Report on the Common Information Model (CIM) Extensible Markup Language (XML) Interoperability Test #2

The Power of the CIM to Exchange Power System Models

Technical Report

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The Power of the CIM to Exchange Power System Models

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REPORT SUMMARY

The Control Center Application Program Interface (CCAPI) and Common Information Model (CIM) translated into Extensible Markup Language (XML) provide a very important standard for exchanging power system models. Interoperability tests conducted in December 2000 validated the use and acceptance of this standard by a number of suppliers who provide products to the electric utility industry. A second set of interoperability tests conducted in April 2001 extended this validation to include the transfer of a large real-world power system model and the running of power flow solutions on exchanged models. This report presents results of these tests.

Background

EPRI spearheaded an industry-wide CCAPI effort to develop open, interoperable applications for Energy Management Systems (EMS) in energy control centers through use of standardized interfaces. Central to the CCAPI concept is CIM, which defines the essential data structure of a power system model. The North American Electric Reliability Council (NERC) had been searching for the best way to exchange power system models electronically, and CIM using the industry standard language XML offered the best solution. The CCAPI project initiated an effort to map CIM into XML, which is supported by all major software platforms. Use of the Resource Description Framework (RDF) schema and syntax to organize XML also was adopted. To validate XML and RDF for model exchange, a series of interoperability tests between products from different suppliers was planned.

Objective

To report results of the second set of interoperability tests performed in Las Vegas on April 29 - May 1, 2001.

Approach

The project team prepared a formal set of test procedures to test the ability of vendor products to correctly import and export sample power system model files. After a period of preparation and preliminary testing, five vendors gathered in Las Vegas in April 2001 to have an impartial observer test their products. Four sample model files were available for this test (PsyCor small model [2 bus], ABB 40 bus, Alstom 60 bus, and Siemens 100 bus) in addition to a real-life large scale model from Duke Energy with over 1700 substations.

Results

The report provides a summary of the test process and results. The test process is first explained to aid in understanding test results, which are reported in a series of test matrices. For purposes of reporting on the tests, results are loosely organized into three categories:

1. Basic import/export of model files - tests an individual product's ability to correctly import and export power system model files based on CIM XML standards. One test goal was to validate changes made to CIM since the last set of interoperability tests.
2. Interoperability test - tests the ability of one vendor's product to correctly import a sample model previously exported by another vendor's product using CIM XML standards.
3. Solution test - verifies correct content of model files and exchange and transformation of power system model files including generation and load through execution of power flow applications. Verification was accomplished by comparing solutions before and after transformation and model exchange. Two of three vendors with power flow applications successfully completed all significant solution tests.

A description of tested vendors' products is provided. A summary of problems uncovered during testing and their resolution also is included.

EPRI Perspective

CCAPI compliance offers control center managers the flexibility to combine—on one or more integrated platforms—software that best meets their energy company's needs for system economy and reliability. This compatibility allows managers to upgrade, or migrate, their EMS systems incrementally and quickly, while preserving prior utility investments in custom software. Migration reduces upgrade costs by 40 percent or more and enables energy companies to gain strategic advantages by using new applications as they become available.

At the same time, as market forces accelerate the pace of the changing business environment for energy companies, the need for greater business and operating flexibility also has increased. Such responsiveness requires that all members of a business enterprise pool their talents and resources. An energy company's information is one of its most valuable resources, and energy companies are working to improve accessibility to this critical resource, whether it be real-time data on power system operation, energy billing information, or load forecasting data.

CCAPI/CIM-enhanced EMSs foster an interdisciplinary approach to conducting business by enabling interdepartmental teams to access a range of needed information via open systems. Hence, in innovative applications, energy companies are planning to implement CCAPI and CIM outside the control center to reduce costs and improve customer service and staff productivity. EPRI continues to sponsor collaborative efforts to advance CCAPI and CIM capabilities for greater information systems integration solutions—in the control center and beyond.

Keywords

Application program interface	Control centers	Energy management systems
Common information model	CIM	XML
Data exchange	Power system model	
Power system reliability	Power system security	

PREFACE

The reliability of the North American power grid is an increasingly visible topic in the news today. This is due in large part to the need to operate closer to available transmission capacities than at any time in the history of the electric utility industry. Ever-increasing demand in the face of reduced power plant construction is a major factor - evidence the recent rolling blackouts in California.

One way to tackle the reliability issue is to improve the models of the power system used to calculate available transmission capacity, so that calculated capacities more nearly match real world capacities. This permits operation closer to maximum capacity while avoiding unplanned outages. One key to improved models is to have the capability to merge NERC regional models into a combined model. Since these models reside in multiple, proprietary databases in Security Coordination Center EMSs located throughout North America, an information infrastructure that facilitates model exchange is an absolute necessity.

One initiative underway to address this need is based on the Common Information Model (CIM) standards that EPRI helped develop as part of the Control Center Application Program Interface (CCAPI) project. The CIM has been translated into the industry standard Extensible Markup Language (XML), which permits the exchange of models in a standard format that any EMS can understand using standard Internet and/or Microsoft technologies. The North American Electric Reliability Council (NERC) recently mandated the use of this standard by Security Coordination Centers (SCCs) to exchange models by September 2001, adding urgency to the deployment of products that support these standards.

This report presents the results of the second interoperability tests using these standards to exchange power system models between products from five different vendors. The goal of this report is to raise awareness of the importance and status of this effort to encourage early adoption by additional product suppliers and energy managers.

David L Becker
EPRI
May 2001

ABSTRACT

On April 29 – May 1, 2001 in Las Vegas, Nevada, five software vendors serving the electric utility industry met for the second time to continue testing the capability of their software products to exchange and correctly interpret power system model data based on the CIM (Common Information Model). The CIM was developed by the EPRI CCAPI project and is now being advanced as an international standard (draft IEC 61970-301 CIM Base). Each vendor present was required to exchange files with the other vendors and to demonstrate that their software correctly converted their proprietary representation of a power system model to/from the CIM XML format.

These interoperability tests address an important industry requirement established by NERC to be able to transfer power system model data between Security Coordinators. NERC has mandated the use of the Resource Description Framework (RDF) as the XML schema/syntax for the CIM, which is defined in another CCAPI standard (draft IEC 61970-501 CIM RDF Schema). These tests demonstrated the use of this draft standard for this purpose and for any other application where a standard way of representing power system models is needed, such as combining multiple, proprietary-formatted power system models into a single merged internal model for an RTO.

Vendors participating in these tests included ABB, ALSTOM ESCA, Siemens, SISCO, and CIM-Logic. Xtensible Solutions prepared the test procedures, witnessed the test results, and will prepare a test report for EPRI. This is an important milestone in the CCAPI project and is the second in a series of planned interoperability tests for 2001 that will demonstrate additional CCAPI capabilities.

ACKNOWLEDGMENTS

EPRI wishes to thank the many people who worked hard to make this second CIM XML interoperability test a success. Not all people who contributed can be named here. However, EPRI would like to give special recognition to the following vendors and contractors:

- Steve Widergren, ALSTOM ESCA, for leadership, assistance with test procedure preparation, and assistance in obtaining permission to use the Duke Energy power system model
- Arnold deVos, Langdale Consultants, for test tools and preparation of the CIM UML and RDF schema files
- Joe Evans, PsyCor, for preparation of the small model, updating of NERC profile in the CIM, and provision of the LAN server for model management during the tests
- Mostafa Khadem, ABB, for preparation of the 40 bus model
- Rob Fairchild, ALSTOM, for preparation of the 60 bus model
- Kurt Hunter, Siemens, for preparation of the 100 bus model
- Robert Kingsmore, Duke Energy, for providing the 1700 substation large scale model
- All participants, for bringing enthusiasm and focused energy with a true spirit of cooperation to Las Vegas to make these tests a success
- The author apologizes if others deserving of special mention were not listed – it was not intentional.

In addition, EPRI acknowledges Terry Saxton, Xtensible Solutions, who prepared the test plan and procedures, witnessed the tests and recorded the results, and wrote this report.

Dave Becker
EPRI

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1 INTRODUCTION

This document reports the results of the second CIM XML interoperability tests, which took place on April 29 – May 1, 2001 in Las Vegas, Nevada. Interoperability testing proves that products from different vendors can exchange information and request services based on the use of the IEC standards that have been developed as an output of the CCAPI project.

The test required that participating products conform to the future IEC 61970-301 CIM Base, which is based on the CIM model file cimu09b.mdl and the future IEC 61970-501 CIM RDF Schema Version 4.

This test was the second in a series of CIM XML interoperability tests planned for the near future (see Section 4 for future test plans).

Objectives of Interoperability Test

The objectives of the interoperability tests and demonstrations were to:

1. Demonstrate interoperability between different vendor products based on the CIM. This includes applications from EMS as well as independently developed applications from third party suppliers.

2. Verify compliance with the CIM for those CIM classes/attributes involved in the information exchanges supported by the tests.

3. Demonstrate the exchange of power system models using the CIM and an RDF Schema and XML representation of the model data.

Secondary objectives included the following:

1. Validate the correctness and completeness of IEC draft standards, resulting in higher quality standards by removing discrepancies and clarifying ambiguities.

2. Provide the basis for a more formal interoperability and compliance test suite development for CCAPI standards. This would eventually become part of set of UCA 2 test procedures and facilities currently being developed by EPRI.

Specific objectives for the second interoperability test fell into three categories:

1. Redo a portion of the small model exchange based on updated CIM version 09b to validate the model changes from version 09a and the ability of participant's products to handle changes. This is referred to as the ***"CIM 09b Validation"*** test.

2. Transfer of larger, more realistic power system models which include generation and loads. This is referred to as the "***scalability***" test.

3. Execution of load flow/power flow applications to verify sufficiency of the model files (in terms of having all necessary elements represented) and correctness of the transformations to/from local representations of the models. This is referred to as the "***solution***" test.

Scope of Interoperability Test 2

This second interoperability test involved CIM XML file exchanges using model files similar to the first tests, except that in a large scale power system model from Duke Energy was used in addition to smaller sample model files and an updated version of the CIM was used (i.e., CIM version 0u09b).

CIM 09b Validation Tests

To meet the first objective of validating the updated CIM version 09b, a subset of the same procedures used in the first interoperability test (after updating to add changes agreed to during the first test) were used.

Scalability Tests

To meet the second objective of exchanging larger, more realistic power system model files than were used in the first test, an actual power system model from Duke Energy was used. This tested the scalability of the draft IEC standards and participant's products.

The actual size of the model can best be gauged by noting the instances of the major classes represented in this model:

Company - 12 instances

HostControlArea - 12 instances

SubControlArea - 13 instances

Line - 3095 instances

ACLineSegment - 4334 instances

Substation - 1752 instances

VoltageLevel -2305 instances

BaseVoltage - 40 instances

BusbarSection - 1162 instances

Breaker - 16347 instances

PowerTransformer - 1090 instances

TransformerWinding - 2180 instances

SynchronousMachine - 308 instances

ThermalGeneratingUnit - 308 instances

GenUnitOpSpec - 308 instances

Compensator - 507 instances

TapChanger - 451 instances

LoadArea - 308 instances

EnergyConsumer - 2063 instances

MVArCapabilityCurve - 566 instances

CurveSchedData - 1318 instances

Terminal - 47582 instances

ConnectivityNode - 16890 instances

These tests validated that a CIM XML file of real-life power system model data generated by one vendor's application could be used by another vendor's application.

Solution Tests

To meet the third objective of running load flow applications, smaller but complete sample models containing generation and loads were used.

Scope of the CIM Tested

The portion of the CIM that was tested is defined in the NERC Profile for power system model exchange. This profile contains the selected CIM classes, attributes, and relationships defined in the Minimum Data Requirements document produced by the NERC DEWG to model transmission substations, lines, and loads sufficient to run State Estimation and subsequent Power Flow/Contingency Analyses applications (see Reference 1).

Organization of Report

This report presents results of the second CIM XML interoperability tests held in Las Vegas.

The introductory chapter presents the objectives and scope of these tests. Chapter 2 describes the test plan that was followed and identifies the participating vendors and their products. Chapter 3 presents the test results, beginning with a summary of each test step that was scored. The test scores, which are given as Pass, Pass with Errors, or Not Applicable, are organized in a series of tables. A summary of the significant results achieved are also provided. The three appendices contain a description of the participant's products used in the tests (Appendix A); the test configuration data, including specific versions of the CIM in UML and XML/RDF, sample model files, and test tools (Appendix B); and issues and resolutions that arose during the tests (Appendix C).

References

1. CPSM Minimum Data Requirements in Terms of the EPRI CIM, version 1.0
2. CIM XML Interoperability Test 2, Test Plan and Procedures, Revision 3, April 28, 2001.
3. Report on the First Common Information Model (CIM) Extensible Markup Language (XML) Interoperability Test, The Power of the CIM to Exchange Power System Models, Product Number 1006161, Final Report, February 2001.

2
THE TEST PLAN

Each application participating in this test was required to (1) generate and export a file that conformed to the standards for the specific model data defined for the test and/or (2) import a file from another vendor's product and correctly interpret the model data contained. A formal set of test procedures were prepared and used to conduct and score the tests (see Reference 2). In addition, participants were also given the opportunity to run power flow solutions on the imported files as another way to validate the proper handling of imported models.

Participating Vendors and Their Products

Each participating vendor was required to use an actual product so that testing would demonstrate interoperability of real products. The participating vendors and their products are listed in Table 2-1 below. Table 2-1 also describes the hardware platform and operating system used.

Table 2-1
Participating Vendors and Their Products

Vendor	Product Name	Platform	OS
ABB	DE400 SPIDER CIM Data Engineering and Oracle V. 8.1.6	DEC Alpha station 500	UNIX 4.0F
ALSTOM	GENESYS - eterra-Modeler and Study Powerflow	IBM-compatible Laptop PC	Windows 2000
CIM-Logic	JCIM	IBM-compatible Laptop PC	Windows 2000
Siemens	Spectrum Information Model Manager (Engineering System)	IBM-compatible Laptop PC	Windows 2000
SISCO	Utility Integration Bus (UIB)	IBM-compatible Desktop PC	Windows NT 4.0, SP6

A description of each product used in the tests is contained in Appendix A. These descriptions also explain how the CIM XML data is used in the product and how successful compliance with the CIM XML format was demonstrated.

Test Approach

As stated in the Introduction, there were three major categories of tests – a CIM 09b Validation test, a Scalability test, and a Solution test. Participants were encouraged to perform either one, two, or all three of these tests.

The CIM 09b Validation and Scalability tests were performed by participants with the same class of products used in Interop Test 1 (i.e., modeling or browser tools alone were sufficient to demonstrate correct operation).

The Solution test, however, required the use of power flow applications to operate on the power system models to calculate power flow solutions. Solutions obtained were used to validate the correct transfer and transformation of model files between participants. The Solution tests used the same model files as the CIM 09b Validation tests to create confidence that the appropriate information is being exchanged and interpreted correctly, thus avoiding performance issues associated with large models, whose solutions can be checked in future tests.

Pretest Preparation

Prior to the official witnessed interoperability tests, sample model files were prepared by PsyCor (small model), ABB (40 bus), ALSTOM (60 bus) and Siemens (100 bus) to be used during the tests. These files contained instances of the CIM classes, attributes, and relationships defined in the NERC profile. For example, the PsyCor model contained two substations connected by a single AC line. The ALSTOM file, termed the 60 bus model, contained 29 substations interconnected by 41 AC lines. Participants applications were only tested for the entities specified in the NERC profile. The models were intentionally kept small to ensure that file size and performance would not be issues in these first tests.

The Duke Energy model used for the Scalability test, on the other hand, contained 1752 substations with 3095 AC lines (see Introduction for more details on this model). Because of the sensitive nature of real models, nominal generation and load values were used and non-disclosure agreements were signed by test participants to gain access to the models. The model file use was restricted to uses concerned only with interoperability testing.

All of the test files were available before the formal testing began to allow participants to checkout and debug their software as well as to discover any discrepancies or errors in the files themselves.

Basic Export/Import Process

Figure 2-1 shows the process applied by the products under test to export and/or import CIM XML files (also referred to as CIM XML documents). For export, an XML/RDF version of the CIM is used by a product to convert a proprietary representation of one of the sample model files into a standard CIM XML representation of that model. The CIM XML document can then be viewed through a browser using an XSL Style Sheet to format the contents for human readability. Separate XML tools are used to validate the format of the file and the conformance with XML and the RDF Syntax. An XML/RDF Validator tool was prepared and packaged for use during this test.

For import, the product converts from the standard CIM XML representation to the product's proprietary internal representation. Product specific tools are used to validate the import was successful.

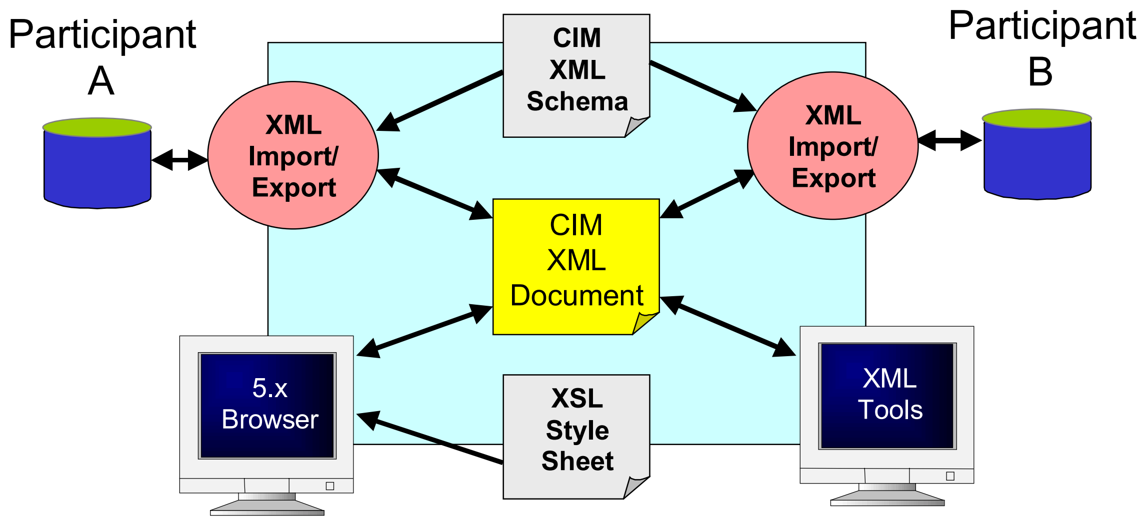

Figure 2-1
Export/Import Process Basics

On-Site Interoperability Test

All five participants in this test spent three full days at the test site in Las Vegas, Nevada. Participants brought their hardware/software and connected to a shared Ethernet LAN set up in the test room. The model files used for testing were loaded onto a LAN server. The sample model files and files successfully exported by a participant's product were loaded to the server so that other participant's could access these files for testing their import capability.

Participants were allowed to correct deficiencies or errors found during testing and then, as time permitted, be retested. All testing was stopped at 5:00 PM on the third day. The final test results achieved at that time are recorded in the test matrices provided below.

Scalability and CIM 09b Validation Testing

Both the Scalability and CIM 09b Validation Testing was accomplished in two parts. First, each participant's product had to demonstrate correct import/export from/to the standard CIM XML/RDF format. This showed to the extent measurable product *compliance* with the standard. Second, each participant able to successfully export a file to the CIM XML/RDF format then uploaded that file to the LAN server to make it available for the other participants to import. This tested *interoperability* of different vendor's products.

The basic steps involved are illustrated in Figure 2-2 below. Each participant (Participant A in Figure 2-2) was first required to import the CIM XML-formatted test files (CIM XML Doc 1) from the server and demonstrate successful conversion to their product's proprietary format (step 1). If the product had an internal validation capability to check for proper connectivity and other power system relationships, that was used to validate the imported file. If the import was successful, the file was then converted back into the CIM XML format (step 2) to produce CIM XML Doc 2, which should be the same as the original. Participant A was required was required to demonstrate compliance by running the XML/RDF validator tool on the exported file (step 3). If successful, the exported file was then be re-imported and compared with the original model to verify that no changes were introduced in the process of converting to the CIM XML format and then back again to the internal product format (Step 4).

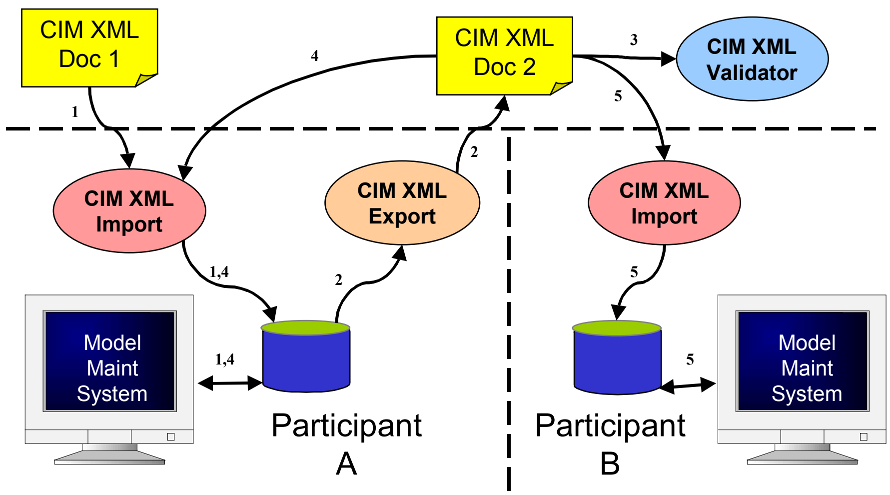

Figure 2-2
CIM XML Interoperability Test Process Steps

At this point the exported file was also loaded onto the LAN server for another participant (Participant B in Figure 2-2) to import and verify that the model imported is in fact the same as the model initially stored in Participant A's application (Step 5). This final step demonstrates interoperability of different vendor's products through use of the CIM XML/RDF standard. (It should be noted that the steps described in this figure are for illustration only and do not correspond directly with the test procedure steps outlined in Table 2-1 below.)

Solution Test

The Solution test was intended to verify the correct exchange and transformation of power system model files including generation and load through the execution of power flow applications. Verification was accomplished by a comparison of solutions before and after transformation and model exchange, as illustrated in Figure 2-3.

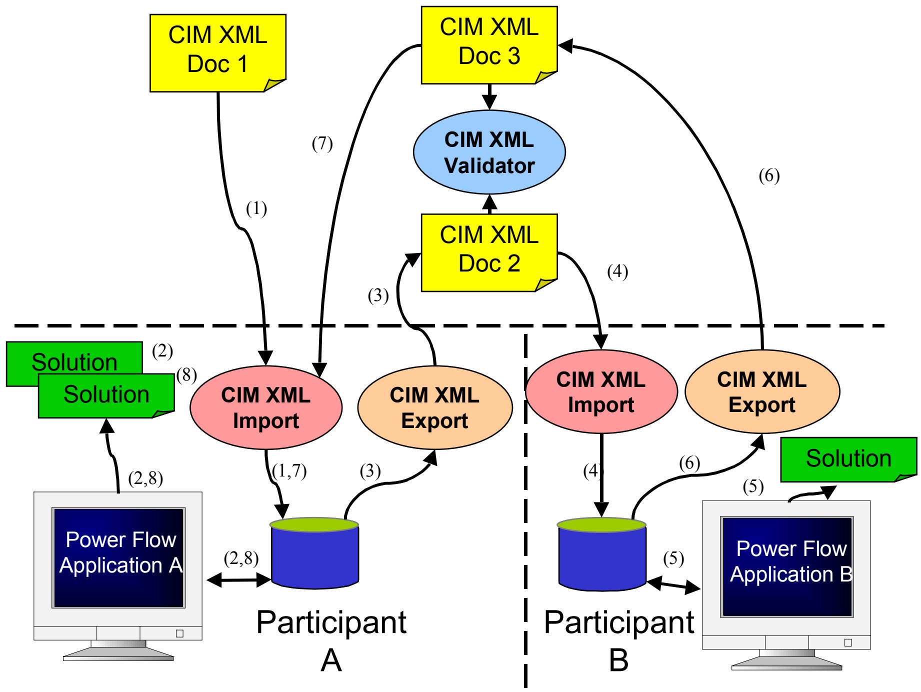

Figure 2-3
Solution Test Process

The steps for this process were as follows:

1. Participant A imported a standard power system model file (CIM XML doc 1) and converted to local representation. The imported model in local representation was then validated using participant's display tools.

2. Participant A then ran a power flow and saved the solution.

3. Participant A exported a file, creating CIM XML Doc 2.

4. Participant B imported CIM XML Doc 2 and converted to local representation. The imported model in local representation was then validated using participant's display tools.

5. Participant B then ran a power flow and checked to verify correct operation. Comparison with Participant A's results from step (2) was the first measure of success for this test.

6. Participant B then exported a file, creating CIM XML Doc 3.

7. Participant A imported CIM XML doc 3 and converted to local representation. The imported model in local representation was then validated using participant's display tools.

8. Participant A then ran a power flow and compared results with the solution obtained in step (2) to determine if the solutions matched within a reasonable margin, which was the second measure of a successful test[1].

The reason for a complete round trip is recognition that solutions generated by Power Flow applications from different suppliers may be different and not readily comparable.

Any of the sample model files could be used for this test. The following instance data was provided for each Sample Model to be used in this test as part of the CIM XML document contents:

- Generation values
- Load values
- Transformer settings
- Generator voltage control values
- Device states
- MVAr values for shunt Compensators

Test Configuration

The details of the specific files used at the beginning of the testing period are specified in Appendix B. This appendix contains file names for the CIM ROSE model, the RDF schema, RDF syntax definition, and sample model files. As testing progressed and problems were discovered and resolved, updates were generated to some of these files.

1 The solutions of multiple runs of a power flow after exporting and re-importing from another participant were expected to result in consistent solutions with reasonable differences that result from model translation to local representation.

3
TEST RESULTS

This section presents the results of the interoperability tests. First, the individual tests that were performed and scored are summarized below. This is followed by the test matrices with scores shown for each test. For details on each test step, including setup required and step-by-step procedures, see the Test Procedures document (Reference 2).

Table 3-1
Description of Tests Performed

	CIM 09b Validation
1	**Basic Import**
1.1	Participant A import small model and demonstrate import was done correctly
1.2	Participant A import 40 bus model and demonstrate import was done correctly
1.3	Participant A import 60 bus model and demonstrate import was done correctly
1.4	Participant A import 100 model and demonstrate import was done correctly
2	**Basic Export**
2.1	Participant A export small model and run validator
2.2	Participant A export 40 bus model and run validator
2.3	Participant A export 60 bus model and run validator
2.4	Participant A export 100 bus model and run validator
3	**Interoperation** - Participant B import of Participant A exported CIM XML file.
	Scalability Test
4	**Basic Import** – Participant A import Duke large scale model
5	**Basic Export** – Participant A export Duke large scale model
6	**Interoperation** - Participant B import of Participant A exported Duke large scale model CIM XML file.
	Solution Test
7	**Import Sample Model (Doc-1)**

8	**Run Power Flow application and save solution (Sol-1)**
9	**Export sample model (Doc-2)**
10	**Import previously exported sample model file (Doc-2) from another participant**
11	**Run Power Flow application and save solution (Sol-2)**
12	**Compare Sol-1 with Sol-2**
13	**Export sample model (Doc-3)**
14	**Import Doc-3 from another participant**
15	**Run Power Flow application and save solution (Sol-3)**
16	**Compare Power Flow Sol-1 with Sol-3**

Summary of Test Results

The following sections report the highlights of the testing.

CIM 09b Validation

Basic Import and Export

Table 3-2 shows the results of the tests on the individual products to determine compliance with the CIM version 09b XML/RDF standards. The primary objective of this test was to successfully import and export one of the sample model files to show compliance, although all sample model files were available for further demonstration of interoperability. All of the participants were able to pass this test. Highlights of the tests are as follows:

- All participants were able to successfully import at least one model file correctly converting from the CIM XML format to their internal proprietary format. Thus all participants were able to demonstrate compliance with the latest Version 9b of the CIM on import.
- CIM-Logic, Siemens, and SISCO successfully imported all the sample models available.
- All of the participants able to export a model file did export at least one file successfully, thus demonstrating compliance with version 9b of the CIM for export.
- CIM-Logic and Siemens exported all sample model files successfully.

Table 3-2
CIM 09b Validation Test Results on Individual Products

Test Procedure	1. Basic Import				2. Basic Export			
Test Number	1 Small Model	2 40 Bus Model	3 60 Bus Model	4 100 Bus Model	1 Small Model	2 40 Bus Model	3 60 Bus Model	4 100 Bus Model
ABB		O	PE[1]	P		O	PE[2]	P
Alstom			O	PE[4]			O	P
CIM-Logic	P	P	P	P	P	P	P	P
Siemens	P	P[3]	P	O	P	P	P	O
SISCO	P	P	P	P	N/A	N/A	N/A	N/A

Notes:
P (Passed) – all aspects of the test were performed successfully
PE (Passed with Errors) – most aspects of the test were performed successfully
O – Originator of model (Model originators did not import or export their own models in this test step.)
Blank entry – indicates test was either skipped or not witnessed
N/A (Not Applicable) - product does not support the functionality to perform this test

1. Node numbers changed, causing loss of connectivity in RDE (may be only display problem), so Transformer values could not be validated. Also Rated MW is needed for Transformer for internal validation, but not provided by Alstom. In Condenser class, Alstom exports non-NERC profile attribute of MVARperSection of nominalMVAR (for whole Condenser)
2. Some information was missing in exported file, and the RatedMW values for Transformers were set to 0. Did not reimport file.
3. Errors were detected in the ABB 40 bus model import when internal validation was run. The ABB data included HeatRateCurves (a subtype of CurveSchedule), which are not a part of the NERC profile. The HeatRateCurves had associated CurveSchedData children. When Siemens imported the data, the CurveSchedData instances associated with HeatRateCurves were not imported. Siemens does not import CurveSchedData instances, if the associated CurveSchedule is not in the NERC profile. ABB uses Ground class (not recommended). AC Line Segments specify a member of Equipment Container relationship to themselves. Enumerated values do not follow CIM standard.
4. ALSTOM's export of 100 bus model changed attribute names and also changed values for Transformer Winding attributes r and x.

Interoperation

This section documents the pairs of vendors that were able to demonstrate interoperation via the CIM XML formatted-model file. Though the CIM XML documents are from different parties, the test verification for import and export followed the same pattern as done on the tests of individual products above.

Table 3-3 is a matrix of results for the interoperability testing. The rows show the source of an exported file. Each column represents an importer for an exported file. For example, the cell (row ALSTOM, column CIM-Logic) indicates the result of the interoperability test of CIM-Logic importing CIM XML documents exported by ALSTOM ESCA.

The entries in each cell should be interpreted as follows:

- P – Pass. Indicates a successful import of another participant's exported file. The specific sample model file imported is indicated.
- PE (Passed with Errors) – most aspects of the test were performed successfully
- N/A - Product does not have export functionality
- Blank (no entry) – indicates test was skipped, not witnessed, or an exported model file was not available for import.

All participants with functionality to export a file did so successfully and then made that file available on the LAN server for other participants to import. Therefore, a blank entry in a column indicates that the participant whose name is at the heading for that column did not demonstrate an import of that file.

These tests demonstrate true interoperability by exchanging CIM XML documents produced by different participants. A Pass indicates that a pair of vendors successfully demonstrated the exchange of a power system model file using the CIM XML format. The specific model file exchanged is also identified.

Highlights of the tests are as follows:

- 16 pairs of vendors were able to interoperate successfully by exchanging at least one sample model file.
- Two vendors successfully imported three files exported by other vendors.

Table 3-3
Interoperation with Sample Models

Export	3. Import					
	ABB	ALSTOM	CIM-Logic	Siemens	SISCO	
ABB			**P** small model	**P**[2] 100 bus	**P**[5] 100 bus	
ALSTOM			**P**[1] 100 bus	**PE**[3] 100 bus		
CIM-Logic		PE[4] **60 bus**		**P** – small model **P** - 60 bus **P** - 100 bus	**P** – small model **P** - 60 bus **P**[6] - 100 bus	
Siemens	PE **40 bus**		**P** 60 bus		**P** – small model **P** - 60 bus	
SISCO	**N/A**	**N/A**	**N/A**	**N/A**		

Notes:
1. ALSTOM's export of 100 bus model changed attribute names and also changed values for Transformer Winding attributes r and x.
2. A number of errors were detected in the ABB exported version of the Siemens 100 bus model.
3. ACLineSegment names in the ALSTOM exported Siemens 100 bus file did not match the original Siemens ACLineSegment names.
4. GeneratingUnitOpSpec relationship to GeneratingUnit not handled properly.
5. See Problem report #5
6. See Problem report #4

Scalability

This test used the same test procedures as used for the CIM 09b Validation test, except that participants imported and exported the Duke Energy large system model.

Due to the size of the model and the time required to import and validate, it was suggested that participants come prepared with a Duke Energy CIM XML document that they had already been created (exported) ahead of time. That meant that they had already imported and validated the model off-site as well as exported it for use by other participants, hopefully prior to the on-site testing. To get credit for a successful import and internal validation, participants had to bring a database and display capability to permit an observer to check on-site that the model was imported correctly. The exported model was validated on-site as well using the XML Validation tool.

Due to the size of the model and the time required to import and validate, it is not expected that all of the matrix of possible interactions will be tested. A participant was instructed to choose one or two of the other participant's large model exported documents to import until success is achieved. Then, as time permits, additional exported models could be attempted.

Duke Model Import and Export

Table 3-4 shows the results of the on the individual products to import and export the large scale Duke Energy model. The XML Validator tool initially experienced problems when applied to this large scale model, but was revised to eliminate the scaling problems. Unfortunately, the revised version was not available until later in the tests, so not all participants were able to demonstrate validation with the tool.

Highlights of the test are as follows:

- All of the participants were able to successfully import the Duke Energy model
- All participants (except for SISCO, which does not have an export capability) were able to successfully export the Duke Energy model .

Table 3-4
Scalability Test on Individual Products

Test Procedure	4. Duke Model Import	5. Duke Model Export
ABB	PE[1]	PE[1]
Alstom	P[3]	P
CIM-Logic	P	P[2]
Siemens	P	P[2]
SISCO	P	N/A

Notes:
P (Passed) – all aspects of the test were performed successfully
PE (Passed with Errors) – most aspects of the test were performed successfully
N/A (Not Applicable) - product does not support the functionality to perform this test

1. Rated MVA not provided in model, so RDE tool calculates r, x = 0 for Transformer Winding, which prevents model use and causes errors in exported model file.
2. Validator not run on exported file.
3. Internal validation reported some errors that were not able to be properly analyzed during the test period.

Interoperation with Duke Model

This section documents the pairs of vendors that were able to demonstrate interoperation via the CIM XML-formatted Duke Energy model file. Though the CIM XML documents are from different parties, the test verification for import and export followed the same pattern as done on the tests of individual products above.

Table 3-5 is a matrix of results for the interoperability testing. The rows show the source of an exported file. Each column represents an importer for an exported file. For example, the cell (row ALSTOM, column CIM-Logic) indicates the result of the interoperability test of CIM-Logic importing CIM XML documents exported by ALSTOM ESCA.

The entries in each cell should be interpreted as follows:

- P – Pass. Indicates a successful import of another participant's exported file. The specific sample model file imported is indicated.
- PE (Passed with Errors) – most aspects of the test were performed successfully
- N/A - Product does not have export functionality
- Blank (no entry) – The column participant did not demonstrate an import of the file exported by the row participant.

All participants with functionality to export a file did so successfully and then made that file available on the LAN server for other participants to import. Therefore, a blank entry in a column indicates that the participant whose name is at the heading for that column did not demonstrate an import of that file.

These tests demonstrate true interoperability by exchanging CIM XML documents produced by different participants. A Pass indicates that a pair of vendors successfully demonstrated the exchange of a power system model file using the CIM XML format. The specific model file exchanged is also identified.

Highlights of the tests are as follows:

- Ten pairs of vendors were able to interoperate successfully by exchanging the Duke Energy model file, thus demonstrating scalability of their products to handle larger model files. However, import times varied from 20 minutes to import directly to an Oracle database to several hours for import into an engineering/modeling tool capable of displaying one-line diagrams.

Table 3-5
Interoperation with Duke Energy Model

		Import					
		ABB	**ALSTOM**	**CIM-Logic**	**Siemens**	**SISCO**	
Export	**ABB**			**P**	**P**		
	ALSTOM	**P**		**P**	**P**	**P**	
	CIM-Logic				**P**	P	
	Siemens			**P**		**P**	
	SISCO	**N/A**	**N/A**	**N/A**	**N/A**		

Solution Test

Power Flow Applications produce MW and MVar flows for each line in the model. The MW & MVar flows are a direct function of the voltage difference between the two ends of a line and the resistance of the line. They serve as a check on the transfer of the characteristics of a line (topological connectivity and impedance), but are direct derivatives of the voltage.

As part of the solution, each Power Flow Application was asked to produce a table of bus voltage and voltage angle readings for each bus in the model. To evaluate power flow solutions, the tables produced by two different executions of a Participant's Power Flow Application were compared.

If the models used for both executions are identical, then the solutions should be very close, although identical solutions are not expected due to the small effects of conversions between participants. If the models are identical, but different Participant's applications are used, again the table values are not expected to be identical, but should be consistent and within a reasonable range of each other.

It should be kept in mind that the purpose of the test was not to evaluate different Participant's Power Flow Applications, but rather to ensure that the contents and format of the CIM XML documents exchanged are sufficient to permit each Participant's product to converge on a solution.

Table 3-6 shows the results of each of the steps in the Solution test. Highlights of the Solution test are as follows:

- Two of the three participants with power flow applications successfully completed all the significant solution tests (only an export step was not done for lack of time). ABB chose not to attempt the Solution test.
- Alstom and Siemens were able to successfully import a sample model file, run their Power Flow application (solution 1), and export.
- Alstom and Siemens were able to import a model file previously exported by another participant and successfully run their Power Flow application (solution 2), thus demonstrating that the contents of the CIM XML document are adequate for running Power Flows.
- Siemens was able to compare two sets of solutions (1 and 2, 1 and 3). In one case, the solutions were almost identical, in the other there was a close match for MW flows, but differences in Mvar flows, bus voltage, and angle were significant.
- Alstom was able to compare solutions 1 and 3. Solutions were almost identical. Alstom was not able to compare solutions 1 and 2, since different sample models were used for each.
- Bottom line: The contents and format of the power system model files exchanged with the CIM XML file representation are adequate for running power flow applications, and the no significant data was lost during data transformations to/from the CIM XML format.

Table 3-6
Solution Test Results

Test Number	7 Import doc-1	8 Run PF sol-1	9 Export doc-2	10 Import doc-2	11 Run PF sol-2	12 Compare sol-1, sol-2	13 Export doc-3	14 Import doc-3	15 Run PF sol-3	16 Compare sol-1, sol-3
ABB										
Alstom	P 100 bus	P 100 bus	P 100 bus	P 60 bus from CIM-Logic	P 60 bus from CIM-Logic	N/A		P 100 bus from Alstom via CIM Logic	P	P[1]
CIM-Logic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Siemens	P 60 bus	P 60 bus	P 60 bus	P 60 bus from ABB	P 60 bus from ABB	P[1]		P 60 bus from Siemens via CIM-Logic	P	P[2]
SISCO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

1. Very close match of solutions (transformer and line flows identical, slight differences in bus voltage and angle
2. MW close match, but differences in Mvar flows, bus voltage, and angle were significant

Summary of Issues Identified

Another output of the testing effort was the identification of issues that affect interoperability, either in the CIM documents themselves, in the sample model files, or in the test procedures. Every attempt was made to resolve issues during testing so that a common resolution could be adopted and implemented by each participant, followed by a retest.

The following is a summary of the issues that were identified organized by category and how they will be resolved. The detailed problem reports with resolutions and status are contained in Appendix C:

- CIM issues for the most part require resolution by the IEC WG13 responsible for the CIM standard, so resolutions were not reached and these are open issues.
- NERC CPSM profile issues are suggestions to the DEWG for changes to improve interoperability or for adopting conventions about how to constrain the flexibility in the CIM model for consistent use in exchanging power system models.
- Tool issues were resolved.
- Sample model file problems for the most part were corrected and revised on the spot, uploaded to the LAN server, and used for retest. However, in some cases, the suppliers of the models will be asked to make revisions before the next set of tests.
- Product issues are up to the participants to resolve.

4 FUTURE INTEROPERABILITY TESTS

Plans for future interoperability tests need to be defined. However, it is expected that they will include the following:

1. Opportunities for more participants to complete the tests used for this second interoperability test.

2. Duke Energy model with Powerflow Applications: Run Powerflow applications using a large scale model.

3. WAPA model with Powerflow Applications: Use the WAPA planning model after conversion to an operational model. Participants can run their Power Flow applications and demonstrate other applications (e.g., OPF and State Estimator), as available. This will test larger models with loads.

4. Incremental updates: Once a protocol has been specified to permit methods to be included in message exchanges and a process to handle incremental model updates is defined, then testing of this incremental update capability will be needed.

5. Additional applications: Run additional applications of exchanged model files, such as State Estimator and Optimal Power Flow.

6. Exchange of solved power flow solutions: This is an existing need that will be tested once a solution is defined.

Items 1-3 are important to NERC for the September 2001 deadline to exchange models using CIM XML. Items 4-6 are for future testing after this date.

A
APPENDIX: PARTICIPANT PRODUCT DESCRIPTIONS

This appendix contains descriptions of the different products used for the interoperability tests. The product descriptions were provided by the individual participants.

ABB Data Engineering Tool (RDE)

The test procedures related to CIM XML model exchange will be performed against the ABB data engineering tool (RDE).

The CIM schema has been implemented in an Oracle database. This CIM Oracle database will be used for both import and export processes.

We will be using ABB’s data engineering tool (RDE). This is also an Oracle database tool that allows view of the data as well as changing of the data. The runtime database system is populated by the RDE either as a full population or as an incremental population.

During the import process, data from the CIM database will be imported to the RDE. During the export process, data from RDE will be exported to the CIM database.

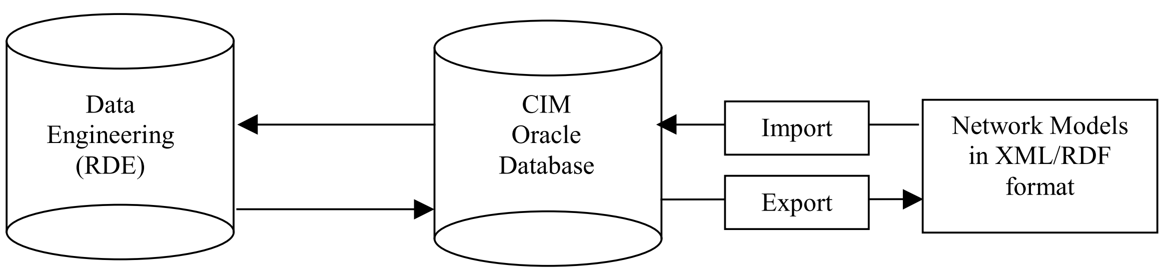

Figure A-1
ABB's Data Engineering Tool (RDE)

ALSTOM ESCA eTerra-Modeler and Study Powerflow

The test procedures related to CIM XML model exchange are to be performed against the ALSTOM eTerra-Modeler product (also referred to as the Modeler) and the Study Powerflow application.

eTerra Modeler

The Modeler is a power systems operations modeling tool for initializing EMS applications with the information they need for real-time operations. The tool is used to generate the power system models and maintain them. Import and export facilities are provided for bulk data import and export while a tailored user interface is used for manual additions, edits, and deletions of information as well as model browsing.

The tool runs in a Windows 2000 environment. Though the design supports a distributed configuration, all components will be located on a single NT platform for the purposes of this interoperability test. Model validation software is included which verifies the integrity of the model and prepares information for use by operational applications such as the Study Powerflow.

Study Powerflow

The Study Powerflow (aka Powerflow) is one of a suite of transmission network analysis applications that also includes State Estimation, Contingency Analysis, OPF, etc. These applications are designed for use by operators in an EMS environment. The Powerflow is initialized with information from the real-time system, other network analysis applications, or the Modeler. The last initialization option is what is used in this interoperability test.

The Powerflow is configurable to use several solution techniques and has many options with respect to how slack generation and other solution variables are handled. A distributed slack scheme is used for these tests.

Modeling Conventions

For this interoperability test, the following conversions between the Modeler information representation and the CIM XML representation are required:

- CIM Bays and VoltageLevels are represented as Equipment Groups in the Modeler.
- CIM BusSections are represented as nodes.
- CIM Condensers are a type of synchronous machine.
- All CIM switch types are modeled as switches.
- Grounds are not modeled as separate objects.
- Single terminal devices are interpreted as shunts.

CIM-Logic JCIM

The test procedures related to CIM XML model exchange are proposed to be performed against the CIM-Logic JCIM product.

JCIM is a stand alone data maintenance tool and also an integrated J2EE development environment. JCIM provides a flexible set of software tools based on a stable set of classes driven by a model specified in UML. These classes can access data from multiple data sources and make the data available to users with standard desktop browsers. Data can be imported to or exported from an Oracle8i relational database from CIM RDF format.

Siemens Information Model Manager

The test procedures related to CIM XML model exchange are proposed to be performed against the Siemens Information Model Manager and Optimal Power Flow products.

The Siemens Information Model Manager (IMM) is a component of the PowerCC product line. It provides the means to maintain power system model data for the configuration of EMS/DMS applications, SCADA and the communication to RTU’s, and ICCP. For the interoperability test only a subset of the data model is used.

The IMM provides import/export of bulk model data as well as a user interface to manually view and edit model data. The import/export format is compliant to the CIM/XML information exchange format. The IMM uses a repository driven by a schema compliant with the NERC CPSM profile of the CIM u09b.

The user interface provides a hierarchical view of the instances imported or manually edited. It allows creation of new instances, as well as modification of exiting ones. Instance data can be deleted selectively. Child instances in the hierarchy are recursively deleted in the same operation.

The import/export function of the IMM records errors in a log for further analysis while running an import. Import translates the RDF/XML document into the internal structure of the IMM repository. Export retrieves all data for a selected instance and exports it according to the defined profile.

Changes and extension of the current model data can be prepared independent of the current active model data in a session. An activation process applies the changes to the current model data and applications get notified about those changes. This part of the functionality is not used in the test environment.

The Optimal Power Flow is one of the functions within Siemens set of study and real-time Network Applications. It can be executed in dispatcher’s mode or optimization mode based on a variety of optimization criteria. For the purposes of this test, dispatcher’s mode is used.

The IMM and Network Applications uses a Window 2000 platform. Although it can be configured for a multiple server environment, the complete systems runs on a laptop for the interoperability test.

SISCO Utility Integration Bus

The test procedures related to CIM XML model exchange are to be performed against the CIM RDF import utility provided by SISCO as part of the Utility Integration Bus (UIB) product.

The UIB is a message broker based enterprise application integration product created to meet the unique needs of utilities. The UIB allows users to publish and subscribe to messages by selecting all or parts of the CIM schema/operational model as well as determine what parts of the schema/operational model are currently being published on the bus by UIB components.

The CIM test files are imported through the CIM RDF import utility provided by SISCO as part of the UIB product, as shown in the diagram below. The import utility stores the CIM RDF information in a meta-data repository supplied with the UIB product. Once the CIM schema definition and operational information files have been imported, UIB applications can browse this information via a Data Access Facility (DAF) interface.

An XML IOP application developed for these interoperability tests will be used to validate the CIM import capability of the UIB only, as shown below. There is no export capability for the model data, so those portions of the test procedure dealing with exporting of files will be skipped.

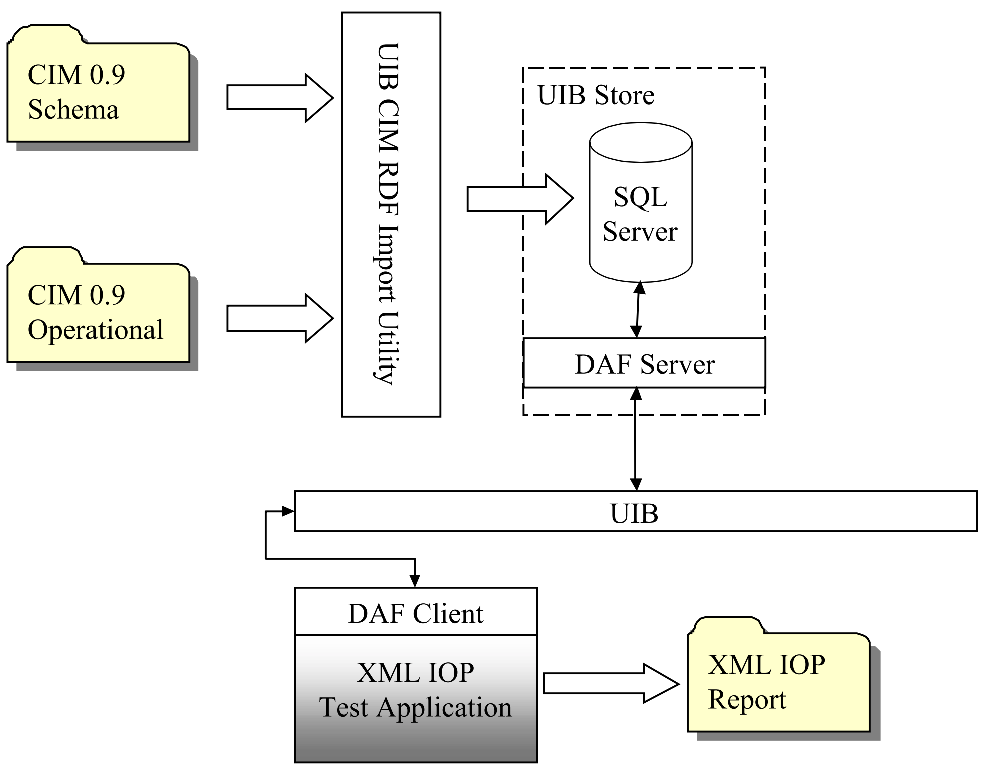

Figure A-2
SISCO Utility Integration Bus

This import capability will be demonstrated through the importing of two (2) CIM files (the 0.9b schema definition and the vendor supplied operational information CIM file). These files are imported through the CIM RDF import utility, provided by SISCO as part of the UIB product. The import utility will translate the CIM RDF information into a SISCO proprietary meta-data repository supplied with the UIB product. The repository is known as the UIB Store and shall use SQL Server as the database that stores the repository information. The UIB Store contains both schema and operational information.

SISCO supplies the UIB Store is with a UIB based Data Access Facility (DAF) wrapper that allows standardized access to the schema and operational information over the UIB via messages. A test application has been written to produce a text report, via DAF, that reflects the operational data imported stored within the UIB Store.

The UIB components being tested do not validate nor export the CIM information in regards to power system network information. Nor do the components make this information available except through the DAF interfaces provided by the SISCO UIB product.

The software to be tested by SISCO consists of the following:

Table A-1
UIB Toolkit Version 1.0

Message Broker	IBM MQSeries V5.1
UIB Store Repository	SQL Server 7.0
DAF Client Interface	SISCO Version 1.0
Operating System	Windows NT 4.0/ Service Pack 6

All software components are installed and located on a single Toshiba Satellite Laptop. The laptop resources are: 4G hard drive, 128MB of RAM, 366 MHz Intel Celeron.

XML Authority will be used to validate XML files.

B

APPENDIX: TEST CONFIGURATION DATA

Test Procedures

The test procedure for this series of tests was CIM XML Interoperability Test 2, Test Plan and Procedures, Revision 3, April 28, 2001 contained in the following file:

- Test procedures: cimxml test 2 plan rev3.DOC

CIM Baseline Version for Testing

The version of the CIM used for these tests was 09b. Specifically, the CIM RDF Schema version of this file was used. Any file generated or imported was required to conform to this RDF Schema, although only the classes , attributes, and relations defined in the NERC CPSM profile needed to be included.

The files used for the CIM UML and RDF schema were as follows:

- CIM ROSE UML file: cimu09b_010422.mdl
- CIM RDF Schema file: cimu09b_010422.rdf

RDF Syntax

The RDF syntax approved for these tests is the Reduced RDF (RRDF) Syntax defined by Arnold deVos. Files produced may contain syntax definitions beyond the RRDF Syntax, but only the RRDF Syntax was used to completely express the power system model in the file produced for testing. Participants reading files were expected to properly interpret the RRDF Syntax definitions contained therein but were not required to interpret and use any definitions beyond the RRDF Syntax.

The file used for the RDF syntax definition was as follows:

- CIM XML syntax definition: Simplified RDF Syntax 6.pdf

Test Files

Each participant was requested to post a sample model file that they have produced using the Reduced RDF Syntax approved for these tests. Each such sample file was accompanied by a one-line schematic diagram illustrating at least parts of the power system model defined in the file.

The test files provided for the sample models were as follows (final updates were made during the test):

- PsyCor small model: SmallModel_010424.zip
- ABB 40 bus model: ABB40bus_04-27-01.xml
- ALSTOM ESCA 60 bus model: esca60.cim9b.04_26_2001.zip
- Siemens 100 bus model: siemens100_RDF_9b_04-20-2001.zip

The Duke Energy model used is available only on a restricted basis.

Tools

The tools used for the interoperability testing were as follows:

- Validation tools: CIMValidate-2001-05-01.zip
- UML to RDF Converter tool: Xpetal-2000-12-16.zip

File Transfer

For sharing or transferring files between participant's systems was accomplished using a shared file server (provided by PsyCor) and connected to by all participants through a LAN switch (provided by ALSTOM ESCA).

C
APPENDIX: TEST ISSUES AND RESOLUTIONS

This appendix contains a list of the issues identified during the CIM XML interoperability testing organized by category. The status of the resolutions reached during the testing period are also reported. The open issues will be addressed within the CCAPI Task Force and IEC Working Group 13.

The issue categories include the following:

- CIM – issues dealing with the CIM model
- NERC CPSM Profile – issues with the format or content of the NERC CPSM profile definition of classes, attributes, and associations to be included in the sample model files, or the way the profile definitions are handled in UML or XML/RDF
- Products in Test – issues concerned with the specific product under test
- Tools – issues with the CIM XML validator tool

No.	Submitter	Category	Problem Statement	Suggested Resolution	Final Resolution and Status
8	Siemens-Hunter	CIM	Valid values for the tculControlMode attribute in the Tap Changer class need to be defined for the attribute to be useful for data exchange (enumeration vs. string)		Open
1	Siemens-Hunter	CPSM Profile	There is ambiguity in the CPSM profile: The CIM allows multiple MVAR capability curves for each synchronous machine, but there is no way to specify the default curve for power flow	Either a mechanism should be added to the CIM to define a default MVAR capability curve for each synchronous machine or the CPSM profile should be more restrictive and allow only one MVAR capability curve per synchronous	Open
9	Alstom-Widergren, Fairchild	CPSM Profile	ACLineSegment needs reference to BaseVoltage. At the moment, it contains reference MemberOfEquipmentContainer. This showed up in the Duke model import as exported by Siemens	The CPSM profile in Section 3.4.1 ACLineSegment (10 Apr 01) should require BaseVoltage (inherited by Conducting Equipment) and not MemberOf_EquipmentContainer.	Open
10	ABB-Milokovic	CPSM Profile	Company class is not included in the profile document. In the Duke model there are 12 companies listed but there is no equipment connected to the specific company.	Add Company class to the profile.	Open
6	Xtensible-Saxton	Model 40 bus	The 40 bus model abb40bus_04_27_01.xml shows AC line segments with a Member of Equipment Container relationship. Also, enumerated values do not follow CIM standard		Open
7	Siemens-Hunter	Model 60 bus	Impedance values are defined as PU values. The CPSM profile specifies definition of impedance values in ohms	NERC profile should be changed to reflect the current CIM version	Agreed
11	Xtensible-Saxton	Product Alstom	Condenser class – Alstom exports non-CPSM profile attribute for MVARperSection of nominal MVAR (for whole Condenser)		Open

No.	Submitter	Category	Problem Statement	Suggested Resolution	Final Resolution and Status
3	Alstom-Widergren, Fairchild	Products Alstom-CIM-Logic	GeneratingUnitOpSpec relationship to GeneratingUnit is not handled properly when Alstom imports model from CIM-Logic		Open
5	SISCO-Dmitry	Products SISCO-ABB	Node names seem to have been changed when importing 100 bus model as exported by ABB. Also, Bays were not exported by ABB.		Open
4	SISCO-Dmitry	Products SISCO-CIM-Logic	Terminal names seem to have been changed when importing 100 bus model as exported by CIM-Logic		Open
2	Alstom-Widergren	Tools	CIM Validator does not scale to check reasonable sized operational models	Review design and check on memory demands	Completed

Target:
Grid Operations and Management

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