System to verify interoperability of smart industrial complex

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Abstract.

BACKGROUND/OBJECTIVES: The application of a smart energy platform in order for value chain companies of the same industry to connect themselves by sharing data connections between companies in the industrial complex.
METHODS/STATISTICAL ANALYSIS: It is necessary to support the existing communication method according to the energy platform's data model and communication protocol, data processing at the point of connection, and the environment for verifying communication performance.
The test system is constructed according to the type and target of the data collection point and the network configuration based on the customer data size.

FINDINGS: OPC Foundation provides the OPC UA Compliance Test Tool (CTT) program as an official tool for testing for functional verification of UA server and client. The OPC UA Conformance Test Tool (CTT) contains only functional tests. This means that it does not provide behavioral, interoperability, load, or performance tests. Since there is no test case suitable for a specific domain such as an energy management system, we present an environment in which test cases can be easily developed according to the requirements of the domain.

IMPROVEMENTS/APPLICATIONS:

The factory-based energy management system can be expanded to industrial complexes, and then used as a conformity verification system for energy management systems linked between industrial complexes.

Keywords: *CEMS, Interoperability, Testing system, OPC UA, smart industrial complex.*

1. INTRODUCTION

The demand for cost reduction is increasing due to the market overheating caused by the mismatch between supply and demand, and the market is gradually reorganized to focus on customized customers. In particular, in advanced industrial countries, as the number of cases (offshoring) of relocating factories overseas due to cost reduction increased, a sense of crisis was prevalent in the manufacturing industry as a whole. [1] To solve this problem, a future factory, a smart factory [2], appeared.

The data is used to identify the relationship between energy sources used and to improve energy use efficiency based on energy demand data for each industry applying problem identification, pattern analysis, and environmental data through basic unit analysis. [3] The collection of customer data such as energy data, operating facilities, production volume, operating equipment, operating patterns, and environmental data is performed by analyzing and managing reduction factors through correlation analysis, basic unit analysis of products, and operation pattern analysis for each device.

2. IEC 62541 OPC UA FOR EMS

The energy field adopts CIM[3] (Common Information Model) as an information model-related standard and OPC-UA (OLE Process for Control-Unified Architecture) as a communication architecture in many domains. The CIM is an abstract information model whose purpose is to model and express various information generated in the energy field in the form of a class. The OPC-UA is a communication architecture standard for how heterogeneous systems or applications exchange information with information expressed in CIM.

By introducing an energy management system in the factory, it measures the energy consumption and production status of products in real time. By analyzing various information with FEMS, it is possible to identify energy waste factors and maximize efficiency. FEMS can eliminate energy wasted elements of overloading and idling by supplying energy as much as the demand required for the production process and facility operation of the plant.

2.1. IEC 62541 OPC UA

As a detail of the IEC 62541 standard, parts 1 and 2 correspond to the normative specification. Part 3 and 4 are presented to understand the modeling and access of information. These two parts correspond to the core documents on the design and development of OPC UA applications. Part 3, which deals with the address space model, describes the components and information model that exposes instance and type information, and defines the OPC UA meta-model used to build the OPC UA server address space. The abstract UA service defined in Part 4 describes possible interactions between a UA client and a UA server application. The basic information model defined in Part 6 provides a framework for all information models using OPC UA. Specifically, it defines the following:

• The entry point in the address space that the client uses to identify the instance and type of the OPC UA server.

• The basic type that builds the required root for each type of hierarchy.

• Built-in or extensible types (object types, data types, etc.).

• Server objects that provide diagnostic information and functions.

Profiles define useful subsets of the OPC UA features in Part 7. The DA information model in Part 8 defines how automation data and other features (engineering units, etc.) are represented and used. The AC Information Model in Part 9 defines process alerts and situation monitoring related to specific state machines and event types. The program information model in Part 10 defines the basic state machines required for program execution, operation, and monitoring. The HA information model of Part 11 defines a method of expressing information about the use of the history access service and the setting of data and event history.

The flexibility and adaptability of OPC UA comes from the information model. This is because the object-oriented information model can be easily applied without interoperability issues. The object-oriented information model makes it possible to integrate production data, alarms, events and historical data into the OPC UA server. Basically, the information model of OPC UA consists of nodes and inter-node references as shown in the figure.

Different transport protocols as shown in the figure are defined for communication between different OPC UA applications, and the supported protocols are used according to various requirements, such as:

• UA TCP with UA binaries for high performance, speed and throughput

• HTTP and SOAP for firewall friendly Internet communication

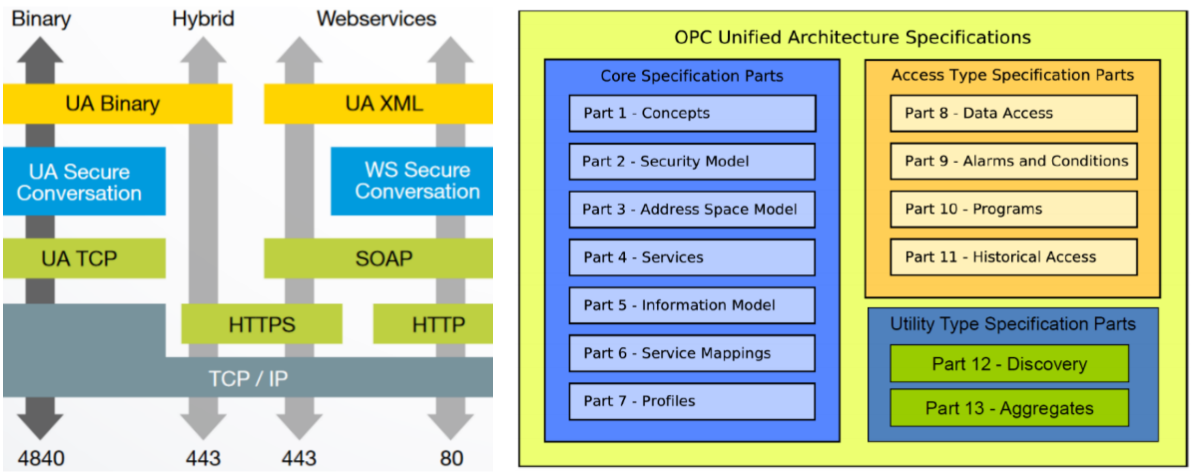

Figure 1. OPC UA Transport Protocol and 13-part specification

The OPC UA standard specifies general-purpose information such as alarms, process values, etc. in an embedded information model. The first built-in information model, Data Access (DA), describes the modeling of automated data such as analog and discrete variables, engineering units, and quality codes. Available data sources include sensors and controllers. Alarms and Conditions (AC) define the status, dialogs and handling of alarms. A change of state generates an event, and the client subscribes to those events and selects the available variables with which it should communicate. Historical data access (HA) makes it possible to provide the client with historical values of variables and events. Pre-processing can be performed on the server side through various aggregation functions, and the program (Prg) represents a complex operation such as a batch processing operation.

The figures 2 describe the proposed standard interface server package. It consists of 3 modules including the base module essential for the OPC UA server, and 5 modules including server operation control, server application module, and system integration. The figure shows OPC UA Server, and must have at least one NodeManager, SeesionManager, and Subscription Manager. The NodeManager essentially has MethodManager, and EventManager and HistoryManager can be configured as needed.

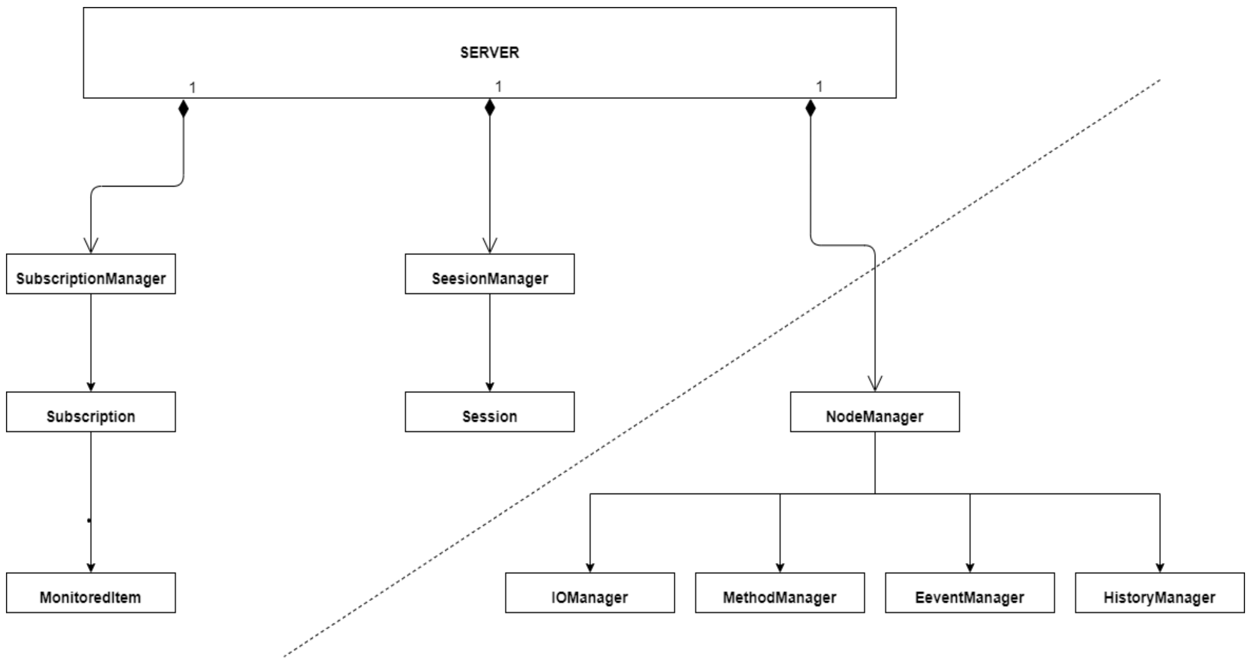

Figure 2. Server Architecture of OPC UA

2.2. TESTING

UA applications can ensure interoperability related to these subsets. This specification defines a subset of two levels, the first being the Conformance Units. The small set of functionality defined by the conformance unit is always used together and can be tested as a unit at the same time can be tested with the conformance testing tool. The second step is a profile consisting of a list of conformance units, where the entire set is reviewed to ensure that the profile has been fully applied during the certification process for OPC UA products. The list of profiles to be used is exchanged during the connection process between the client and the server, and through this, the application can determine whether all required features are supported by the communication partner.

EPRI in the United States devoted itself to the CCAPI (Control Center Application Program Interface) project across the industry to develop open and interoperable applications for energy management systems (EMS) using standardized interfaces. [4] CIM, the core of this CCAPI concept, defined the essential data structure of the power system model. The North American Electric Reliability Council (NERC) was looking for an optimal way to electronically exchange power system models, and as a result, CIM using RDF (Resource Description Framework) schema and syntax The CCAPI project for configuring XML. [5] Accordingly, to evaluate the XML and RDF for model exchange, a series of interoperability tests comparing products from different vendors were planned and conducted. Ten test results reports can be found in the search. Interoperability test for EMS is based on CIM XML standard to exchange power system model through file transfer. Includes full model transfer, partial model transfer, and evolutionary model update. OPC UA application can support multiple profiles and each

Profiles can include other profiles. There are various categories. These are server-related profiles, client-related profiles, security-related profiles, and transmission-related profiles. This profile usually consists of several conformance units. Conformance units are testable units. Assuming a call service as one conformance unit, each conformance unit has a test case.

The OPC UA Compliance Test Tool (CTT) is an official test program provided by the OPC organization for functional verification of UA server products and client products. The OPC UA uses profiles for the purpose of testing OPC UA applications with various functions. Test cases for the characteristics of the profile are defined to verify that a specific application accurately supports the profile. An independent testing organization tests the application and then signs and issues a software certificate. This certificate contains information on the profile supported by the application. Profiles can be used as human-readable sentences, and supported profiles can also be exchanged between OPC UA applications. Through this, each application can reject the connection when the other application does not support a specific profile. The OPC UA application supports multiple profiles, and each profile can have a different profile. There are profiles according to server, client, security, and transmission, and each profile is usually composed of a plurality of conformance units.

3. EXPANDED TO INDUSTRIAL COMPLEXES WITH INTEROPERABILITY

The Industrial Complex Corporation energy management system should establish an information exchange system that integrates data operating in energy management, manufacturing, and demand fields in an environment composed of related factory EMS.

Considering the wide range and speed of change in the energy management system, the integrated platform applied to the environment must have the flexibility and expandability of the system itself so that it can integrate new services and applications that are released quickly.

Table 1: Principles of the industrial complex energy platform architecture

Classification	Requirements
Function	Standardization, openness, interoperability, security, scalability, upgrading, maintenance, commonality, ubiquity, integrity, ease of use
Non-functional	Performance, compatibility, portability, data integrity, maintainability, standards conformance, availability

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For functional and non-functional architectural principles in the table above, refer to the requirements of the GRIDWISE Architecture Council, Utility Advanced Metering Infrastructure (AMI) and the National Institute of Standards and Technology (NIST) in the United States. [5-7]

3.1. DATA STANDARD CONFORMANCE

It is difficult to provide suitable application services to operate EMS without data verification procedure. It is possible to obtain reliable data through the verification step in the device and data transmission, and use it to provide application services. EMS operation and total monitoring scenarios apply international standard-based data model development and international standard communication protocol and data model.

The purpose is to manage the energy of industrial complexes by expanding them in individual buildings and factories. Data enables energy efficiency projects based on industrial complexes, and it can be built microgrids based on distributed energy.

3.2. ENERGY MANAGEMENT SERVICE USING DATA

Almost EMS (Energy Management System) reduce cost by using only energy peak control based on energy usage data patterns. The data-based EMS service can apply substantial energy saving factors by using background data (company operation information, facility environment information, etc.) that cause facility operation.

3.3. TOTAL MANAGEMENT OF INSTRUMENTS

Most sites are performing instrument performance management at the unit device level. There are many cases of dependence on the installation environment as measuring instruments are configured as an integrated system at the industrial complex site. The EMS operation and monitoring scenario applies the international standard-based data model and communication protocol. The requirements for integration of measuring instruments can establish an environment for total monitoring by linking EMSs, and expandability according to the development of facilities and communication technologies.

4. STANDARDS-BASED EMS MODEL

4.1. CEMS (COMPLEX ENERGY MANAGEMENT SYSTEM) MODEL

The data model of the smart industrial complex for the operation of energy platforms such as FEMS and CEMS is reflected in the 'Innovative Data Center Construction and Operation' regulations, and empirical data is used for data model standardization. The data model uses IEC TC57's Common Information Model (CIM) to map the data of the energy platform with the international standard data model, and design the energy platform data model compatible with the international standard-based data model. It is necessary to establish a standard methodology to produce meaningful data from newly collected and already accumulated data.

Figure 3. CEMS Functional Display

The interoperability can be expected through a standard called OPC UA in devices, applications, and platforms by adopting an international standard-based communication system. Common standards and tests of data quality and communication interoperability are essential for building an energy platform in a smart industrial complex. The interoperability test develops evaluation guidelines and test procedures to ensure effectiveness in the use of measurement data.

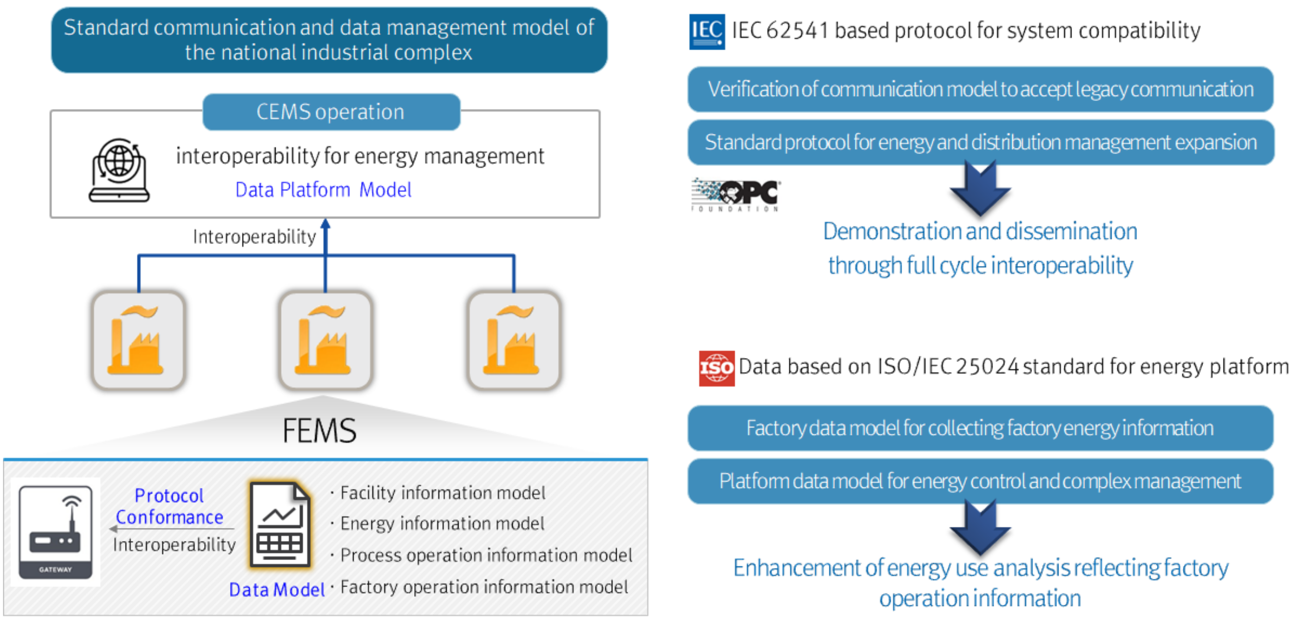

Figure 4. Standard conformance requirements for energy management systems

4.2. STANDARD-BASED TESTING SYSTEM

Interoperability, the ultimate goal of international standards, is related to the exchange of information, and each application function is aimed at understanding and working properly with messages, which are information exchanged between applications. Interoperability in the electric power field refers to a function or property that supports information exchange and interworking so that different types of power facilities can operate together. When information is exchanged between different applications, meaning is not lost and transmitted completely. It means making it understandable. Interoperability is an attribute related to semantics rather than syntax and is independent of messaging technology. Data format, packet structure, communication protocol, etc. are irrelevant to the essential aspects of interoperability. In the existing electric power industry, the use of proprietary applications was common, and it was common for individual utilities to build and operate applications with specific purposes in dedicated in-house standards, but smart grids are not limited to specific companies or product standards. Interoperability has emerged as an issue because it is based on international standards that do not exist. The format of data exchange between applications based on CIM or DMS standards produced by the IEC TC57 standard group is basically XML (eXtensible Markup Language), and XML message transfer between applications is designated as the standard to follow OPC UA. Therefore, in order to test substations and feeding stations based on international standards, tests in accordance with the international standard environment must be additionally performed, as well as pure functional individual tests that have been previously performed.

The first is a communication service-based conformance test. It is to test whether the given communication service between the client and the server is properly implemented. The second is the interoperability test between devices or application systems. It is to test whether the communication of information between each other is properly understood and carried out. Third, it is the validation that tests the XML grammar of the information model. By performing these essential tests in advance, interoperability can be guaranteed to a minimum during integrated operation on the network.

The conformity testing procedure for carrying out the conformance inspection describes a series of inspection-related procedures, and the role of the equipment to be inspected in the application program actually used and the required performance level are the contents to be inspected. The conformance test is performed by the user according to the supported interface for each device being tested based on the capabilities verified in the PICS (Protocol Implementation Conformance Statement), PIXIT (Protocol Implementation eXtra Information for Testing) and MICS (Model Implementation Conformance Statement) provided by the manufacturer. Adjust. Standard PICS must be provided, and PICS suitable for a specific service follows what is specified for SCSM. MICS must provide object model elements of detailed data provided from a system or device. MICS is implemented in SCD files according to IEC 61850-6. In addition to PICS, PIXIT documentation must be provided. Interoperability, which is the ultimate goal of the standard, is related to the exchange of information, and the purpose of each application function is to understand the message, the information exchanged between applications, and to operate properly.

We perform interoperability tests to achieve the following goals. First, it verifies interoperability between different products based on CIM and OPC UA. Applications developed independently by third-party vendors, including EMS applications, will be tested. Second, it verifies the compliance of CIM (class/attribute of CIM) in relation to the exchange of information supported by the test. Third, the exchange of power system models using CIM is verified, and the RDF schema and XML representation of the model data are verified. Fourth, the exchange of messages between different suppliers is verified using the services defined in the interface definition standard. Test the OPC UA service to verify mutual communication service. The OPC UA CTT (Conformance Test Tool) contains only functional tests, and there is no function, operation, interoperability, load, and performance test programs, and there are no test cases suitable for a specific domain such as an energy management system. There is a need for an environment in which test cases can be easily developed according to the requirements. Through the development of a GUI-based integrated test case tool, a study was conducted to secure an environment in which users can conveniently develop various test cases operating in CTT without understanding the CTT system.

5. CONCLUSION

In order to establish an information exchange system between various energy management systems of industrial complexes, a system that defines the OPC-UA common information model based on the IEC 62541 standard and deals with it in real time. By implementing a standard interface system in accordance with IEC 62541 OPC-UA communication architecture, 12 legacy systems and 6 categories of energy management system applications can be interoperable. Standards-based EMS defines the type and target of the data collection point based on the customer's data size and designs the network configuration. In order to analyze energy demand and supply optimization, it is essential to review various production processes or production facilities such as production facilities, products, and operating methods. The interoperability of FEMS can be expected by defining standard conformance requirements and establishing a test system for them.

It aims to establish a standard conformity verification system for integration between various industrial complexes. we present the OPC-UA communication conformance test and data model verification system. First of all, we studied the expansion and application of the factory energy management system from the perspective of industrial complexes, and in the future, we will establish a test environment for verifying requirements in order to have an environment in which industrial complexes can also be integrated.

6. ACKNOWLEDGMENT

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