CIM shown on the right, it is not enough to fully match the bay model on the left. In CIM, every Substation may have many Bays and VoltageLevels; each Bay is contained at most in one VoltageLevel which is associated with a BaseVoltage. They are logical connected by means of UML aggregation and association relationship. In this case, the Bay class and its attributes on the left can directly map to the four classes in CIM without any information loss.

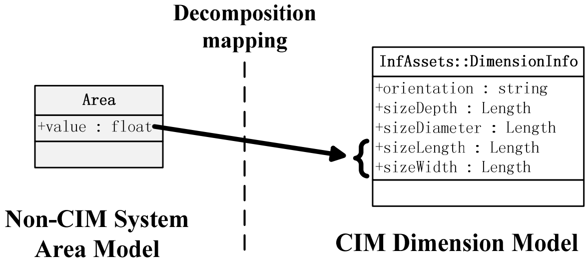


Fig. 3. Decomposition mapping for Area model

Sometimes due to modeling granularity and data maintenance differences, proper conversions are applied to direct mapping. For example, in Figure 3, Area class is used to represent substation area attribute in one non-CIM model on the left while only atomic measurement data are modeled in DimensionInfo class in CIM. Area value has to decompose into two raw attributes, sizeLength and sizeWidth, on the right. Therefore, it is common to transfer complex calculation and test results into direct measurement and observation data, which results in one-to-many mapping between two slightly different models.

2) Indirect Mapping

There are other information models other than CIM, which have different geneses and serve different constituencies, such as IEC 61850 for power system automation and IEC 61400-25 for wind power plant monitoring and control. This kind of models focuses on automation and protection control while CIM emphasizes static physical description and business function. Although the intersection exists, the differences of application domains and modeling methodologies challenge the integration of various products or systems that are compliant with the differing models. IEC TC 57 WG19 leads the long-term research to reach harmonization between heterogeneous models for information integration of smart grid.

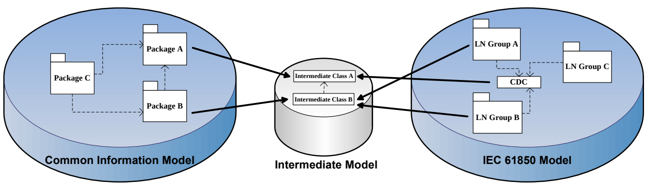


Fig. 4. Intermediate model for CIM and IEC 61850 indirect mapping

Indirect mapping do not attempt to fully transform one model to others, but to establish correlations between classes that need to exchange by using intermediate model. Figure 4 shows the one of intermediate models to bridge gaps between CIM and IEC 61850. Classes in Package B dependent on the common classes in Package A, and classes in Package C both relies on classes in Package A and B. At the same time, LN Group A, B and C all consider CDC as common class on the right in IEC 61850 model. Given the condition that one application needs to integrate data modeled respectively by classes in package A from CIM system and in LN Group A and B from the IEC 61850 system. The indirect mapping is fulfilled by creating appropriate classes in intermediate model to achieve seamless transformation.

(2) Same Model but Different Version

Even if all information systems are claimed to adopt CIM, the phenomenon of mixed use different version of CIM throughout the same utility is very common [15], which also blocks information exchange and increases the difficulty of integration.

CIM has many versions from the first published edition CIM10 to current updating release CIM15. The dramatic changes have occurred, especially in the IEC 61968 part that is still intensively revised and rapidly expanded in order to adapt to the new requirements. For example, Figure 5 demonstrates the comparison of transmission line model in Wires package from different CIM version. In CIM 13v19, all the attributes in ACLineSegment class are inherited from its superclass Conductor while only the length attribute left in Conductor and others are moved into subclass in CIM 14v15. When line models need to exchange, these changes will cause incorrect automatic generation and parse CIM/RDF documents without updating.

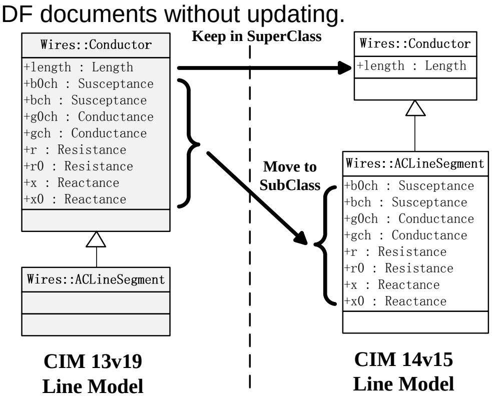


Fig. 5. Transmission line model changes in CIM

Adding and deleting classes, evolving attributes into class relationships, relocating and combining attributes, and updating class relationships are common differences appeared in CIM version management and synchronization processes. The RDF document tags ought to follow the very version of CIM RDFS syntax definition. Although the namespace helps the version control suggested by IEC 6168-100, the unsolved semantic difference and structure diversity still cause the difficulty for parsing XSD and RDF. According to the practical experiences, a specific CIM version must be determined on architecture level in utility to form unified model structure and semantic specification. So, formally published IEC 61970-301(ed3.0) [1] and 61968-11(ed1.0) [2] are recommended.

(3) Model Extension

Major objects in integrated systems can map to CIM. But for the private objects that are not modeled in CIM, the local extension must be added to CIM to meet the exchange requirements. On one hand, with the grid upgrade and continually business expansion, models in legacy systems are unable to support the current needs of utility operation and management. The gradually amendments and supplements other than frequently completed replacements are good choice to prevent higher maintenance cost and longer development cycle. On the other hand, CIM for distribution and utility business function is not yet mature enough. Because of difference requirements of local utility management modes and business analysis data, only the private models for exchange are considered as candidate extensions to existing CIM for local usage. Although the multi-namespace can distinguish the extensions in RDFS and RDF, it relies on proper parse algorithms and not apparent in UML. So, the extensions should set apart from standard parts without affecting the original [17], which facilitates the model backward compatibility as well.

1) Package Extension

The extended portion is categorized into a single package in parallel with IEC 61970 and IEC 61968 packages and establishes the dependency relationship with them. The extended classes also are assorted into sub-packages by compliance with CIM classification. For example, there are WiresExtension package for added equipment and DomainExtension package for special unit symbols, et al.

2) Class and Attribute Extension

There are two situations for class and attribute extension. One is that extended class and its attributes can directly generate from proper superclass because no corresponding model exists in CIM. The other is that the extended attributes have to be added to extended subclass as well although the corresponding class exists because simply append to superclass will change standard CIM.

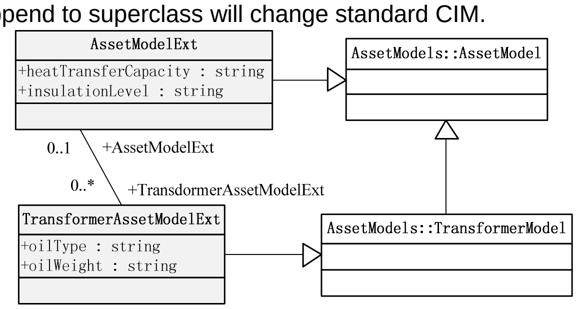


Fig. 6. Transformer extension model

In Figure 6, two local attributes, heatTransferCapacity and insulatonLevel, are extended in AssetModelExt class which is generated from AssetModel common class. Similarly, the atrribute oilType and oilWeight are placed into TransfomerAssetModelExt class. Not all properties are fit to directly model without further processing. The atomicity and maintainability are considered as one of preconditions. So the proper transformations or combinations are needed if necessary.

3) Relationship Extension

When many desired extended objects contain both public and self-contained parts, the public part should be extracted and modeled as the common class extension. In this case, a possible contradiction between modeling rules appears because CIM temporary does not support dual inheritance. It is clearly demonstrated in Figure 6 that TransfomerAssetModelExt class can inherit all attributes from AssetModel and TransfomerModel class, but nothing from AssetModelExt class. An association relationship has to be created between TransfomerAssetModelExt class and AssetModelExt class to resolve the conflict in this case.

Another relationship extension situation is that it is not appropriate to directly establish association relationship between CIM and extension class. This automatically forces other subclasses to obtain the connections that should not have.

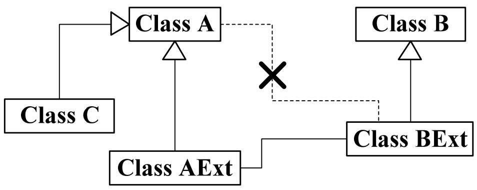


Fig. 7. Association relationship extension

In Figure 7, there is no any relationship between class A and class B originally. Class C is generated from class A. However, local extended class BExt needs some logical connectivity with class A. If the association is directly created, class C then has the association relationship with class BExt. If class A represents the root class IdentifiedObject in CIM, class BExt will gains accesses to all models, which is absurd and should not be allowed. As a result, to avoid this happened, class AExt is generated from class A; meanwhile, the association between AExt and BExt class is created.

Profile and messaging pattern design

The profile, usually presented in XSD, is a subset of CIM in accordance with abstract business function requirement plus specific restrictions. It simultaneously varies with the model changes and business adjustments. Message pattern is the way of profile data transmission and transaction among systems depending on services provided as well as business demands.

(1) Model-based Profile

IEC 61968 decomposes complex utility business components into a set of standard interfaces called profiles for various application domains including network operation (NO), asset management (AM) and meter reading (MR), et al.

1) Profile Version Updating

Current standard profiles are based on different CIM versions because of the long time span of each profile formation, which may not match the appointed global unified model thus affecting XML data file generation and analysis. Especially the profiles for common distribution power system model (CDPSM) and static transmission network model (CPSM) 3.0 are both based on CIM version 11 that is not aligned to CIM 14v31 applied by IEC 61968-11. Although the profile namespace can distinguish the version difference, the inconformity may lead to some data meaninglessness and increase the profile mapping cost. Consequently, it is necessary to establish the mechanism that profiles should synchronize periodically with updated CIM and its local extensions on utility level and publish to all data services to make corresponding interface adjustments.

2) Model Extraction

Except CPSM and CDPSM for grid model, the business profiles do not require the rigorous and completed structure description of model hierarchy like CIM/RDF file does. Only the reduced logical semantics extracted from the original model are necessary to simply the data transmission and transaction.

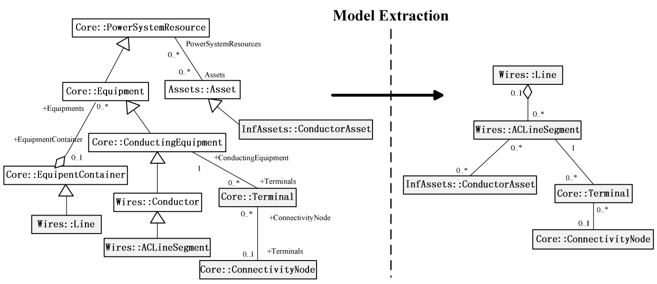


Fig. 8. Line model extraction

For example, the profile for utility line management business needs merely Line and AClineSegment affiliated with topology model. However, the thorough description of these two classes structure in CIM is redundant and complicated as Figure 8 shows. Line is one kind of EquipmentContainer that may contain much Equipment.

Tracing three layers back, ACLineSegment indirectly generates from Equipment and connects Terminals that inherit from ConductingEquipment. Similarly, Conductor Asset is reasonably associated with Equipment. To sum up, Line contains many ACLineSegments, each of which associates with ConductorAssets and Terminals. After extraction the line mode is simplified that satisfies the minimum data needs.

3) Custom Design

The rules on what does the profile consist of and how the content of profile is organized have not yet unified formed or standardized in IEC 61968.

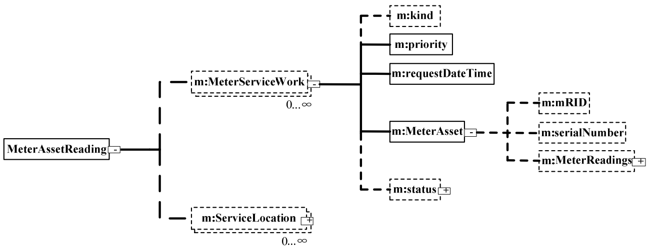


Fig. 9. MeterAssetReading profile in IEC 61968-9 [28]

For example, in Figure 9, the MeterAssetReading profile in IEC 61968-9 [18] for metering reading and control business contains two main concrete classes, ServiceLocation and MeterServiceWork. These two classes have no logical relationships in CIM but can be placed in parallel with each other in profile by custom design as long as business demands. Only mRID and serialNumber attributes and connection to MeterReadings are chosen from multiple attributes and relationships of MeterAsset. Meanwhile, the cardinalities of priority and requestDataTime attributes are set to be obliged to request. However the reason of these adjustments is not elaborated in standard.

The problems arise when there are gaps between local business requirements and standard profiles. The standard profiles barely focus on common abstract component interfaces, which are not designed for local specific usage. So, if the name instead of mRID attribute of MeterAsset is required by local meter management system, MeterAssetReading profile has to be modified or recombined with other profile to make up the deficiency.

As a whole, two methods are applied when profiles synchronize with global unified model that includes standard portion and custom extensions. One is directly mapping extension parts into standard profiles to form mixed ones while the other is creating separate custom profiles. The former method will violate the standard that is not conducive to future updating. And then the latter will lead to extra cost of message transactions though maintaining the integrity of standard profile and facilitating management. Whichever method is applied, profile naming and design roles [10] have to be complied.

(2) Message Pattern

Beside profiles, the payload of message, IEC 61968 also standardizes the generic message header part using Noun and Verb definition and other optional auxiliary attributes to manage message transmission mechanism or pattern. However, it not enough to accomplish the business message integration without custom use cases and sequence design.

Business-driven message pattern design is based on business data demands and services provided by integrated systems. The pattern has two sets of interactive modes, namely request-reply [10] and subscribe-publish, which are combined into the complex interactive patterns. All adapters or interfaces should have the ability to recognize modes and respond right actions by analyzing and using corresponding Noun and Verb in message head with synchronous or asynchronous communication. Once the business or data source changes, the corresponding use case has to be revised.

Code or description standardization for specific attribute in message is another important part in pattern design, such as ErrorCode in reply message and IDs in request message. Business function code in profiles, such as metering data quality code in IEC 61968-9 [18], also facilitate utility management. The coding system must be comprehensive scientific, correct and complete and guarantee no logical conflict to avoid jeopardizing grid security.

Verification Tool and Metadata Management

(1) Verification Tool

Model compliance, profile consistency and message pattern conformity all depend on verification tools. Most of participants and research organizations in IEC61968 interoperability tests provide many similar tools, such as CIMTool, CIMSpy, CIMPhony and CIMvian [16] that can accomplish model parse, profile design and topology analysis. However, all of these tools are focus on some of the aspects and currently lack of pattern check and on-line verification ability which is vital to business.

1) Model Comparison

It is necessary to thoroughly analyze whether to use CIM, the version of CIM adopted and private extensions contained as soon as utility systems are about to upgrade and integrate. The verification tool loads IEM as standard model and compares all system models by using RDF schema (RDFS), which is the premise of other verifications.

2) Model Data Verification

It is necessary to thoroughly analyze whether to use CIM, the version of CIM adopted and private extensions contained as soon as utility systems are about to upgrade and integrate. The verification tool loads IEM as standard model and compares all system models by using RDF schema (RDFS), which is the premise of other verifications.

3) Profile Verification

Profile verification is actually Web Ontology Language (OWL) comparison for power system model (CPSM & CDPSM), abstract business sub-function interface reference model (IRM) and its local extensions including semantic and structure tests. All messages generated and transferred through services or adapters are verified by XSDs that can be generated from OWL.

4) Message Pattern Check

Each utility business or use case includes corresponding profiles and time sequence of interactive process. All required part, such as Noun and Verb, and optional part of messages are pre-defined. So, the pattern check will ensure that each step of message exchange progress is consistent with determinate custom design as desired.

IEC 61968 interoperability tests mainly concentrate on data correctness for analysis in single business thread but currently ignoring all of things that can really raise problems if multi-threads simultaneously occur. As a result, deadlock and mutual exclusion that occasionally take place in operation systems have to be on-line detected to guaranty the integrity for each business message process that cannot be solved by ESB alone. Thus, the pattern dynamic verification is critical to utility managers and system operators to solve the problems in time.

(2) Metadata Management

Besides verification tool, metadata management is another important means to facilitate information integration that comes from diverse data sources. Metadata management establishes unified methodology of model application and data logical connections data sets that are independently maintained by different systems.

1) Diverse Model Usage

Model mapping and transformation can solve the discrepancy between different models but not for the consistency of different understanding and application of the same model. For example, the sectionalizer in distribution network has not yet been modeled in CIM. It has unique characteristics and function compared to breaker and disconnector. So one way is to create sectionalizer class generated from generic Switch class like breaker does and the other way is to use the combination of Switch and PSRType classes temporarily until the formal decision is made by IEC or local authority. When two systems using these different methods are going to exchange the same distribution line data including several sectionalizers, the mutual un-recognition will cause model merge fail. Consequently, it is necessary to reach metadata semantic matching agreement in entire utility by unified management.

2) Unified Data Relationship

Another core function of metadata management is the logical connection maintenance among data sets from different systems. Because every system in utility merely focuses on its own expertise, each block of self-maintained data involves only a small part of whole aspects. When these data blocks need to be orderly integrated for comprehensive utilization, the logical connections between blocks ought to be established through metadata management according to CIM definition.

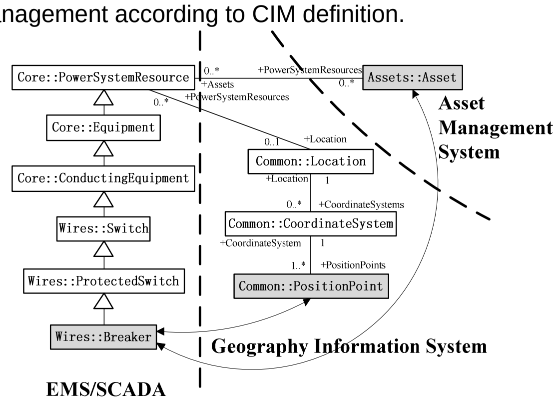


Fig. 10. Breaker data integration

Figure 10 shows an example of breaker data integration for utility business application. Once the breaker failure indicator alerts the operator to take immediate action, the field crew may receive the request to check on the field. If the failure breaker needs to be substituted, the asset management information is required as well. These independent data are distributed in three systems that are EMS/SCADA for operation status, GIS for geographical location and asset management system (AMS) for asset attributes. The metadata management will create a relational table at enterprise level to connect instances of Breaker, PositionPoint and Asset. It is useful to provide the data matching service on ESB.

Case Study

Feeder management is one of important businesses in utility. The transformation from traditional radial structure to complex mixed connection improves the distribution network stability and reliability but makes topology analysis more difficult that depends on more precise feeder model and accurate boundary definition.

The feeder model in CIM continually changes. Currently, the static feeder topology connection can be accurately modeled by flexible combination of Line and ACLineSegment. However, it is not enough to model the dynamically modified scope of feeder as soon as one or some of its affiliate switches change their operating positions. Fundamentally, the temporary operating condition in this case is not the static topology alternation but the dynamic recombination. As a result, the use of TopologicalIsland and TopologicalNode is reasonable to model this distinguishing feature. Above all, there is no need to extend CIM.

Utility managers and operators in control center are likely to visualize the nearly real-time feeder changes for analyzing the power transfer ability after reconfiguration. It is necessary to integrate data from various systems, such as topology model, measurement value, geological information and asset data, et al. Because the standard profiles in IEC 61968 are not specifically defined for local usage, the specific profile is created to facilitate the management requirement that feeder is considered as a data exchange unit for various applications.

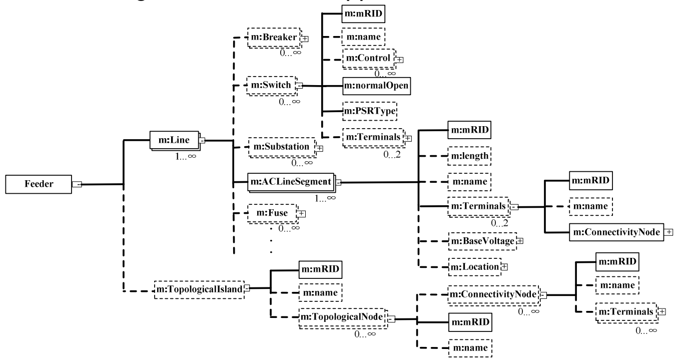


Fig. 11. Feeder profile

The feeder profile consists of two parts shown in Figure 11. One part has at least one Line that contains affiliate electrical equipment with their static topology, condition, asset and location models. The other optional part composes the dynamic topological model that includes the corresponding connectivityNodes and Terminals. The combination of two components in the same profile has the advantage of clear representation of static and dynamic differences.

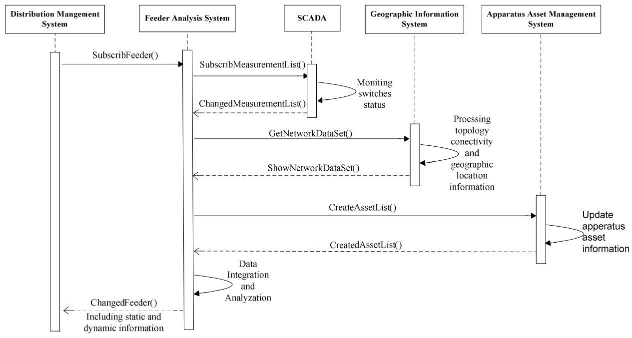


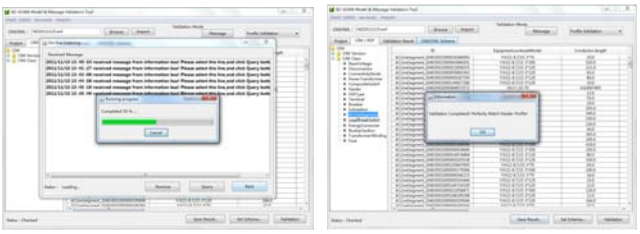
Fig. 12. Feeder management use case

Figure 12 demonstrates the use case of feeder management. Feeder Analysis System (FAS) accepts the subscription request from DMS that informs the feeder change alert. FAS then monitors switch operating positions from SCADA reports and accesses the GIS and AMS for required information using standard profiles, such as MeasurementList, AssetList and NetworkDataSet. After data integration and topology analysis, FAS sends the changed feeder data back to DMS by feeder profile for further use.

The red color in Figure 13 demonstrates the scope of one feeder in local utility distribution network. Part A shows the normal operating mode and part B figures out the changed scope after two switches change their conditions. All the message exchanges among systems conform to IEC 61968 mechanisms and monitored by on-line verification tool deployed on ESB. Figure 14 shows the verification results of feeder model, profile structure and message pattern. The verification tool on-line detects the messages transmitted on ESB and records messages and pattern progress information in pointed buffer pool on local server as Figure 14 (A) shows. The tool also provides the option to operator and manager to check whether the selected and saved messages are compliant with the corresponding profiles and displays the result shown in Figure 14(B) after the verification via proper XSD according or the namespace. Once the conflict occurs, the tool will automatically highlight the error and point out the standard preferable modification.

A B

Fig.13. Dynamic feeder scope changes



A B

Fig.14. On-line verification progress

Conclusion

Effective integration of information is one of core foundations for smart grid development. This paper proposes a whole set of solution for the implement of system data exchange based on IEC 61968. Key technologies are elaborated including model extension, profile design, metadata management and verification process. The feeder data integration case for local utility business successfully shows the feasibility of the proposed methodology. The verification tool contains expert modules for every aspect of feeder integration progress to ensure consistence and compatibility.

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