WIDE AREA SECURITY MONITORING DISPLAY FOR CALIFORNIA ISO

CONSULTANT REPORT

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Wide Area Security Monitoring Display for California ISO

Requirements Specification Document

1008724

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ABSTRACT

This is a Requirements Specification Document for a Wide Area Security Monitoring Display (WA-SMD) to be developed for the use of software developers for EPRI's Grid Operations and Planning area. The main purpose of this project is the development of a wide-area security monitoring and graphical display system (WA-SMD) that can be simultaneously accessed by several authorized personnel, geographically dispersed, using a web browser. The simultaneous access to the same graphical display over the Internet provided by WA-SMD will significantly improve the coordination among operators, planners, engineers, and security coordinators during emergency situations. The display should provide near-real time status of wide areas of the North American electric power grid and shall employ client server architecture. The application's display will use a CIM compliant model of the power system stored and updated on the server. The client shall have access through the Intranet and/or a secure Internet. WA-SMD should be an active display that shows critical real-time operating parameters of the power system.

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1. Introduction

1.1. Purpose

This document is a Requirement Specification Document (RSD) for a web-based application that will be used as a security-monitoring display to be developed for EPRI. The proposed web application will be called Wide Area Security Monitoring Display (WA-SMD).

The purpose of this document is to clearly specify the user interface requirements and the related system requirements so that a software designer can implement a fully functional WA-SMD application following the software guidelines from EPRI. The resulting WA-SMD will meet the following goals:

- Consistent Graphic User Interface that is easy and intuitive to use,
- Reduced end-user training required to use WA-SMD, and
- Lower Total Cost of Operations (TCO) for the end users of WA-SMD application.

The WA-SMD application will gather information from the CIM (Common Information Model) compliant database and create multiple diagrams and alarms to alert the user of any known problems in near real time. The information gathered from the database will include data related to the flow of energy between generators, network reduction, production cost, exchange of power, transfer schedule, transfer evaluation, state estimation, unit commitment, load forecasting (weather based), tagging of lines, etc.

1.2. Scope

The WA-SMD website in combination is designed to aid the users to easily view near real-time, simultaneous access to status information and graphical display, using Internet tools, on wide geographical areas of the North American electric power system. This display software can be used in utilities, in NERC regions and in Regional Transmission Organization (RTOs) such as Independent System Operators (ISO) or other transmission organizations (TRANSCOs, power pools). The display software will be able to run standalone against a set of data, integrate with operations, or planning applications.

The WA-SMD will be an on-line security assessment tool that compliments and improves the security functions of existing energy controls centers at various RTOs, ISOs, TRANSCOs, power pools, or utilities. The main function of the WA-SMD is to facilitate three levels of real-time displays, a world map showing the geographical locations of the power system entities (like companies, substations, etc), a one line diagram that shows the connectivity of all the power system elements, and a bus breaker substation model to monitor the operational status of all power system elements. The WA-SMD will interface to the CIM compliant database using standard Application Programming Interfaces as defined by the CCAPI organization.

The WA-SMD application will be built using components so that the migration from desktop and client/server based application to a web application will require less effort. The graphics tools and, when appropriate, the WA-SMD code will be built using the ActiveX and COM technology. The target operating systems for WA-SMD will be:

Window 98,

Windows Me

Windows NT 4.0, and

Windows 2000.

2. Implementation Overview

2.1. System Architecture

The client software that runs in Internet Explorer (browser) will work on Windows 98, Windows Me, NT 4.0, 2000 or later and the server software will work on Windows 2000 Advanced Server and Server. The required components will be developed using Microsoft Visual C++ 6.0, ATL-COM, etc. All required ASP script code would reside on the server. All the data for the program will be stored in the CIM compliant database.

The user will have the choice to select between different diagrams by performing common mouse and keyboard operations.

Typical user will use WA-SMD over the web. WA-SMD will be located on the Web server that has IIS 5.0 or later installed. It will also include server component(s) and ASP scripts. It is recommended that the database be independent for better performance, but the system will function even if the two are on the same server. The basic layout of this mode is shown below.

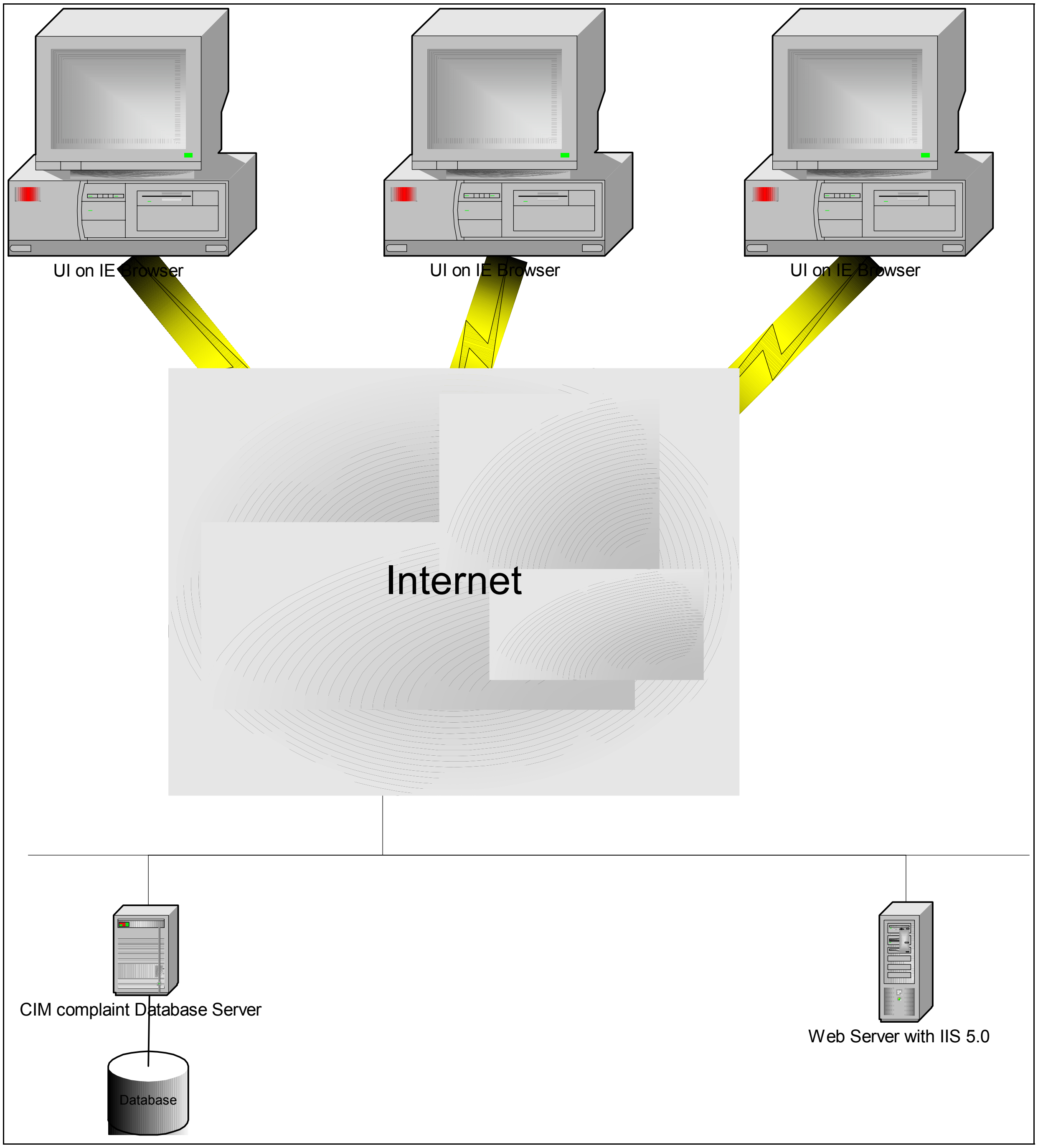

Figure 2.1: System Architecture

2.2. User Interface

WA-SMD will be a web-based application that will be accessed either over the Internet or the Intranet.

2.3. Logon to WA-SMD

In order to access the WA-SMD application, the user will have to first navigate to the appropriate URL for this application. When the correct

URL for WA-SMD is selected, the WA-SMD logon page will be loaded. A correct Login Name and Password will have to be entered. When a correct Login Name and password is entered and the login button clicked, the WA-SMD home page gets loaded.

2.4. WA-SMD Home Page

As soon as the user enters the correct login, WA-SMD home page will be displayed.

2.5. Password Protection

In order to access the WA-SMD application, the user will have to first navigate to the appropriate URL for this application. When the correct URL for WA-SMD is selected, the WA-SMD logon page will be displayed. A correct Login Name and Password will have to be entered. When a correct Login Name and password are entered and the login button clicked, the WA-SMD home page gets loaded. If higher security is required for the particular installation, the https protocol in conjunction with 128 bit encryption can be used. This will require that the user get a certificate from a Certificate issuing authority. This certificate needs to be installed on the server. Other kinds of security that can be deployed are that all clients will be issued a Client Certificate. This certificate will be required by the server to authenticate the user. It is to be noted that all these are configurations that need to be setup based on the specific needs of the particular installation and that these do not require any custom code to be developed.

2.6. System Security Data Description

This section of the RSD explains about the type of data to be displayed in the WA-SMD Application. The following are the types of data found in the displays:

- Flow over Tie-Line,
- Flow Gate,
- Generation,
- Alarms,
- Security Margin,
    - Voltage Collapse,
    - Sag Limits,
    - Transient Stability,
- Spinning Reserve, and
- Standby Reserve.

3. System Displays

3.1. Introduction

The display section of WA-SMD shows the different visual capabilities of the application. The exact set of displays will depend on the particular installation. So in this chapter all the different kinds of display capabilities that are included in WA-SMD application are described. For a particular installation one or more of these displays will be customized. All these display types will be displayed within the Internet Explorer browser. Based on the installation requirements one or more of these displays will be combined within the same browser window.

3.2. GIS Display showing Transmission Line(s)

This display utilizes the GIS control from GGS. It displays the geographical region for which the transmission lines need to be displayed as shown in Figure 3.1. This figure shows the path of the transmission line in the western area of the United States as an example. This display allows the user to view certain user configurable attributes of the transmission lines and substations being displayed like the voltage levels, substation names, etc. The user also gets an idea about the geographical locations of substations and transmission lines. The user can choose the kinds of alarms generated within a substation and along the transmission line to be displayed in this display. When an alarm is triggered, like at Substation D, the substation will change to red and the alarm will be displayed. The user will be allowed to zoom in and out in this diagram. The user can choose to move the mouse cursor over the alarmed substation and a description of the alarm and location will be displayed as a popup window. When the user clicks on a substation the user will be taken to the corresponding Station display. The user will be allowed to configure the color of the transmission lines based on the voltage levels in this display.

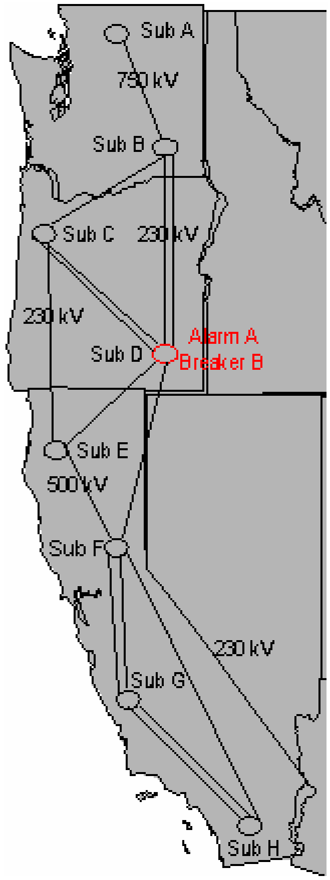

Figure 3.1: GIS Display showing Transmission Line

3.3. GIS Display showing Power Flow Diagram

The Power Flow Diagram allows the user to view the flow of energy from substation to substation. This is illustrated with an example in the Figure 3.2. When the user clicks on a substation the user will be taken to the corresponding Station display.

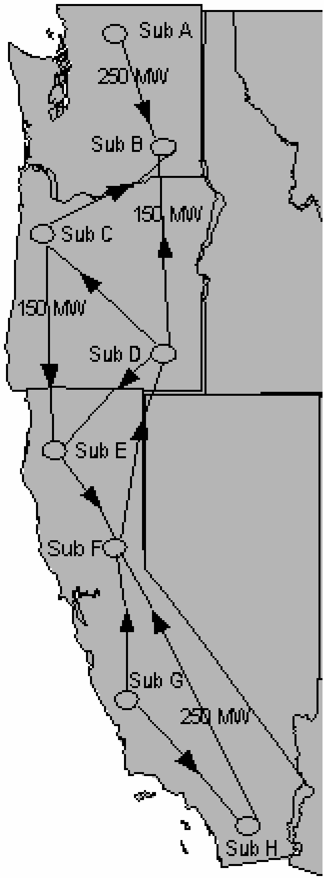

Figure 3.2: GIS Display showing Power Flow

3.4. Station Diagram

This display uses the Diagram control developed in the GGS project for EPRI. The display example shown in Figure 3.3 is only an example; the actual implementation will look different based on the electrical symbols and colors used in the given installation. The non-customized version of the application will include a default set of symbols and colors for the power system resources (PSR).

The user will be allowed to zoom in and out within the display. Zooming out will allow the user to see more power system resources within the same window size. It is to be noted that this view will not be geographically accurate.

If the user is in edit mode, the user will be allowed to add, delete, and update power system resources. In the edit mode the user can modify the properties of the PSR by double clicking on the PSR using the mouse. The user will be allowed to stretch PSRs by moving the nodes of the PSR. The user can displace the symbol of the PSR by dragging the corresponding PSR. The user can change the shape of the orthogonal line(s) connecting the symbol of the PSR with the PSR's node by dragging the line. These orthogonal lines of the PSR will be either horizontal or vertical (not inclined).

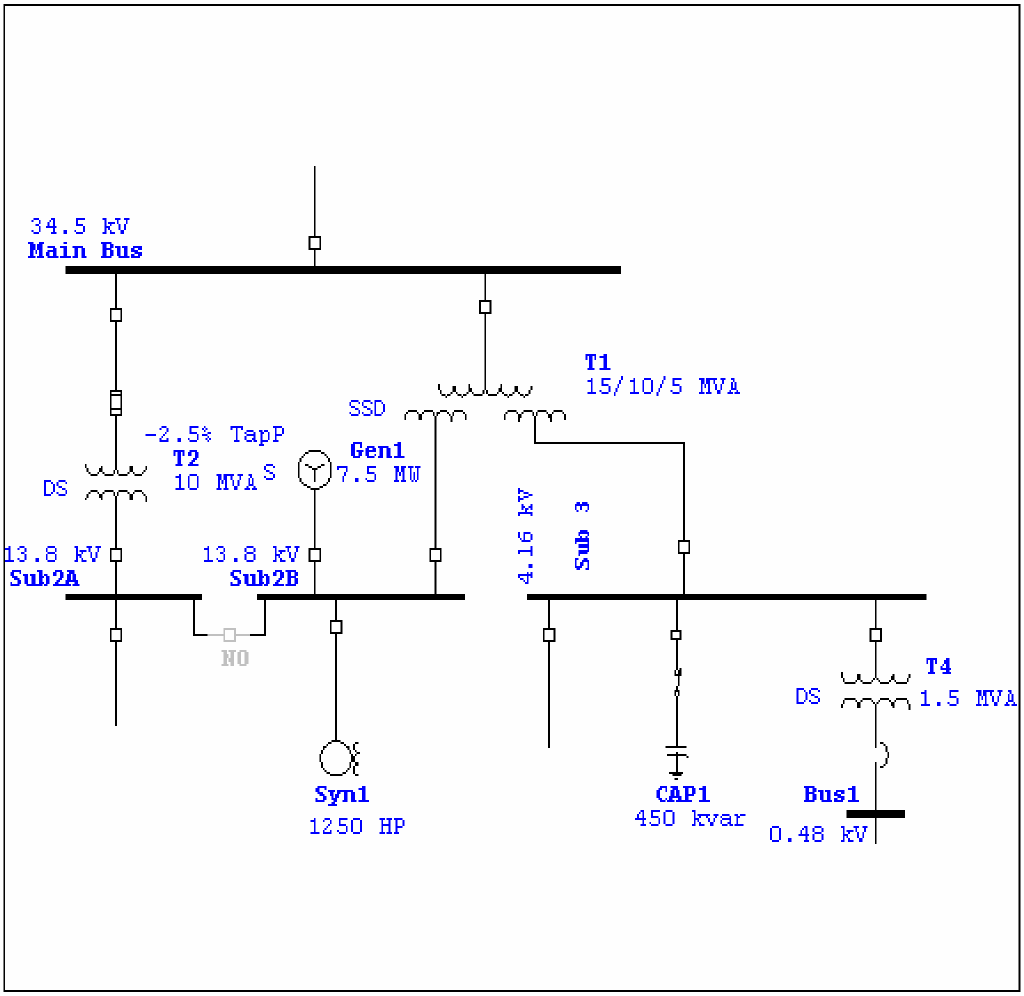

Figure 3.3: Station Diagram

3.5. Bubble Diagram

This displays a geographical map with circles setup for companies. Here it is assumed that a company is located at one geographical point and not spread over an area. The main aim of this display is to show the amount of power generated by a company, amount of power used by the company, the transfer of power between companies in near real time, and the name of the company. This concept is illustrated in Figure 3.4.

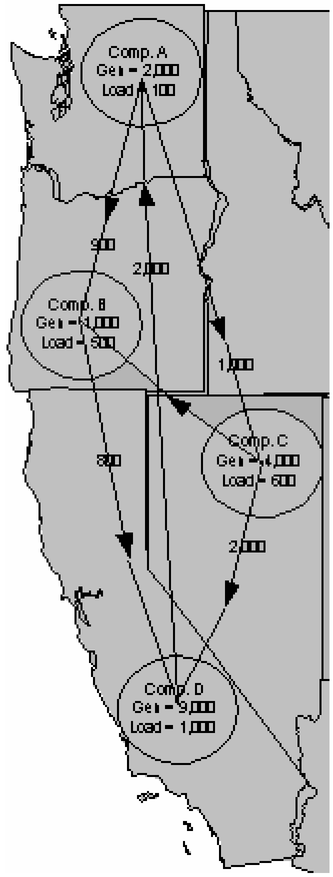

Figure 3.4: Bubble Diagram

3.6. Plots

This will enable the user to have the ability to display graphs by embedding it in the browser. The data for the graphs is taken from the CIM compliant database. All the graphs to be displayed will also be installation specific. One or more of these graphs may be displayed within the same browser window.

3.6.1. Line Plot

This is used to show changes or progress of data. One group of data is represented horizontally and the other vertically. The scale for the two data sets can be started either from zero or any other convenient value. It will be possible to have multiple Y axes if it is required for this kind of plot.

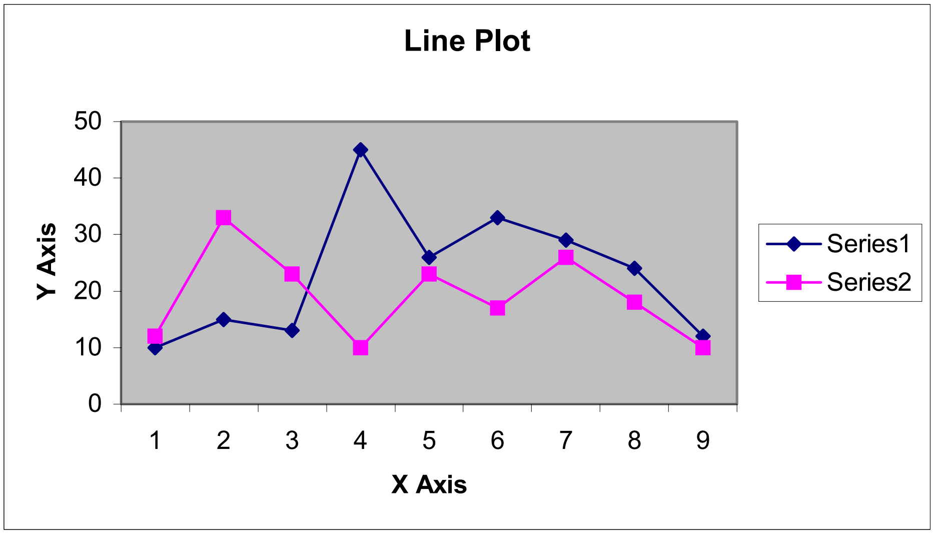

Figure 3.5: Line Plot

3.6.2. Bar Plot

This is used to compare data. One group of data is represented horizontally and other is represented vertically. The scale for the two data sets can be started either from zero or any other convenient value.

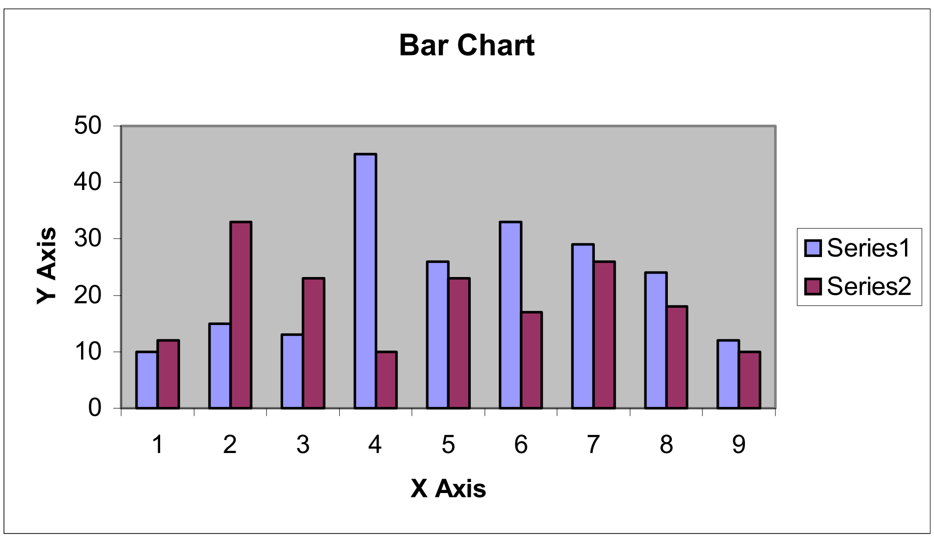

Figure 3.6: Bar Chart

3.6.3. Scatter Plot

This is used to compare data. This is similar to the LinePlot. The difference is that here the points are not joined by straight lines. This type of plot is useful to study the distribution of data points.

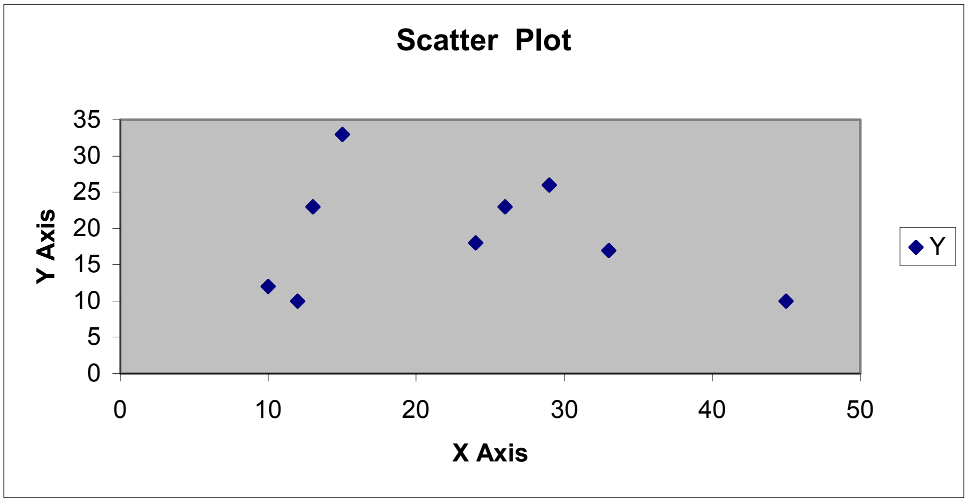

Figure 3.7: Scatter Plot

3.6.4. Pie Plot

This is used to take an item or quantity and represent its individual parts. It is in the form of a pie.

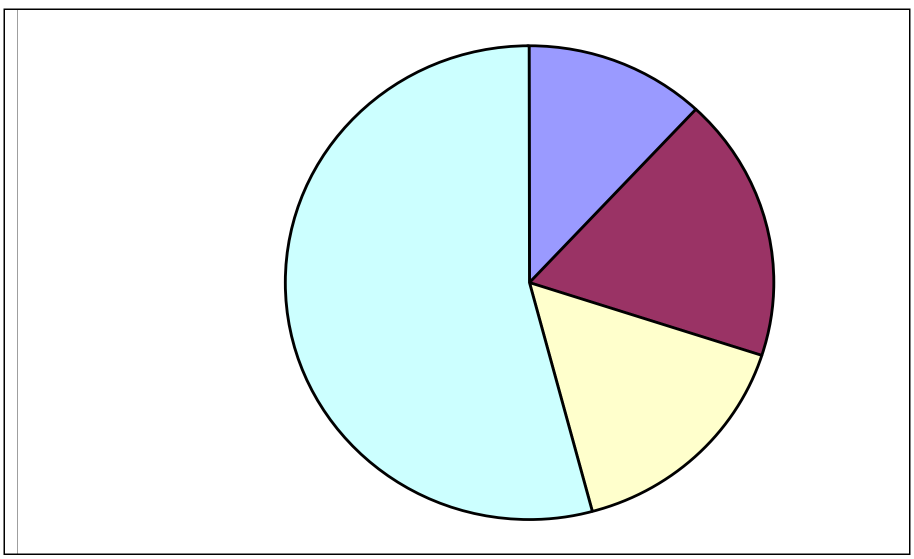

Figure 3.8: Pie Plot

3.7. Report Viewer Display

This display shows reports to the user based on the data queried from the database. The query to be performed is based on the needs of the specific installation of WA-SMD. The display shown in Figure 3.9 should be treated only an example. Using this display the user is able to Pre-View and then print (if desired) the report to the local printer. This display uses the product, Crystal Reports, which is the most popular reporting tool in the PC market. Since this report will be displayed in a browser window, the web-server that is going to serve the reports needs to have licensed copy of Crystal Reports for the Web installed. If a specific installation of WA-SMD does not require the Report Viewer display then Crystal Reports for the Web is not required for that installation of WA-SMD application.

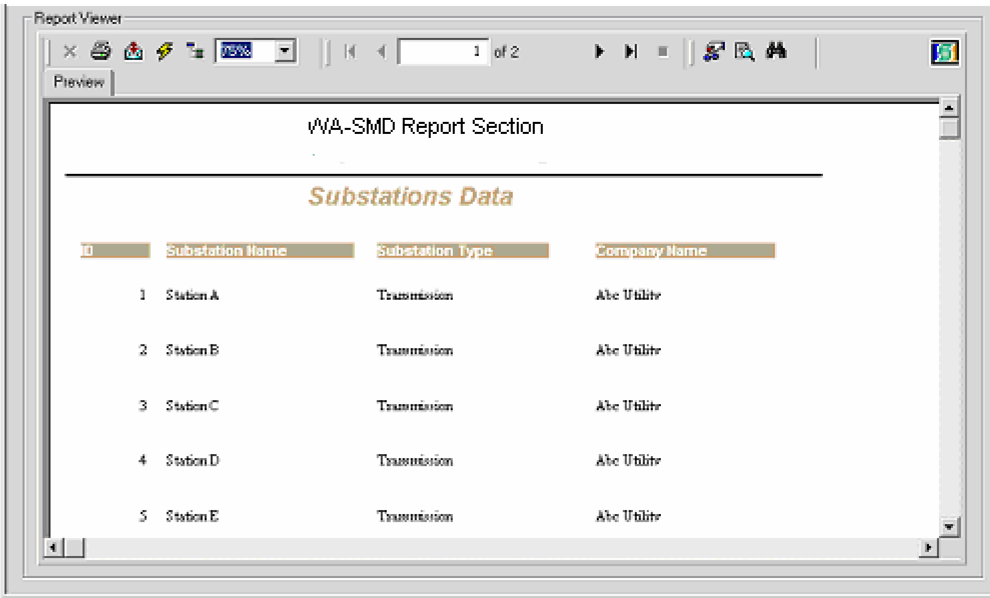

Figure 3.9: Report Display

3.8. Event Log Viewer

The event log viewer shows all the events (information, warning, error - log types) that occur when the WA-SMD application is running. This display is only available to those connected on the LAN, in other words, those users who are connected through the intranet and are using Windows 2000 or NT as their operating system. These events are those that are reported by the components whose services are utilized by the WA-SMD application.

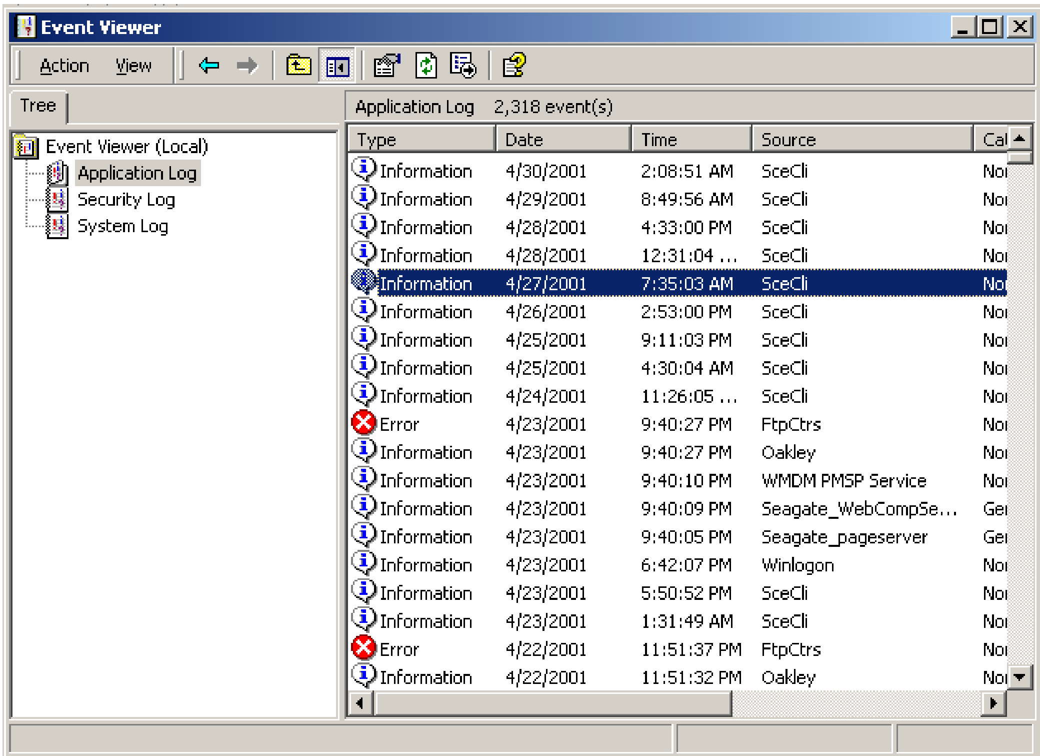

Figure 3.10: Event Viewer Display

If one of the events is double clicked a detailed page showing more information about the event is displayed.

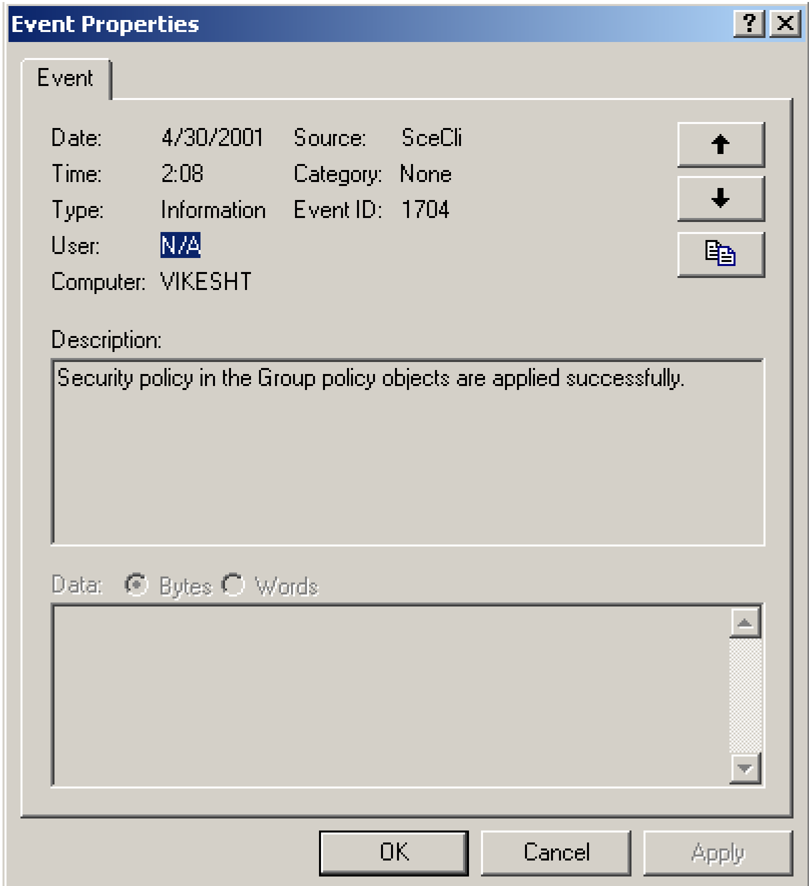

Figure 3.11: Event Viewer Detailed Display

3.9. Tree View

The tree view will allow the user to view the entire Power system network within a single window as shown in Figure 3.12.

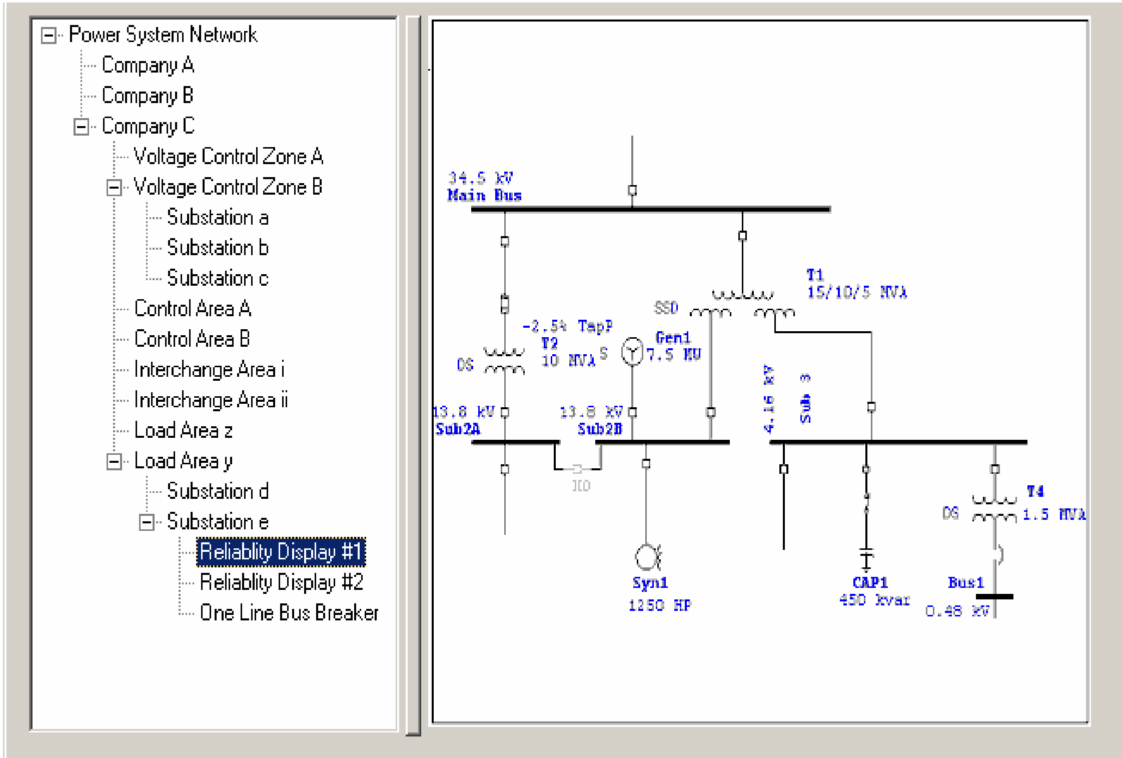

Figure 3.12: Tree View

3.10. Hierarchical Display

The hierarchical display can contain two kinds of data, company names or station names. The hierarchical display of companies is a display that shows a list of all the companies. Once the user clicks on one of the companies a corresponding hierarchical display with all the substations associated with that company would be shown. The hierarchal display of companies is shown in Figure 3.13 and of substations within the selected company is shown is Figure 3.14. When the user clicks on a substation name the corresponding station display will be displayed.

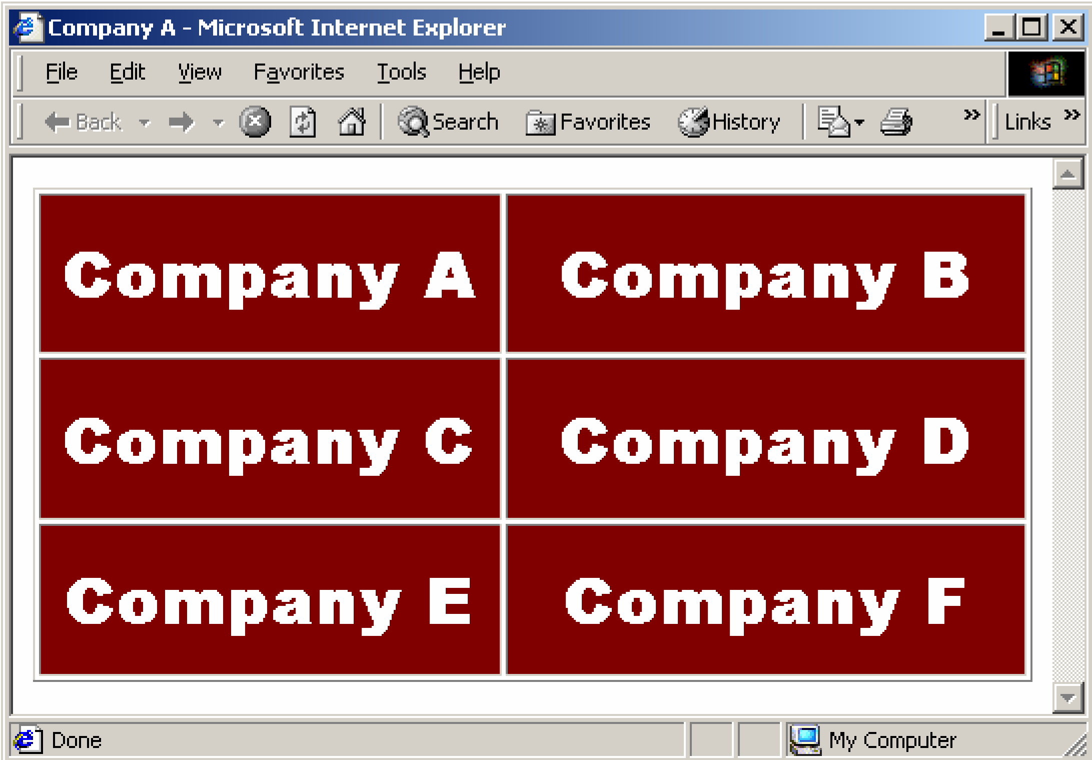

Figure 3.13: Hierarchical Display of Companies

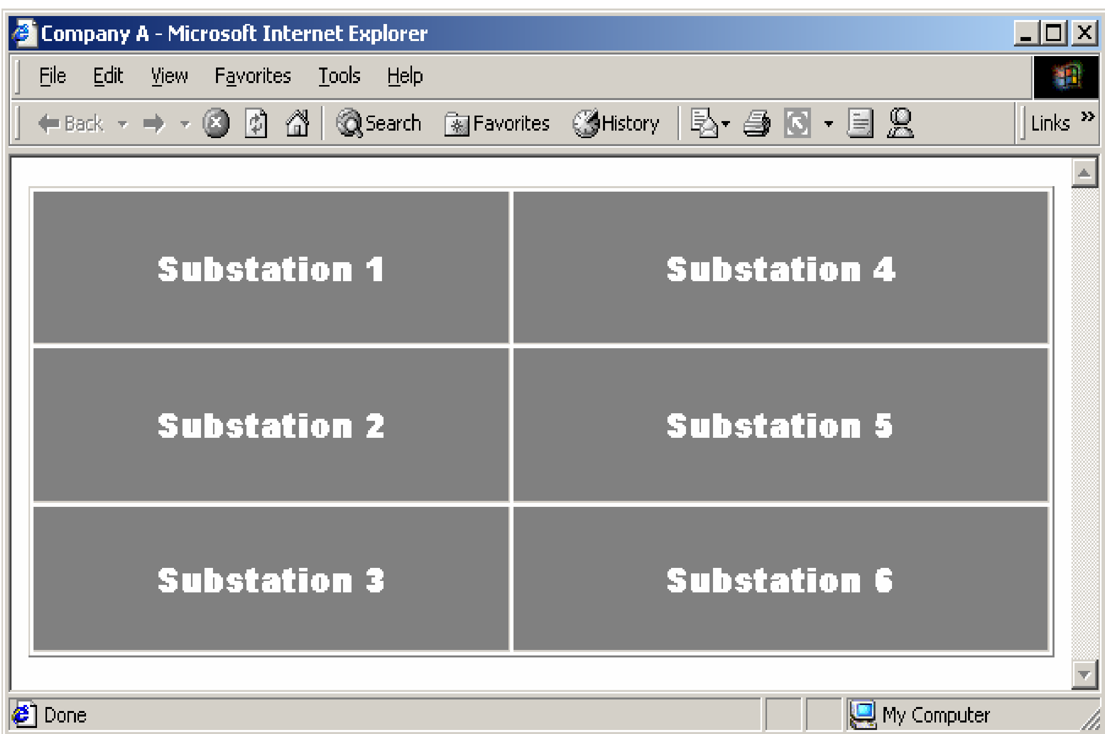

Figure 3.14: Hierarchal Display of Substation within a Company

3.11. Tabular Display

The tabular display is used anytime data needs to be presented to the user in a tabular format. An example of such a display is shown in Figure 3.15.

	Power Generated (MW)	Power Used (MW)
Company A	2000	1900
Company B	1000	1200
Company C	1500	1600
Company D	250	251
Company E	340	339
Company F	5000	5000
Company G	450	500

Figure 3.15: Tabular Display

3.12. Consolidated Display

The consolidated display allows the user to combine any of the displays mentioned in this chapter. An example is shown below in Figure 3.16. The use of the browser makes it very easy to consolidate the displays that are ActiveX controls. These controls support scripting and so can be customized based on the data read from the CIM compliant database.

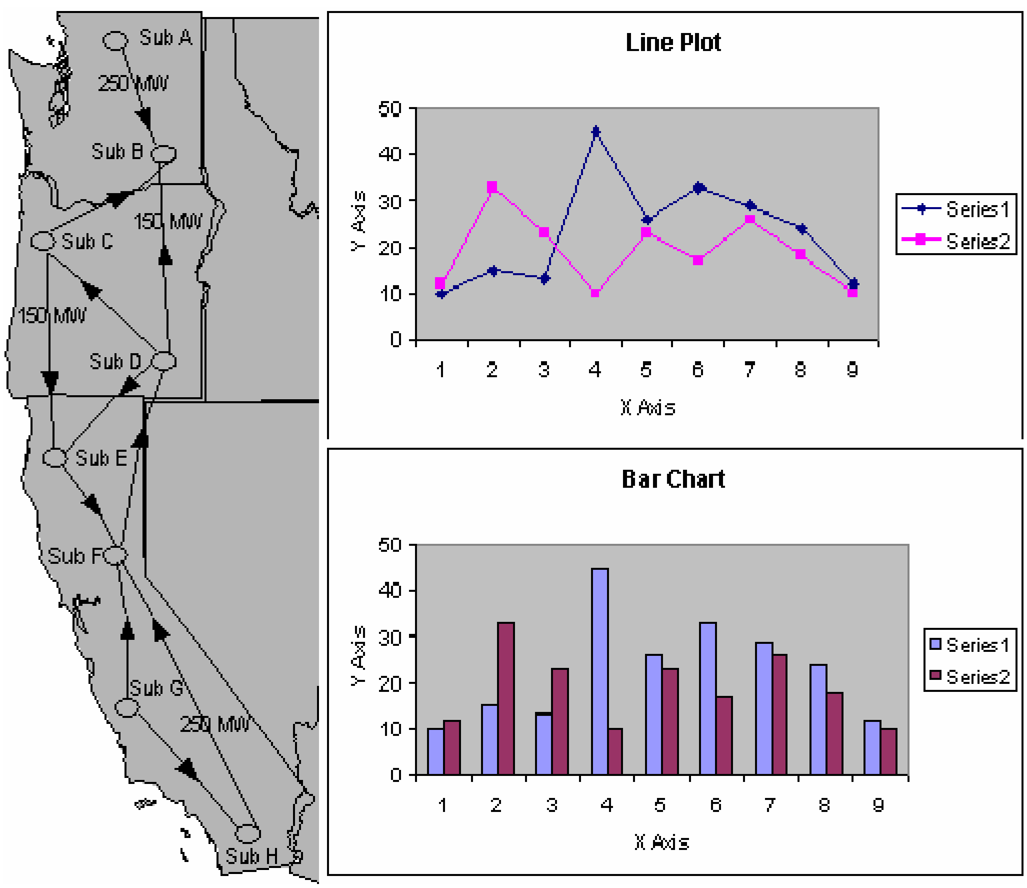

Figure 3.16: Consolidated Display

4. Specification Overview

This section of the RSD provides a general description of the application's characteristics.

4.1. Overview

The initial implementation of WA-SMD will be a basic web based application. The system will have the following components:

1. Real-time Alarms,
2. Graphical Data,
3. User interface, and
4. Zoom Capabilities.

WA-SMD will interface with the CIM compliant database using standard Application Programming Interfaces as defined by the CCAPI.

The user interface environment for WA-SMD will be very interactive. Graphical symbols will be used to describe the web-based application.

4.2. Product Function

WA-SMD will provide the following basic functionality.

4.2.1. Power Flow

This option will allow the user at any given time to see the flow of energy from Power Company to Power Company. The user will have access to the flow of power as well as the status of the power.

4.2.2. Status of Generators

This option will allow the user to check on the status of any generators.

4.2.3. Reserve, Stand by Reserve, Spinning Reserve, and Total Reserve

This function will allow the user to periodically find the reserve power of any generator at any given time. If the reserve power is below or above normal the alarm will begin blinking on the WA-SMD website.

4.2.4. Circuit Breaker Status

This group of functions will allow the user to see if an overload of the circuit breaker occurs. Once an overload occurs, a blinking alarm will be triggered on the WA-SMD website.

4.2.5. Alarms

WA-SMD will perform various security checks periodically. If an alarm does sound then the user will be allowed to click on the alarm and the pertinent company and alarm information will be available. The alarm will be triggered when the following errors occur:

- Overload in Circuit Breaker,
- Generator Status is not Normal, and
- Reserve Power Status is not Normal.

4.2.6. Zoom Capabilities

This option will allow the user to click any portion of the displays or diagrams and zoom into a specific company, zone, or region. The zooming capability will not have any perceptible delay.

4.3. User Characteristics

WA-SMD is designed to work in Microsoft Internet Explorer web browser environment. While the system will be delivered with an easy-to-understand users manual, it is assumed that a typical user of the WA-SMD application will have basic Internet surfing skills.

4.4. Performance, Dependencies, and Constraints

The performance of the WA-SMD application will depend on the following factors:

4.4.1. Database Design

The database design is based on a hierarchical relationship of all the major data components in the system. The performance of the system will depend on the amount of data used.

4.4.2. Configuration of the Web Server Computer

The configuration of web server, on which this application will be run, will be a factor in the performance and the operational speed of the system.

4.4.3. User Interaction

All user navigation, within the system, will be handled through the mouse and the keyboard. WA-SMD will be tested (and implemented) on the latest version of a standard browser like Internet Explorer 5.5.

4.4.4. Database Server

Performance will depend on the database server if data is stored independently. It is recommended that the database server not be on the web server.

4.5. WA-SMD Performance and Functional Requirements, Server Site

The following are the performance and functional requirements for the server side of the WA-SMD website:

4.5.1. Display

- WA-SMD will have the ability to archive chosen displays and recall it as needed.
- WA-SMD will be callable from an application program, with results from the application program superimposed on the display.
- Each display will have an identification showing the area, date, and time of the latest update.
- Parameters of each power system element (graphic object) will be editable through a pop-up dialogue box.
- Diagrams will be automatically generated, manually generated, or edited, or retrieved from saved diagrams.

4.5.2. Data

- The power system data will be in a CIM compliant database.
- The CIM data will be accessed using the API certified by the CCAPI group as the mechanism to extract data from a CIM complaint database.
- The CIM complaint database may be updated every five seconds.
- The network data shall be embedded in and linked to each graphic object.
- WA-SMD will support the proposed bus and line hierarchical naming convention of the NERC Data Exchange working group (DEwg).

4.5.3. Performance

- WA-SMD will be updated every fifteen seconds.
- WA-SMD will be capable to serve 100 clients simultaneously.
- WA-SMD will be able to switch between displays with less than one second delay.
- There will be no perceptible delay in zooming.

4.5.4. Views

- The user will have the ability to select a view port on the normal screen.
- WA-SMD will have the ability to provide three views for the graphical display namely the, geographical layout, one-line diagram, and bus breaker diagram.
- Each view will have the ability to zoom and scroll.
- WA-SMD will have the ability to select views based on voltage levels.

- All the views will be printable, with all common printers supported.

4.5.5. Color Coding

- Out of range/overload values will be color-coded and use some other indication for colorblind users.
- Voltages, MW, an MVAr flows will be color coded to indicate load level relative to rating.

4.6. WA-SMD Performance and Functional Requirements, Client Site

The following are the performance and functional requirements for the client site of the WA-SMD website:

4.6.1. Display

- Diagrams will be automatically generated, manually generated or edited, or retrieved from saved diagrams.
- WA-SMD users will be able to select an area, by bus/breaker name or number, by area or zone, by company or region.
- Parameters of each power system element (graphic object) will be viewable through a pop-up dialogue box.
- Parameters and diagrams will be editable by authorized set of users. This information will be stored in the CIM.
- WA-SMD will be able to display data attributes on the display such as voltage, real and reactive power, bus/breaker names, bus limits, line transfer limits due to thermal, voltage and dynamic conditions, load real and reactive power, etc.
- WA-SMD will have the ability to archive chosen displays and recall them as needed.
- Each display will have an identification showing the area, date, and time of latest update.
- At the client site, WA-SMD will have the ability to access from the server using a World Wide Web browser through the Internet or a secure Intranet.
- The user at the client site will have the ability to access any of the server sites.
- The user will be able to update WA-SMD on demand.
- At the client site, WA-SMD will have the ability to create windows of several different server site displays (Areas).
- The network data will be embedded in the graphic object.

4.6.2. Performance

- WA-SMD will have an option to set a predetermined automatic update interval.
- The client side initial WA-SMD display generation will be achieved within one minute.
- Updating of WA-SMD will be completed within fifteen seconds of the request.

- Zooming in WA-SMD will have no perceptible delays.
- WA-SMD will be able to switch between displays with less than one second delay.

4.6.3. Views

- The user will have the ability to select a view port on the normal screen.
- WA-SMD will have the ability to provide three views for the graphical display -- geographical layout, one-line diagram, and bus breaker diagram.
- Each view will have the ability to zoom-in, zoom-out, and scroll.
- WA-SMD will have the ability to select views based on voltage levels.
- All views will be printable, with all common printers supported.

4.6.4. Color Coding

- Out of range/overload values shall be color-coded and use some other indicator for colorblind users.
- Voltages, MW, and MVAr flows shall be color-coded to indicate load level relative to rating and use some other indicator for colorblind users.

5. System Interface Requirements

5.1. User Interface

The user interface will be consistent with any standard HTML form based web-based application. It will follow the standard rules and guidelines of web-based applications based on the standards defined by BEST Systems and Software Guidelines by EPRI

5.2. WA-SMD Hardware Configuration/Requirements

It is to be noted that the server environment could be set up using either one or multiple server(s). This choice has to be made based on the particular installation of WA-SMD. The factors that would affect the choice are based on the number of simultaneous clients and the size of the power system model that is to be monitored using this application. The following are the minimum hardware requirements for the server and the client computer:

5.2.1. Web Server computer:

- Window 2000 Advanced Server as the operating system,
- Minimum of 1 GHz Xeon processor with 512 MB RAM,
- RAID array with 10,000 RPM disks of which 8GB is free,
- 100 Kbps access to the Internet/Intranet,
- CD-ROM drive

5.2.2. Database Server computer:

- Window 2000 Advanced Server as the operating system,
- Minimum of 1 GHz Xeon dual processor with 512 MB RAM,
- RAID array with 10,000 RPM disks of which 8GB is free,
- 100 Kbps access to the Internet/Intranet,
- CD-ROM drive

5.2.3. Client computer:

- Windows 98/Me/NT/2000 as the operating system
- Minimum of 500 MHz Pentinum III processor for the server computer with 512 MB RAM,
- 1 GB of free hard disk,
- 100 Kbps access to the Internet/Intranet,
- CD-ROM drive,
- SVGA display with a resolution of 1280 x 1024

It is to be noted that for any installation of this application it is difficult to guarantee the performance requirements mentioned in this RSD (based on the RFP), assuming that the user has installed the minimum hardware configuration. The application needs to be tested in the given situation with the above mentioned min hardware with the particular power system model. If it is found that the performance needs to be improved, then additional hardware needs to be installed (not replaced). There will be no need to work on improving the software performance, since the software will be designed to be highly efficient from the very beginning.

5.3. Software Interface

The WA-SMD application will be developed on Windows 2000 platform. The following standards, tools, and technologies will be used for the development:

1. Microsoft Visual C++ 6.0,
2. Microsoft Visual Interdev 6.0,
3. ATL-COM, MFC, and STL,
4. Database Server software that will be CIM Compliant using the EPRI API,,
5. IIS 5.0 for web-based application,
6. Microsoft Test for testing,
7. ISO 9000 templates from BEST Systems,
8. Visual Source Safe for version control,
9. Charting, Tabular, Event Logging, GIS controls produced by the GGS project for EPRI,
10. Internet Explorer 5.5 or later.

5.4. Communication Interfaces

As WA-SMD will be a web-based application, Intranet/ Internet connections will be required for the user.

Appendix A: Definitions, Acronyms, and Abbreviations

Load flow
This Load-flow analysis is done to determine the bus voltages for the given network and loads.

Active X Control
Active X Control refers to binary components built using the COM architecture for building Microsoft Windows controls.

ADO
ADO refers to ActiveX Data Objects. It enables the client applications to access and manipulate data from a database server through Object Linking and Embedding Database (OLE DB).

API
API refers to Windows Application Programming Interface. The interface provided by Windows (functions, structures, etc.) that a programmer uses in programs to interact with Windows.

CCAPI
Control Center Application Program Interfaces

CDA
Control Data Access

CIM
Common Information Model

DLL
Dynamic Link Libraries

DEwg
Data Exchange working group

EMS
Energy Management Systems

FERC

Federal Energy Regulatory Commission

FSD
Functional Specification Document

GOP
Grid Operations and Planning

GUI
Graphical User Interface

HTML
HTML refers to Hypertext Markup Language. HTML (Hypertext Markup Language) is the set of "markup" symbols or codes inserted in a file intended for display on a World Wide Web browser.

IDC
Interchange Distribution Calculator

ICCP
Inter-Control Center Communications Protocol

ISN
Inter-regional Security Network

ISO
International Standards Organization and Independent System Operators

MFC
Microsoft Foundation Class

MSDE
Microsoft Data Engine

NERC
North American Electric Reliability Council

OASIS
Open Access Same-time Information System

ODBC
ODBC refers to Open Database Connectivity. Open Database Connectivity (ODBC) is a standard or open application-programming interface (API) for accessing a database.

OLE DB
OLE DB refers to Object Linking and Embedding Database. OLE is Microsoft's framework for a compound document technology. Briefly, a compound document is something like a display desktop that can contain visual and information objects of all kinds: text, calendars, sound, motion video, and so forth.

PSADD
Power Systems Applications Data Dictionary

RTOs
Regional Transmission Organizations

TRANSCOs
Transmission Organizations

UCA
Utility Communications Architecture

UI
User Interface

Visual Basic
Visual Basic is a software development tool from Microsoft for creating the user interface for a Windows application.

Visual C++
Visual C++ is a software development tool from Microsoft for creating the high performance applications and components for a Windows application.

Visual FORTRAN
Visual FORTRAN is a software development tool from Compaq for creating modules and applications for the Windows platforms.

Visual Studio 6.0
Visual Studio 6.0 is a software development system from Microsoft that provides resources for creating applications for a Windows application.

Appendix B: CIM

CIM Introduction

The objective of this appendix is to give a brief technical introduction to the Common Information Model (CIM). This model is a result of the work performed in the CCAPI project sponsored by EPRI.

The CIM is an abstract model that represents all the major objects in an electric utility enterprise typically contained in an EMS information model. Because the object classes represented in the CIM are abstract in nature, they may be used in a wide variety of applications. The use of the CIM now goes far beyond its initial application in an EMS. The CIM enables integration in any domain where a common power system model is needed to facilitate interoperability and plug compatibility between applications and systems independent of any particular implementation. The scope of the CIM provides standard objects for the inter-operation of systems and applications used for production, transmission, distribution, marketing, and retailing functions of electric utilities.

The CIM is defined and maintained using a set of Unified Modeling Language Class Diagrams. The Unified Modeling Language is an object-oriented modeling language used for system specification, visualization and documentation. UML is a way of describing software with diagrams and is a language that both users and programmers can understand.

An overview of the major classes for the CIM is shown in Figure B-1. The classes shown in Figure B-1 form the foundation of the CIM. An electric utility is basically in the business of delivering electricity across wires from producers to consumers. The model in Figure B-1 is developed in an abstract manner to support any application that needs to model the flow of electricity from producers to consumers.

The CIM can be populated to include equipment covering the generator and generator substation, the EHV and HV transmission system including transmission and distribution substations, through the primary and secondary distribution feeders all the way to the customer's premise. In an EMS, the typical number of loads and transducers is in the range of several thousand. For DMS, the typical numbers of loads and meters is in the range of several million. The same logical CIM applies, however, the performance and implementation issues are very different. The CIM allows equipment to be grouped very flexibly into a variety of different containers. In EMS, the conducting equipment is typically grouped and viewed by substations. In DMS there is a need to group and view the conducting equipment by feeders.

CIM Class Diagram

The CIM class diagram in Figure B-1 describes the types of objects in the system and the various kinds of relationships that exist among them. There are three principal kinds of relationships:

- Associations (A PowerSystemResource “is measured by” a Measurement),
- Generalization and subtypes (A Switch is a type of Conducting equipment). A generalization relationship is marked with a triangle at the end with the Generalized class), and
- Aggregation (A ConnectivityNode “ is a member of “ a TopologicalNode, or a TopologicalNode “is composed of” ConnectivityNodes). An aggregation relationship is marked with a diamond at the end with the container class.

Generalization or inheritance is a powerful technique for simplifying class diagrams. The PowerSystemResource class is used to describe any physical power system object or grouping of power system physical objects that needs to be modeled, monitored, or measured. All the subclasses of PowerSystemResource inherit the following relationships:

- PowerSystemResource “measured by” Measurement,
- PowerSystemResource “owned by” Company, and
- PowerSystemResource “member of” PowerSystemResource.

The ConductingEquipment class is used to define those objects that conduct electricity. The following associations are used to specify the connectivity of these objects:

- ConductingEquipment “has” Terminals,
- Terminal “is member of” ConnectivityNode, and
- ConnectivityNode “is member of” TopologicalNode.

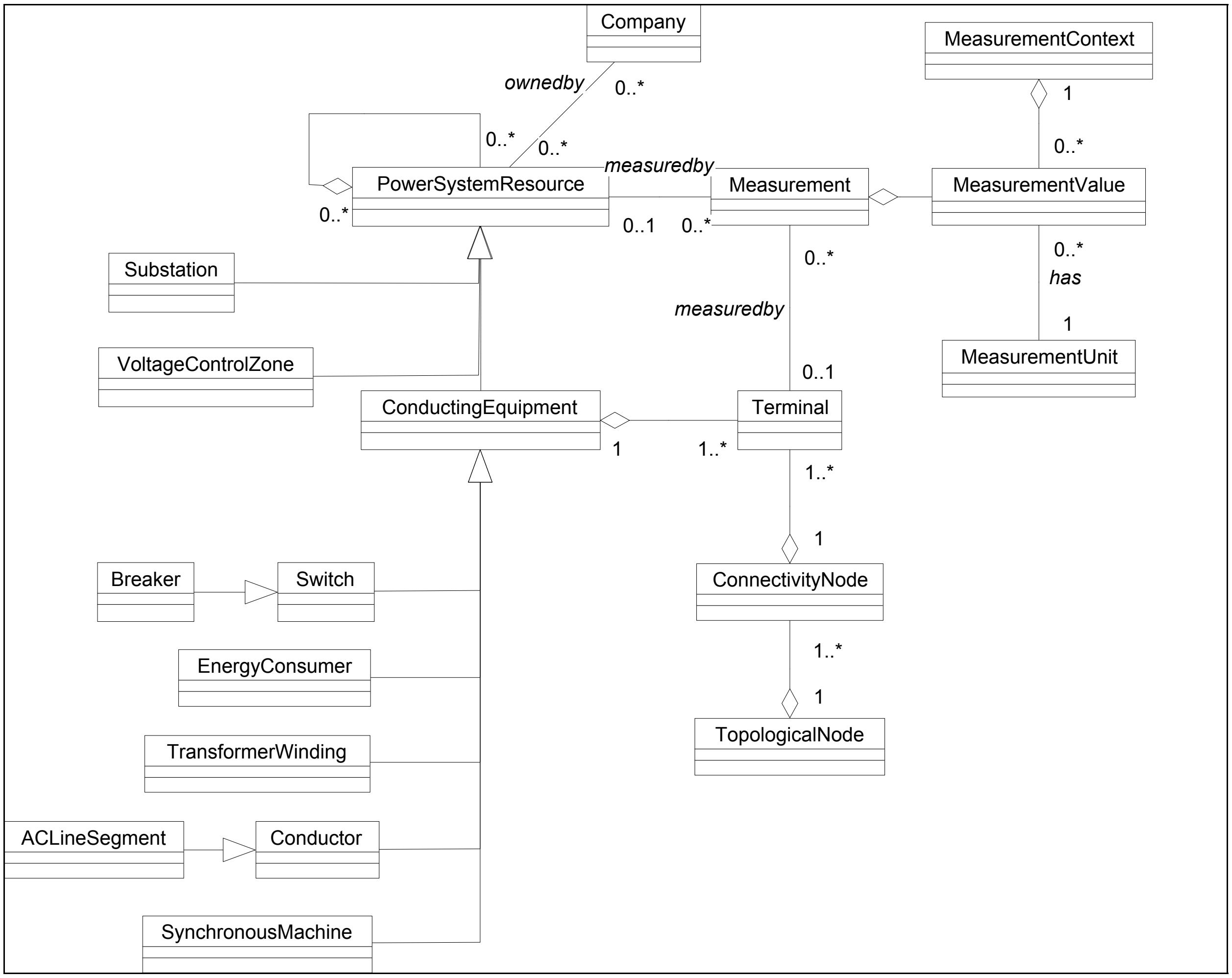

Figure B-1: Fundamental CIM Class Diagram

Aggregation of Conducting Equipment

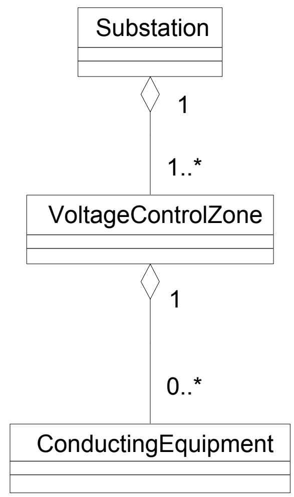

Figure B-2: Aggregation Relationships for EMS Network Models

For Energy Management System network application models it is very common to assume that each Substation consists of a number of VoltageControlZones as shown in Figure B-2.

Each ConductingEquipment object must belong to one VoltageControlZone. In this model, each VoltageControlZone must belong to one and only one Substation. This requires creation of lots of miniature VoltageControlZones that only exist within a single Substation. This model reflects the hierarchical database organization of legacy Energy Management Systems.

A more general implementation is shown below. Conducting Equipment can be aggregated into VoltageControlZones and Substations independently. Then only one VoltageControlZone has to exist for each system wide voltage level.

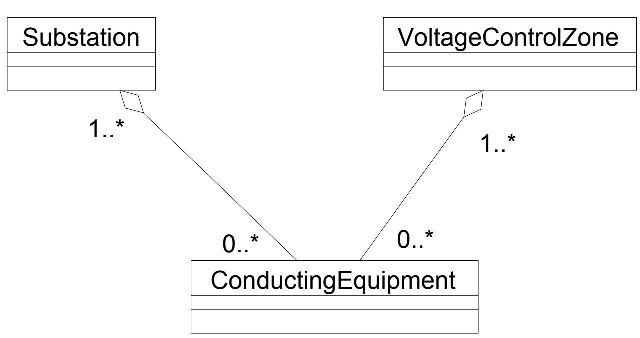

Figure B-3: General Relationships for Aggregation of Conducting Equipment

The CIM class model is completely generalized. It allows the aggregation relationships shown in Figure B-2 and Figure B-3 to both be specified using the PowerSystemResource "is member of" PowerSystemResource relationship.

The EPRI Common Information Model provides specific knowledge of the power system. The entities, attributes, and relationships for the EPRI Common Information Model (CIM) are defined in the EPRI Control Center Application Program Interface Guidelines

Use of Boundary Classes or Views

The CIM classes have been defined to ensure that a relational implementation will be normalized. Normalization is the process of deconstructing a class with many attributes into many classes, each with fewer attributes in order to eliminate redundant data and to avoid problems with inserting, updating, or deleting data. In object-oriented analysis, two important steps are the analysis of the use cases and the identification of all nouns used. These nouns become candidates for classes. Relational database normalization corresponds to defining classes for all the important nouns in the use cases. The main advantage of normalization, or of finding nouns that can be used as classes, is defining a model that is not dependent on any single application. The classes, or tables, contain only the attributes, which are inherent properties of the corresponding objects. Attributes, which are properties of related objects, are stored with their corresponding objects.

In relational database terms, a view is a virtual table that joins together fields of one or more data tables. In relational databases a clear distinction is made between the base tables and views.[1]

A base table is a "real" table, i.e. a table that physically exists in the sense that there physically exists stored records that directly represent that table.

By contrast, a view is a "virtual" table, i.e. a table, composed of records from other "real" tables, that does not actually exist in physical storage but is rendered to look like a "real" table. Views can be thought of as different way of looking at the "real" tables.

Since the CIM base tables are normalized, a user or application will typically require a view that joins attributes from multiple tables.

Defining Views for the CIM

The CIM is defined as a normalized database. As shown by the earlier examples, a single base table by itself does not provide meaningful information to the reader. It is necessary to join attributes from multiple tables to obtain meaningful views.

Assume we wish to show the attributes for a Breaker as shown in the following view table.

[1] C.J. Date, "Introduction to Database Systems", Addison Wesley, 1991

Company	SubstationName	VoltageControlZoneName	BreakerName	State
PAL	AIRPRT	V138	7	0
PAL	AIRPRT	V138	8	0
PAL	AIRPRT	V138	9	0
PAL	AIRPRT	V69	1	0
PAL	AIRPRT	V69	10	0
PAL	AIRPRT	V69	11	0
PAL	AIRPRT	V69	2	0
PAL	AIRPRT	V69	3	0
PAL	AIRPRT	V69	4	0
PAL	AIRPRT	V69	5	1
PAL	AIRPRT	V69	6	0

Figure B-5 Breaker View Table

The attributes in the Breaker View table are derived as follows:

CompanyName is derived from CompanyName in the Company table.

SubstationName is derived from PowerSystemResourceName in the PowerSystemResource table.

VoltageControlZoneName is derived from PowerSystemResourceName in the PowerSystemResource table.

BreakerName is derived from PowerSystemResourceName in the PowerSystemResource table.

State is derived from the MeasurementValue attribute in the MeasurementValue table.

Graphical Representation of Joins

Figure B-6 shows a graphical representation of a simple join between the Breaker table and the PowerSystemResource table.

A join line indicates "Select the records from both tables that have the same values in the fields that are joined." This is an inner join.

Breaker is a subtype of ConductingEquipment, which is a subtype of PowerSystemResource.

Every record in the Breaker table has a counterpart with the same primary key in the PowerSystemResource table.

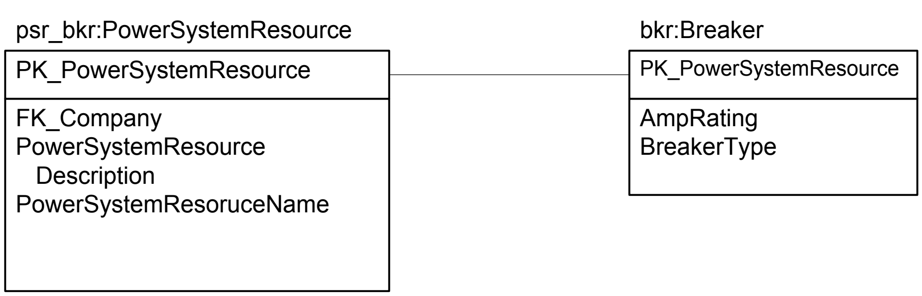

Figure B-6: Join Definition

The join in Figure B-6 will result in a view where the records match with the records in the Breaker base table. The attributes in the PowerSystemResource base table will be joined to the attributes in the Breaker base table.

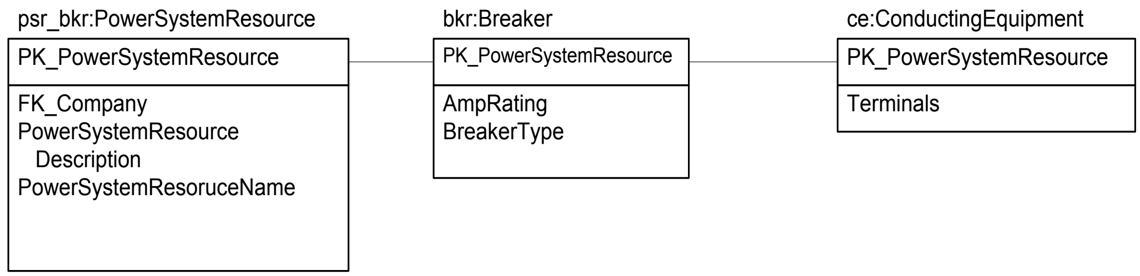

Figure B-7: Join Definition

The second join in Figure B-7 will result in a view where the records still match with records in the Breaker base table. The attributes in the ConductingEquipment table will be joined to the attributes in the Breaker base table and PowerSystemResource table.

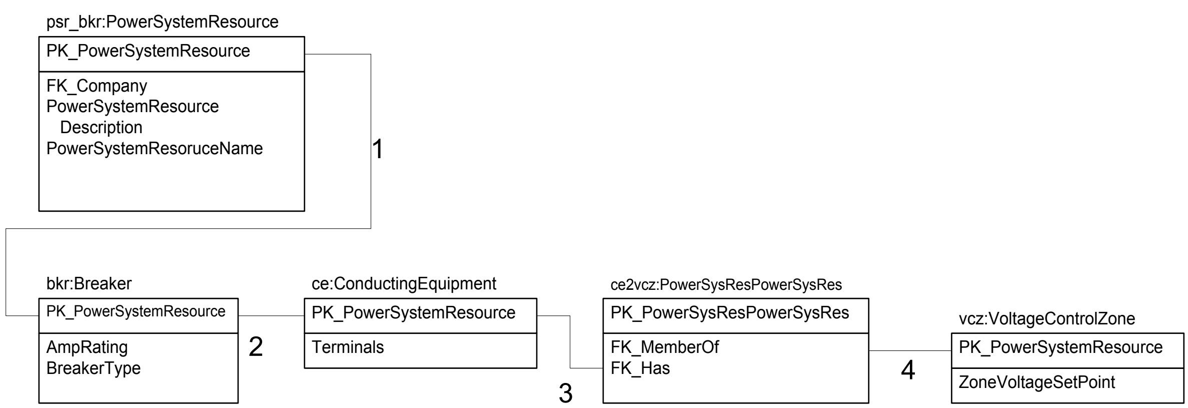

Figure B-8: Join Definition

The third join in Figure B-8 will join in the records in PowerSysResPowerSysRes table that refer to Breakers with the FK_Has foreign key. For the Power and Light system, the PowerSysResPowerSysRes table has been populated so that every Breaker is contained within a single VoltageControlZone.

This join will not change the number or sequence of records in the Breaker base table.

The fourth join Figure B-8 will join in the VoltageControlZones attributes. This join will not change the number or sequence of records in the Breaker base table.

The complete join definition in order to obtain all the fields shown for the Breaker view table in Figure B-2 is shown in Figure B-9.

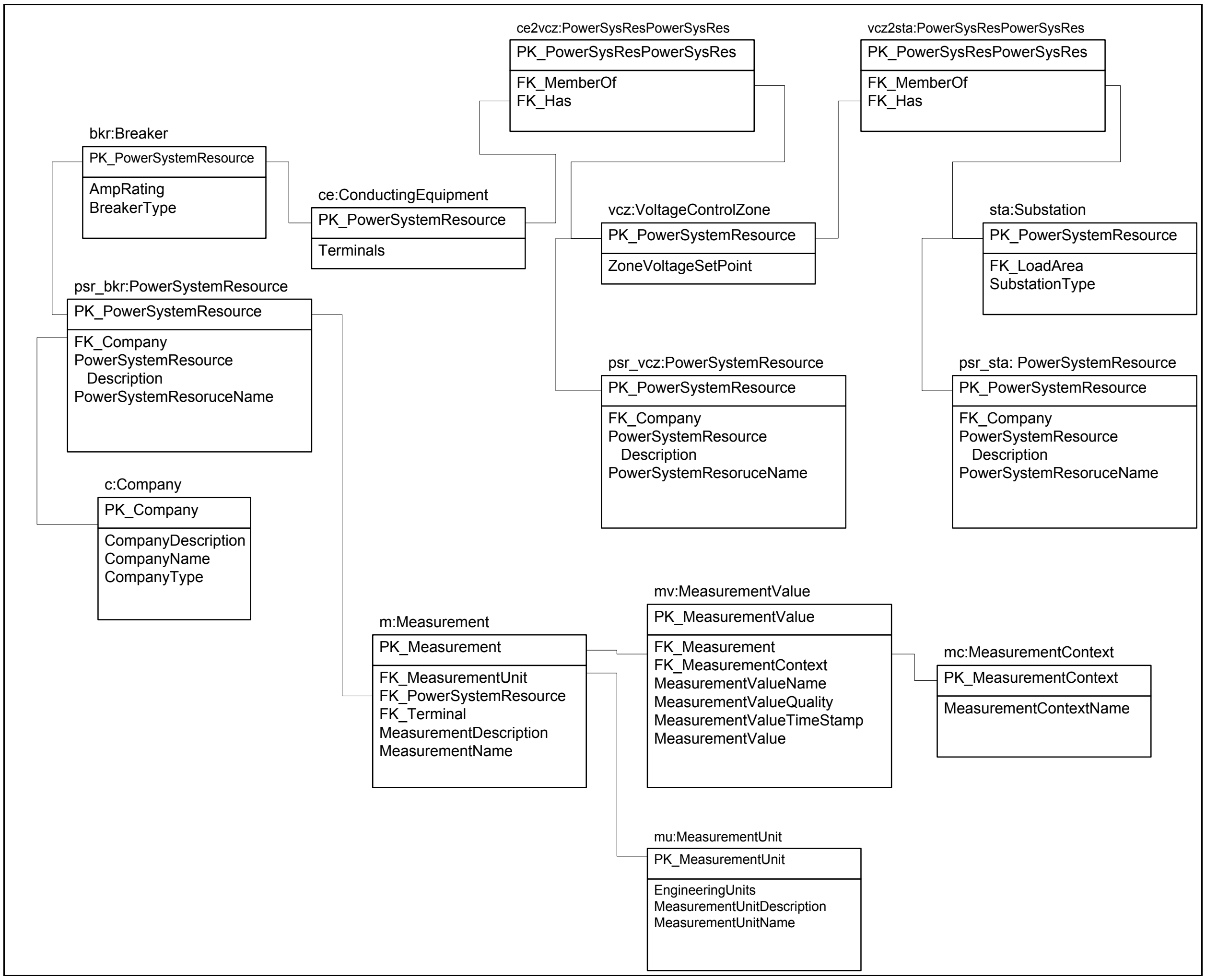

Figure B-9: Diagram of Join Definition for a Breaker

Support for Inserts on View Tables

There are a number of complicating issues with adding objects into a relational database view. Updating of views generally requires the enforcement of numerous database integrity checks. Adding an object to the view table appears simple on the surface, but requires a significant amount of integrity checking and results in multiple operations on the CIM base tables.

In the Breaker View table, the following fields are required: CompanyName, StationName, and VoltageControlZoneName.

The successful completion of the operation for inserting a new breaker requires the following integrity checks on the required fields:

1. The entered CompanyName must exist,
2. A Station with the entered StationName must exist within the entered CompanyName, and

3. A VoltageControlZone must exist within the entered StationName.

Inserting an object in the Breaker View results in the following operations on the CIM base tables:

Insert Breaker record,

Insert Switch record,

Insert ConductingEquipment record,

Insert PowerSystemResource record,

Insert Measurement record for Switch Status,

Insert MeasurementValue record for “OTS” Context,

Insert MeasurementValue record for “OTS SCADA” Context, and

Insert PowerSysResPowerSysRes record for the Breaker to VoltageControlZone relation.

SQL Definition

The SQL definition statement for the Breaker View is shown below.

```
SELECT [c:Company].CompanyName, [psr_sta:PowerSystemResource].PowerSystemResourceName AS
SubstationName, [psr_vcz:PowerSystemResource].PowerSystemResourceName AS VoltageControlZoneName,
[psr_bkr:PowerSystemResource].PowerSystemResourceName AS BreakerName,
[bkr:Breaker].PK_PowerSystemResource AS PK_Breaker, [mv:MeasurementValue].MeasurementValue AS
State, [mu:MeasurementUnit].EngineeringUnits, [mc:MeasurementContext].MeasurementContextName
FROM (((((((Breaker AS [bkr:Breaker] INNER JOIN ConductingEquipment AS [ce:ConductingEquipment] ON
[bkr:Breaker].PK_PowerSystemResource = [ce:ConductingEquipment].PK_PowerSystemResource) INNER JOIN
PowerSysResPowerSysRes AS [ce2vcz::PowerSysResPowerSysRes] ON
[ce:ConductingEquipment].PK_PowerSystemResource = [ce2vcz::PowerSysResPowerSysRes].FK_Has) INNER
JOIN VoltageControlZone AS [vcz:VoltageControlZone] ON
[ce2vcz::PowerSysResPowerSysRes].FK_MemberOf = [vcz:VoltageControlZone].PK_PowerSystemResource)
INNER JOIN PowerSysResPowerSysRes AS [vcz2sta:PowerSysResPowerSysRes] ON
[vcz:VoltageControlZone].PK_PowerSystemResource = [vcz2sta:PowerSysResPowerSysRes].FK_Has) INNER
JOIN Substation AS [sta:Substation] ON [vcz2sta:PowerSysResPowerSysRes].FK_MemberOf =
[sta:Substation].PK_PowerSystemResource) INNER JOIN PowerSystemResource AS
[psr_vcz:PowerSystemResource] ON [vcz:VoltageControlZone].PK_PowerSystemResource =
[psr_vcz:PowerSystemResource].PK_PowerSystemResource) INNER JOIN PowerSystemResource AS
[psr_sta:PowerSystemResource] ON [sta:Substation].PK_PowerSystemResource =
[psr_sta:PowerSystemResource].PK_PowerSystemResource) INNER JOIN (((((Company AS [c:Company]
INNER JOIN PowerSystemResource AS [psr_bkr:PowerSystemResource] ON [c:Company].PK_Company =
[psr_bkr:PowerSystemResource].FK_Company) INNER JOIN Measurement AS [m:Measurement] ON
[psr_bkr:PowerSystemResource].PK_PowerSystemResource = [m:Measurement].FK_PowerSystemResource)
INNER JOIN MeasurementValue AS [mv:MeasurementValue] ON [m:Measurement].PK_Measurement =
[mv:MeasurementValue].FK_Measurement) INNER JOIN MeasurementContext AS [mc:MeasurementContext]
ON [mv:MeasurementValue].FK_MeasurementContext = [mc:MeasurementContext].PK_MeasurementContext)
INNER JOIN MeasurementUnit AS [mu:MeasurementUnit] ON [m:Measurement].FK_MeasurementUnit =
[mu:MeasurementUnit].PK_MeasurementUnit) ON [bkr:Breaker].PK_PowerSystemResource =
[psr_bkr:PowerSystemResource].PK_PowerSystemResource
WHERE ((([mu:MeasurementUnit].EngineeringUnits)="STATE") AND
(([mc:MeasurementContext].MeasurementContextName)="SCADA_EMS_001"))
ORDER BY [c:Company].CompanyName, [psr_sta:PowerSystemResource].PowerSystemResourceName,
[psr_vcz:PowerSystemResource].PowerSystemResourceName;
```

Measurement Pattern

The CIM measurement pattern is also shown in Figure B-1. The measurement pattern can be used to model a complete range of relationships between physical objects and their measurements, calculated values, and manually entered values. All the state information for objects is stored in the MeasurementValue table. The MeasurementValue table thus contains a heterogeneous collection of different types of measurements (e.g., MW, Mvar, temperature, voltage, frequency, and pressure) for a wide variety of equipment (e.g., transformers, pumps, capacitors, generators, etc.). The MeasurementValue table contains real-time data and solutions from different applications (e.g. state estimator, powerflow user#1, and powerflow user #2). The source of the MeasurementValues is defined to be a MeasurementContext.

The CIM allows Measurements to be associated with PowerSystemResources and Terminals. MW, MVAR, MVA, Voltage, and Frequency measurements should always be associated with Terminals in order to provide a consistent treatment and to avoid ambiguity.

Non-electrical measurements e.g. temperature and breaker status measurements should be associated with the PowerSystemResource.

CIM Base Table

In the sections above, CIM has been setup as a normalized relational database by using the following conventions:

Every class is given a unique identifier attribute: PK_ClassName and Relationships are defined by using foreign keys. The foreign key is generally given the attribute: FK_RelatedClassName. For example the PowerSystemResource class has an FK_Company attribute. This identifies the Company that owns the PowerSystemResource.

Many to many relationships are modeled by introducing intermediate tables. For example, the many to many relationship of PowerSystemResource "is member of" PowerSystemResource is modeled using the PowerSysResPowerSysRes table. This table has the following attributes:

- PK_PowerSysResPowerSysRes,
- FK_Has – Identity of the object within the container, and
- FK_MemberOf – Identity of the container object.

CIM API

At present a generic API named, GID, is being standardized by the CCAPI project. This API will define a generic interface to access data from a CIM complaint database. Three submissions have been made towards this at this time and one of these is expected to be embraced by all the major EMS vendors and utilities. In the WA-SMD project BEST Systems will use the GID recommended by the CCAPI group.

Appendix C: Reference

The following references have been used in designing the user interface for the system.

1. Scope of Work for WA-SMD, BEST Systems, April 5, 2000
2. ISO 9001 Quality Management System, BEST Systems, Inc., Version 1.0, September 30, 1997
3. Graphical User Interface Design for Engineers, BEST Systems Programming Guide, Release 9706.02
4. EPRI Software Guidelines for Power Delivery Group, 1995
5. IEEE Standard 830-1993: IEEE Recommended Practice for Software Requirements Specifications, IEEE Standards Collection, Software Engineering, 1994 Edition, ISBN 1-55937-442-X,
6. Software Engineering, Ian Sommerville, Fifth Edition, 1996 Addison-Wesley, ISBN 0-201-42765-6

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