Design of Automated Smart Grid CIM Interoperability Test System Based on TTCN

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ABSTRACT

We design a TTCN-3 based smart grid CIM test system for verification and validation of CIM interoperability among test nodes complying with IEC 61968 standards. The designed system allows a tester to easily generate TTCN scripts by graphically creating message sequence charts for validation of test verdicts. It also contains a test script execution engine for test automation with the TTCN scripts. The execution engine provides a function of matching CIM messages sent from test nodes at a run time with message templates generated by a tester for validating of test verdicts. These features of the designed system enable automating smart grid CIM interoperability tests between test nodes.

KEYWORDS

CIM Interoperability Test, TTCN-3, Smart Grid, IEC 61968, AMI

1 INTRODUCTION

A smart grid refers to an intelligent power network that integrates information technology into the existing one-way power network, which consists of the generation, transmission and distribution, and electricity market, to optimize energy efficiency through a two-way exchange of electricity information between suppliers and consumers in real time. A basic concept of the smart grid is to efficiently operate as one body an entire power system by connecting the power plants, transmission and distribution facilities, and consumers over an information communication network and sharing information. Smart grid standards such as IEC 61970 [1], IEC 61968 [2], Open Automated Demand Response (Open ADR) 2.0 profile specification [3], and Smart Energy Profile (SEP) 2.0 specification [4] provide a standardized information models for managing energy consumed or generated by homes, buildings, and industrial facilities on the basis of the Common Information Model (CIM). Test cases for CIM interoperability could be derived from various service scenarios and use cases. Various test cases and relative test components make it difficult that a tester establishes a test environment for a CIM interoperability test. For easy configuration and test validation, we design a CIM interoperability test system based on the Testing and Test Control Notation Version 3 (TTCN-3) [5], which provides a TTCN-3 test script editor and an execution engine to automatically verify and validate interoperability of IEC 61968 standards-compliant test nodes.

2 RELATED STANDARDS AND WORKS

There exist numerous standards for the Smart Grid. This paper focuses on interoperability tests for Advanced Metering Infrastructure (AMI) applications, systems, and devices. The IEC 61968 series was developed to facilitate inter-application integration of the various distributed software application supporting the management of utility electrical distribution networks [2]. In particular, Part 9 of IEC 61968 specifies the information content of a set of message types that can be used to support many of the business functions related to meter reading and control [6].

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In response to concerns by utilities and vendors that CIM is too abstract to be used, IEC 61968-100 specifies an implementation profile for IEC 61968 applications using Java Messaging Service (JMS) and web services [7]. This standard defines how message payloads are conveyed using Web services and the JMS. It also provides recommendations for web service implementation using Service Oriented Architecture (SOA) service patterns and Web Services Description Language (WSDL). Guidance is also provided with respect to the use of Enterprise Service Bus (ESB) technologies [7].

ESB refers to a software architecture construct that provides foundational services via an event-driven and standards-based messaging engine. This provides a means to derive interoperable implementations of IEC 61968 parts 3 through 9.

Using ESB technologies, EPRI CIM test project developed test cases and test procedures to verify and validate IEC 61968-9 meter reading and control messages. The test procedures are in conformance with the NIST Testing and Certification Committee (TCC) Interoperability Process Reference Manual (IPRM) and Certification Process Reference Model (CPRM). The project developed interoperability test case and test procedures to test 61968-9 messages applicable to scheduled meter reads, on demand meter reads, meter outages, meter tamper detection, and remote connection and disconnections [8].

3 DESIGN OF IEC 61968 CIM INTEROPERABILITY TEST SYSTEM

In this section, we design a functional architecture of an IEC 61968-9 CIM interoperability test system on the basis of the guidance with respect to the use of ESB described in IEC 61968-100. ESB enables the designed system to capture messages delivered between test nodes. The captured messages are used to validate IEC 61968-9 CIM interoperability among the test nodes. After briefly introducing TTCN-3 standards which provides a core language and system architecture for a standard conformance testing or an interoperability test, we explain a functional architecture of a CIM test system for interoperability test of IEC 61968-9 meter reading and control based on IEC 61968-100 and TTCN-3.

3.1 Overview of TTCN-3 Test System

TTCN-3 can be used for the specification of all types of reactive system tests over a variety of communication ports. TTCN-3 is not restricted to conformance testing and can be used for many other kinds of testing including interoperability, robustness, regression, system and integration testing. The TTCN-3 test system shown in Figure 1 can be thought of conceptually as a set of interacting entities where each entity corresponds to a particular aspect of functionality in a test system implementation. These entities manage test execution, interpreting or executing compiled TTCN-3 code, realize proper communication with the System Under Unit (SUT), implement external functions, and handle timer operations [5].

![Figure 1. TTCN-3 Test System Architecture](image)

The TTCN-3 Executable (TE), the main part of the structure of a TTCN-3 test system implementation deals with interpretation and execution of TTCN-3 modules. The remaining
part of the TTCN-3 test system can be divided into Test Management (TM), SUT Adaptor (SA), and Platform Adaptor (PA) entities. In general, these entities cover a test system user interface, test execution control, test event logging, as well as communication with the SUT and timer implementation [5].

3.2 Functional Architecture of IEC 61968 CIM Test System

Referring to the TTCN-3 test system, we design a functional architecture of an IEC 61968 CIM test system. The designed system reflects three requirements as follows. First, the system should have functions of web-based test configuration and TTCN script execution in order to automatically validate the verdict of test cases. Second, it should allow a tester to experience online interoperability testing through the Internet anywhere. Lastly, it should support protocol adaptors for communication with test nodes. To fulfill these requirements, the designed system contains a test script editor that enables a user to create and manage TTCN scripts runnable on its test engine. It also enables users to set its test configuration and do online interoperability testing under the configuration. For the support of a Simple Object Access Protocol (SOAP) interface, the system provides a SOAP adaptor for communication between an ESB and test nodes. The IEC 61968 CIM interoperability test system shown in Figure 2 consists of four components: Web-based CIM test client, CIM test server, ESB, and SUTs. The web-based CIM test client provides web interfaces to configure test nodes, edit message sequence charts and XML message template, and report test results. The CIM test server acting as a sort of web server is capable of executing TTCN test scripts which include network configuration of test components, their behavior, and XML message templates for test verdicts. When receiving messages sent from an ESB, the server determines whether the test result is pass or fail. The ESB performs a function to route all the messages delivered between SUTs such as Meter Data Management System (MDMS), Metering System (MS), Customer Information System (CIS), and Outage Management System (OMS) specified in the IEC 61968-9 interface reference model. It also performs a role to send the messages to the test server after cloning them. These functions are implemented as a proxy service on the ESB. The proxy service enables the SUTs to communicate with each other via the ESB by the help of its clone and send mediators. For more information, we explain the detailed operations of the designed system from test case generation to validation of test verdicts. First, a test case is created through the CIM test client running on a web browser. The test case expressed as a test script contains test sequences, XML message template, and communication interfaces and behavior of test components that could be set as a test simulator or a real test node. A CIM test server runs the created test script. The Master Test Component (MTC), the ESB, and SUTs specified in the script start their operation. In this process, all of the messages sent from SUTs via the ESB are delivered to the MTC. The MTC determines verdicts of the test case according to the TTCN XML matching and mapping rules. Then, it returns the test results to the test server.

![Figure 2. IEC 61968 CIM Interoperability Test System](image-url)
3.3 Structure of Test Case Execution Engine

A test-case execution engine and its operation are shown in Figure 3. With the help of the message editor, a tester can generate message templates for validating test verdicts based on the XML schemas defined in IEC 61968-9. The tester can also configure test components running on the execution engine and specify their behaviors and test sequences with the scenario editor. The editors output TTCN scripts, which are integrated into one TTCN test script. The integrated script runs on the test case execution engine. According to the test configuration described in the script, the engine starts to run each test component. The test components perform their operations according to their behavior defined in the script. In the process of test case execution, XML messages are delivered between test components via the ESB. The test execution engine compares the delivered XML messages to relative XML message templates. Then, it determines whether the test nodes are interoperable with other systems complying with IEC 61968-9.

![Figure 3. Test Case Execution Engine](image)

4 CONCLUSIONS

In this paper, we design a TTCN-3 based IEC 61968-9 CIM interoperability test system, which provides a TTCN script editor and an execution engine that automatically verifies and validates interoperability among IEC 61968-9 standards compliant test nodes. The designed system allows a tester to create a test case and execute them on it. The test case expressed as a test script contains test sequences, XML message templates, and communication interfaces and behavior of test components. The MTC, the ESB, and SUTs specified in the script start their operation with the test script run on a test execution engine. All of the messages delivered between SUTs are sent to the MTC through the proxy service running on the ESB. The proxy service clones incoming messages and sends them to the MTC as well as the original destination. The MTC determines if the test case is pass or fail based on TTCN XML matching and mapping mechanisms.

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6 REFERENCES


