Arnold Schwarzenegger
Governor

MAINTAIN, ENHANCE AND IMPROVE RELIABILITY OF CALIFORNIA'S ELECTRIC SYSTEM UNDER RESTRUCTURING

APPENDIX VII

CAISO Station Displays

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:

Lawrence Berkeley National Laboratory

CERTS
CONSORTIUM FOR ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

MARCH 2006
CEC-500-2006-035-APVII
LBNL-58939

Prepared By:
Lawrence Berkeley National Laboratory
Consortium for Electric Reliability Technology
Solutions (CERTS)
Joseph H. Eto
Berkeley, CA
Contract No. 150-99-003

Prepared For:

California Energy Commission

Public Interest Energy Research (PIER) Program

Don Kondoleon,
Contract Manager

Mark Rawson, Bernard Treanton, Linda Kelly,
Ron Hoffman, Don Kondoleon
Project Managers

Mark Rawson
Program Area Team Lead

Laurie ten Hope
Office Manager,
ENERGY SYSTESM INTEGRATION AND ENVIRONMENTAL RESEARCH OFFICE

Martha Krebs, Ph. D.
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

B.B. Blevins
Executive Director

CAISO Station Displays

1008723

CASIO Station Displays

1008723

Technical Update, May 2003

Cosponsors

Public Interest Energy Research Program (PIER)
California Energy Commission
1516 Ninth Street
Sacramento, California 95814

PIER Project Manager:
D. Hawkins
L. Scott

LBNL
1 Cyclotron Road
Berkley, CA 94720

LBNL Project Manager:
J. Eto

EPRI Project Manager
P. Hirsch

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

Incremental Systems
PowerData Corporation

This is an EPRI Technical Update report. A Technical Update report is intended as an informal report of continuing research, a meeting, or a topical study. It is not a final EPRI technical report.

ORDERING INFORMATION

Requests for copies of this report should be directed to the EPRI Orders and Conferences, 1355 Willow Way, Suite 278, Concord, CA 94520, (800) 313-3774, press 2 or internally x5379, (925) 609-9169, (925) 609-1310 (fax). Copies of this report may also be downloaded from the California Energy Commission's website: http://www.energy.ca.gov/research

CITATIONS

This document was prepared by

Incremental Systems
4618 194th Avenue SE
Issaquah, WA 98027

Principal Investigator
R. Podmore

PowerData Corporation
15193 SE 54th Place
Bellevue, WA 98006

Principal Investigator
M. Robinson

This report was prepared for

EPRI
3412 Hillview Avenue
Palo Alto, California 94304

And

Public Interest Energy Research Program (PIER)
California Energy Commission
1516 Ninth Street
Sacramento, CA 95814

This report describes research jointly sponsored by EPRI and the California Energy Commission.

The report is a corporate document that should be cited in the literature in the following manner:

CAISO Station Displays, EPRI, Palo Alto, CA, California Energy Commission, Sacramento, CA: 2003. 1008723.

ABSTRACT

The objective of this report is to describe the results of a project to build Station One-Line Diagram displays for the CAISO system.

The development and maintenance of the Station One-line displays for Energy Management System applications has historically been a very time consuming, tedious and error prone task. Several man years of effort may be required to build the station displays for a large interconnected power system. Once these stations displays have been built they have been locked into the proprietary formats of a single vendor.

However, Station One-line displays are an essential tool for the validation and operation of a whole family of network based programs including; operator training simulator, state estimator, contingency analysis, operator power flow, security constrained dispatch and topology estimator.

The goal of this project has been to implement an easy to use procedure to build and maintain the station displays for the CAISO operational model with a minimal amount of manual labor and to do this in an environment where the Station One-line displays can be used to support a variety of networks applications from multiple suppliers.

During the time frame of this project from mid 2000 to mid 2003, the CAISO EMS Project Team, the CASIO EMS supplier (ABB Network Management), the CERTS project team, and the industry in general have made significant advances towards developing Energy Management Systems that are more open and maintainable.

The industry has adopted standard CIM XML data formats for operational model exchange. The major EMS suppliers have conducted inter-operability tests. Utilities spend many man years to build and validate their operational models. These models are no longer locked into EMS vendor proprietary databases with onerous legal restrictions that prevent their exchange with other utilities, RTOs and application suppliers. The major EMS vendors can now automatically generate one-line displays from network topology. The objects on these displays have embedded connection, name and measurement data. This embedded display information can now be exchanged between different systems with simple formats. With the development of these standards and tools, it is now technically feasible for a large Independent System Operator (ISO) to support a parallel research and development effort on new operational power applications, while at the same time implementing a new Energy Management System.

The experiences with importing the CAISO 2000 operating model and the WSCC Planning Model have been used to enhance the PACE Power Application Computing Environment and the EPRI Operator Training Simulator software so that they can handle very large models with more than 10,000 buses in a robust, stable and efficient manner.

CONTENTS

1 1

SUMMARY 1

Objectives 1

Station One-line Diagrams with Embedded Object Information 3

Station Displays for CAISO 2000 Operating Model 5

Station Displays for WSCC Planning Model 19

Station Displays for CAISO 2003 Operating Model 25

Summary and Conclusions 25

2 27

TECHNICAL APPROACH 27

PACE Power Application Computing Environment 27

3 32

USER INTERFACE TOOLS 32

Overview 32

PowerVisuals Viewer 33
Substation Diagrams 34
System Map 35
Display Call-up Procedures 35
Changing Contexts 36
Monitoring System Conditions 36
Device Control Functions 36
Adjusting Generating Unit Controls 38
Controlling Loads 39

PowerVisuals Editor 39
Connecting Visual Objects 42

PowerVisuals Synchronizer 45

1

SUMMARY

Objectives

The overall objective of the CERTS project is to research, develop and commercialize new methods, tools and technologies to protect and enhance the reliability of California's electric power system under the emerging competitive electricity market structures.

The following network oriented applications are available from EPRI and other members of the CERTS project team:

- EPRI Operator Training Simulator (OTS)
- EPRI Advanced Topology Estimator
- Var Monitoring Tracking and Prediction
- Stability, Nomograms and Remedial Action Schemes
- Phasor Measurement System
- Optimal Power Flow
- Voltage Security Analysis
- Dynamic Security Analysis
- Short Term Electricity Market Simulator

The value of these applications are all enhanced with a detailed and accurate operational model of the CAISO system. This operational model requires an integrated set of station and system map one-line diagrams. The one-line diagrams are needed to understand topology of the model, maintain the model for system changes, view program results and implement program controls.

The CERTS projects are being implemented with the following strategy:

- An open power application computing environment is being created in parallel with the new Energy Management System.
- The impact on the new EMS project scope, schedule and staff is being minimized.
- CIM XML standards are being used for model and data exchange.
- EPRI OTS is being used as a test bed for the new CERTS applications.

The objectives of this particular project included the following:

- To import existing CAISO operational models into a CIM compliant database.
- To create Station One-line diagrams from the network topology in the CIM.
- To demonstrate that useful Station One-line diagrams can be built and maintained with a reasonable amount of labor effort.
- To demonstrate that the Station One-line diagrams can be used with a variety of network applications.

Station One-line Diagrams with Embedded Object Information

In the early generations of SCADA and Energy Management Systems that were installed from the 1970s through the 1990s Station One-line diagrams have been built without embedded object information. Network topology models were built independently from the station one-line diagrams. The network topology model is defined in the database by specifying the From Node and To Node numbers for each electrical device. The One-line diagrams are drawn independently using a graphical editing tool. The One-line diagrams may differ from the topology of the model in the database. An error in the network topology database will not be automatically shown on the Station one-line display.

This situation is shown by comparing Figure 1-1 and 1-2. When the DOYL-DAW line symbol is moved diagonally towards the bottom right corner the line symbol becomes disconnected and the line MW and MVAR flows and line name do not move with it. When an object is disconnected on the Station One-line diagram, the topology model in the database is not updated.

In the early 1990s a number of independent software developers introduced the concept of Station One-Line diagrams with embedded object information. This situation is shown by comparing Figure 1-1 and Figure 1-3. When the DOYL-DAW line symbol is moved diagonally towards the bottom right corner the line symbol remains connected and the line MW and MVAR flows and line name move with it. The topology of the schematic is rendered to model the topology in the network database. Any errors in the network database are very easy to see on the one-line diagram.

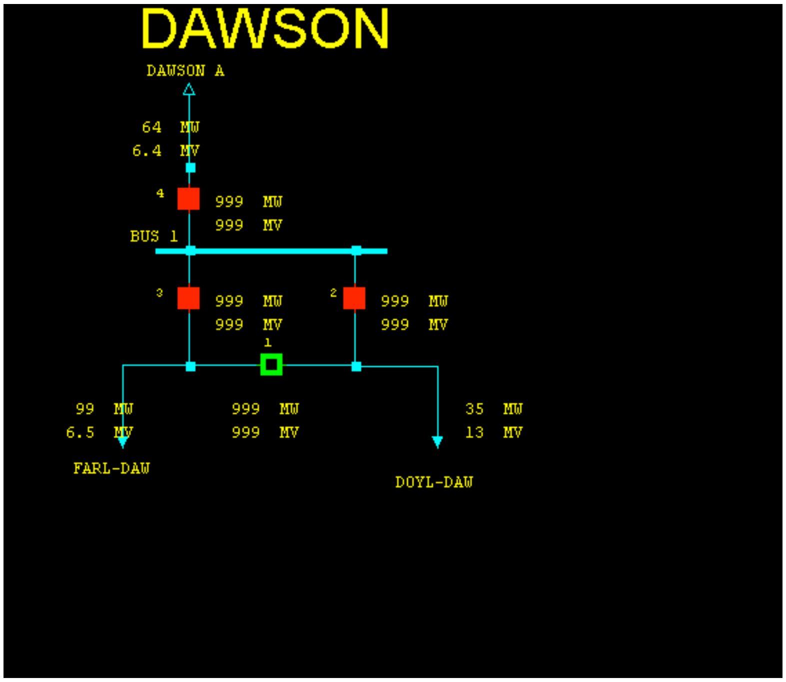


Figure 1-1: Sample Substation One-Line Diagram

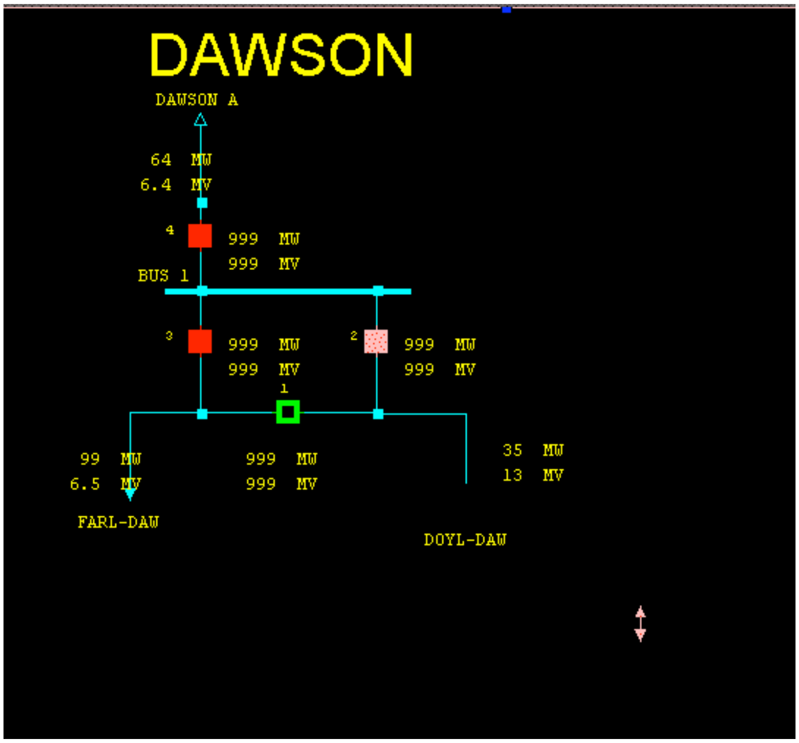


Figure 1-2: Effect of Moving Line Symbol without Embedded Object Information

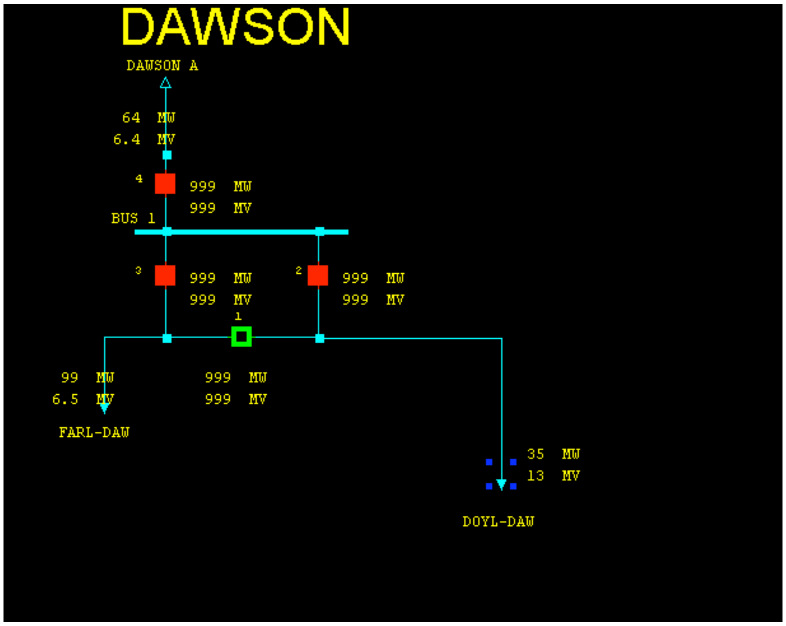


Figure 1-3: Effect of Moving Line Symbol with Embedded Object Information

Station Displays for CAISO 2000 Operating Model

This section describes the results obtained with the CAISO 2000 operating model. This model had been developed by CAISO staff by merging models from the following systems:

- San Diego Gas and Electric EMS provided by GE Harris
- Southern California Edison OTS provided by Siemens
- Pacific Gas and Electric Company EMS provided Siemens

At the time of the model conversion, the CAISO the staff were still in the process of updating and validating the CAISO 2000 operating model using the data engineering and display tools on the SPIDER system supplied by ABB Systems Control. The model was not yet able to support a converged State Estimator solution for the full CAISO system.

The CAISO 2000 Operating Model was exported as an ACCESS database from the existing CAISO Energy Management system. It was then converted to the CIM database using a Generalized Model Importer.

The CAISO 2000 operating model represented up to the boundaries of the California system with a small amount of detail for the external neighboring stations.

The numbers of the various components in this model are shown below:

	QTY
Breakers	5012
Busbars	3219
Generators	920
Loads	2126
Series Devices	234
Shunts	424
Stations	1846
Switches	14435
Synchronous Machines	920
Transformers	969
Transmission Lines	2834
Zones	34

Displays were automatically generated laid out for all of the CAISO stations using the PowerVisuals Autobuilder program.

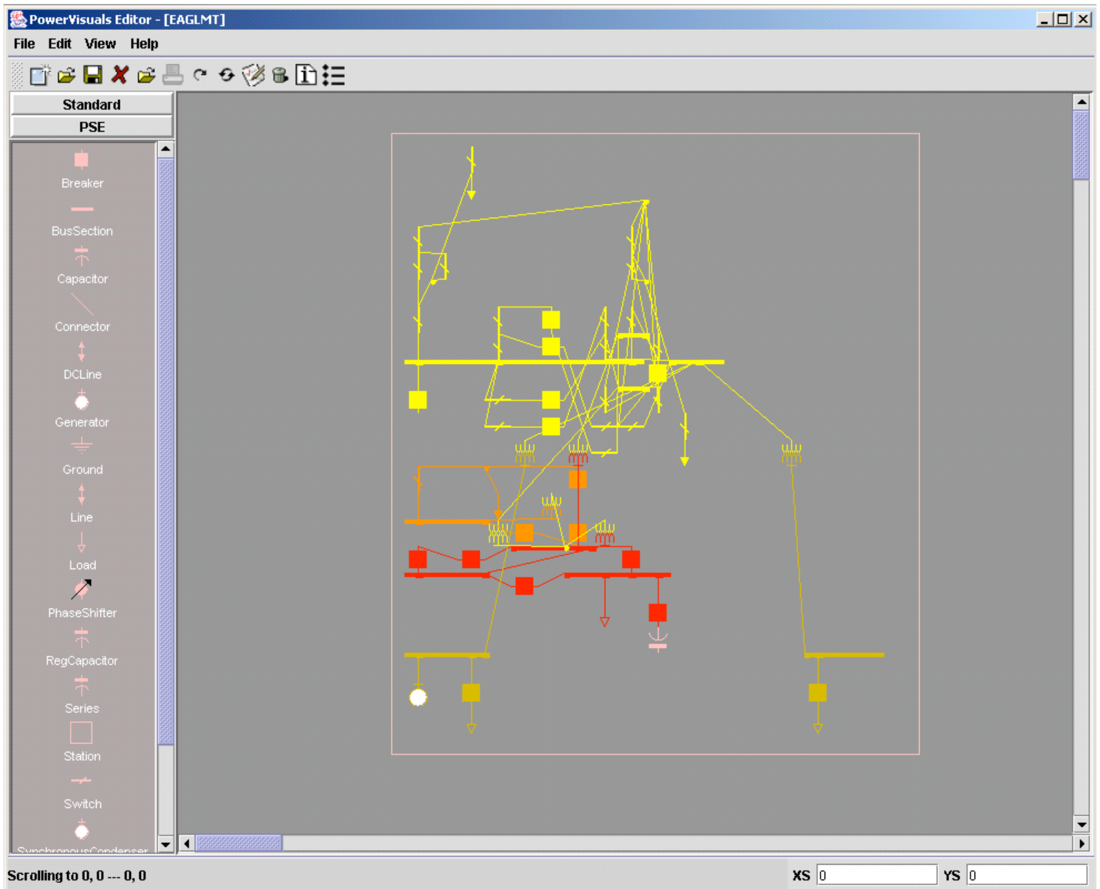


Figure 1-1: Initial layout of station display for automatic display builder

A typical automatic layout of a station one-line display is shown in Figure 1-1. Many of the small displays can be used with little manual editing. However, as shown by Figure 1-1 the medium to large stations require a manual layout session before they are usable.

Stations were laid out for the Pacific Gas and Electric, Southern California Edison and San Diego Gas and Electric Company systems. A major station in one of these systems was selected and laid out manually. The high voltage lines on this station diagram would then indicate the neighboring high voltage stations. These station names were added to a list of stations to be built. This process was continued until the station One-line displays were laid out for most of the major 500 KV, 345 KV and 230 KV substations in the CAISO system.

The One-line displays were manually laid out for 197 stations. The elapsed time in minutes for the manual layout and the number of lines in each station are shown in Table 1-1.

Examples of results for the Gates, Lugo, Malin, Midway and Tesla stations are shown in Figures 1-2 through 1-6.

Table 1-1: Manual Layout Time and Number of Lines for CAISO EHV Stations

CO	STATION	MINS	LIINES	CO	STATION	MINS	LIINES	CO	STATION	MINS	LIINES
SCE	ALAMIT	35	4	SDGE	HNTGBH	16	4	PGE	PROCSM	1	1
PGE	ALHAMB		4	PGE	HURLEY	47	11	SCE	PULPGN	1	1
PGE	ALTENG	3	3	PGE	INSKIP	0.5	1	SDGE	PVERDE	3	2
PGE	AMES		8	SDGE	IVALLY	11	4	PGE	RALSTN	3	2
SCE	ANTLPE	18	4	PGE	JAYBRD	4	2	PGE	RANCHO	12	6
SDGE	ANZA	1	1	PGE	JENNGS		2	PGE	RAVENS	32	9
SCE	ARCOGN	13	2	SDGE	JOHANN	6	2	SCE	REDOND	25	5
PGE	ATLNTC	3	2	PGE	JVENTR	2	2	PGE	RESTAP	1	3
SCE	BAILEY	6	4	PGE	KALINA	1	1	SCE	RHONDO		4
PGE	BANKPP	1	1	PGE	KELSO	2	2	PGE	RIOOSO	45	16
SCE	BARRE	29	5	SCE	LACIEN	8	2	PGE	RNDMTN		13
PGE	BORDER		2	SCE	LAFRES	35	9	SDGE	ROA230	1	1
PGE	BRNTWD	4	4	SCE	LAGBEL	30	7	PGE	ROSEBG	1	2
PGE	BURNYF	1	2	PGE	LAKE	4	4	SDGE	SANLUS	11	10
PGE	CAMINO	5	3	PGE	LASPOS	10	5	SDGE	SANTGO	14	4
PGE	CARMIC	5	2	SCE	LBEACH	14	3	SCE	SAUGUS	12	5
SCE	CENTER	20	4	SCE	LEWIS	24	5	SCE	SERRAN	21	9
SCE	CHEVMN	4	2	PGE	LFC51	2	2	PGE	SLUISP	15	2
SDGE	CHINO	20	8	SCE	LGHTHP	33	6	PGE	SMDPRT	1	1
PGE	CLOVER	0.5	1	PGE	LIVNLB	2	2	SCE	SNCLRA	25	11
PGE	COCOPP		8	PGE	LLSUB	3	2	PGE	SNRMNR	1	1
PGE	COCOSB	32	10	PGE	LODI	5	5	SDGE	SONGS	25	9
PGE	COG.PP	1	1	PGE	LOGNCK	2	2	PGE	SOUTH	1	3
SCE	COLDGN	1	1	PGE	LOSBNS		18	SCE	SPRGVL	14	4
PGE	CORTIN		9	PGE	LUGO		14	PGE	STAGG	12	6
PGE	COWCRK	0.5	1	SCE	MAGNDN	14	10	PGE	STIGCT	1	1
PGE	CTNWDP	58	29	PGE	MALIN		2	SDGE	SXCYN	7	7
PGE	CTNWDW		9	PGE	MARTIN	110	16	SCE	SYCAMR	12	1
PGE	D.WLNT	1	1	PGE	MAXWEL	4	2	SDGE	TALEGA	5	9
SCE	DELAMO	13	4	PGE	MCLELN	1	1	PGE	TASJRA	2	2
PGE	DELTSW	3	3	PGE	MEAD		4	PGE	TBLMTJ		3
SDGE	DEVERS	30	9	SCE	MESA	27	8	PGE	TBLMTN		17
PGE	DIABLO		12	PGE	MESAP		7	SCE	TENGEN	1	1
PGE	DIXON		3	PGE	METCLF		20	PGE	TESLA	155	30
PGE	DOSMGO	9	2	PGE	MIDFRK	4	1	SCE	TEXACZ	1	1
SCE	EAGLRK	8	3	PGE	MIDWAY		28	PGE	TIPPRT	1	1
PGE	EASTSH	5	4	SDGE	MIGUEL	10	11	SDGE	TJI230	1	1
SCE	EDMONDS	14	1	PGE	MIRLOM		**14**	PGE	TRACY		2
PGE	EIGHTM	2	2	SCE	MNDALY	10	2	PGE	TRCYPP	40	11
SDGE	ELCNTR	1	1	SCE	MOHAVE		4	PGE	UNIONV	10	4
SCE	ELDORD		12	SCE	MOORPK	22	9	PGE	USWND1	1	1
PGE	ELKGRV	2	2	PGE	MORBAY		8	PGE	USWND4	2	2
SCE	ELLIS	45	9	PGE	MOSSLD		14	PGE	USWNDR	1	2
SCE	ELNIDS	22	5	SDGE	MSSION	12	17	PGE	USWPJR	2	2
SCE	ELSEGN		2	SDGE	NELSON	2	2	PGE	VACADX		23
PGE	EMBARC	3	2	PGE	NEWARK	172	33	SDGE	VALLEY	21	5
SDGE	ENCINA	16	8	SDGE	NGILLA	6	3	PGE	VCADXJ		5
SDGE	ESCNDO	12	13	SDGE	NGLAPS	1	1	SCE	VESTAL	18	5
PGE	FLOWD2	2	2	SDGE	OLDTWN	7	7	SCE	VILLPK	31	4
PGE	FOLSOM		2	PGE	OLINDA		3	PGE	VINCNT	46	15
PGE	FTHLSM	7	3	SCE	OLINDA		3	PGE	WALCRK		2
PGE	GATES		20	SCE	OLNDWA	25	7	SCE	WALNUT	26	3
PGE	GLENN	5	9	PGE	OLSEN	0.5	2	PGE	WALTID	10	6
PGE	GOLDHL	86	11	SCE	OMAR		3	PGE	WAPAT2	1	1
SCE	GOLETA	18	2	PGE	ORANGE	12	5	PGE	WAPAT3	1	1
SCE	GOODRH	1	2	SCE	ORMOND	16	4	PGE	WAPAT6	1	1
SCE	GOULD	4	2	SCE	PARDEE	19	13	SCE	WARNE	1	1
SCE	GROWGN	1	1	PGE	PARKER		5	SCE	WARNTP	6	3
PGE	GRZLYJ		6	SCE	PASTRA	9	7	PGE	WEBER	10	15
SCE	HARBGN	3	2	PGE	PEABDY	2	2	PGE	WESTLY	4	5
PGE	HARDNG		2	PGE	PEABJT	3	6	PGE	WESTLY		5
PGE	HEDGE	23	10	PGE	PNOCHE	41	13	PGE	WHTRK	14	4
PGE	HELM		9	PGE	POCKET		7	PGE	WINDMAS	2	2
SCE	HINSON	12	9	SDGE	PQUTOS	14	17				

The average time for the manual layout of the station displays including the very largest and very smallest displays is 14.2 minutes. Applying this average to the 1846 stations in the CAISO system gives a total of time of 55 man days. This task could be performed by engineering technicians, operator trainees or students.

This exercise demonstrated the feasibility of maintaining a separate set of displays to support the CERTS applications with minimal cost and minimal impact on the EMS maintenance staff.

The CAISO 2000 operating model, which was used to build the Station One-line displays had not been fully validated and tuned to support the state estimator and operator power flow programs. In early 2001 CAISO awarded a contract to ABB Network Management for delivery and installation of a new Energy Management System. Further work with the CAISO 2000 was suspended pending the development of a new EMS operational model that will be available in a CIM XML format.

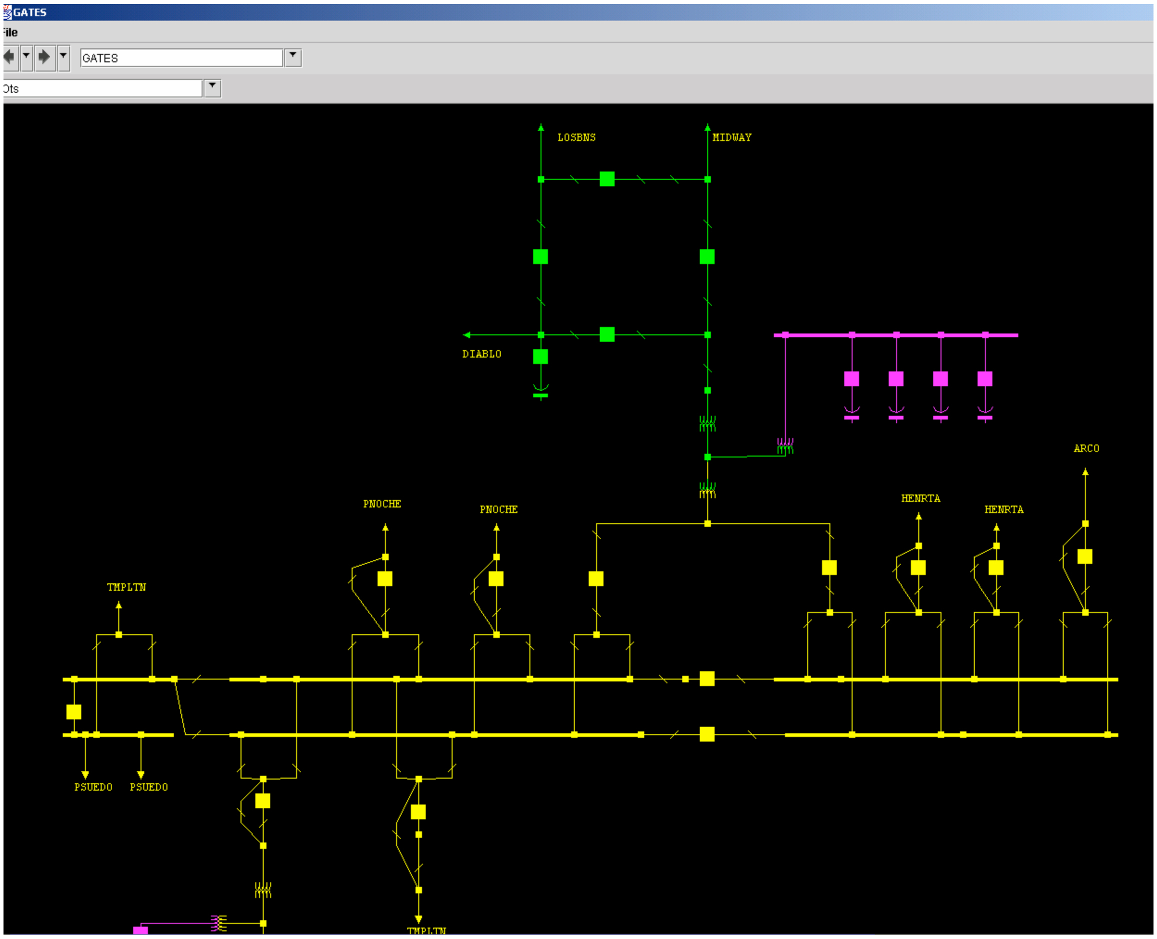


Figure 1-2a: Gates Station - Operating Model – 500KV, 230KV Bays

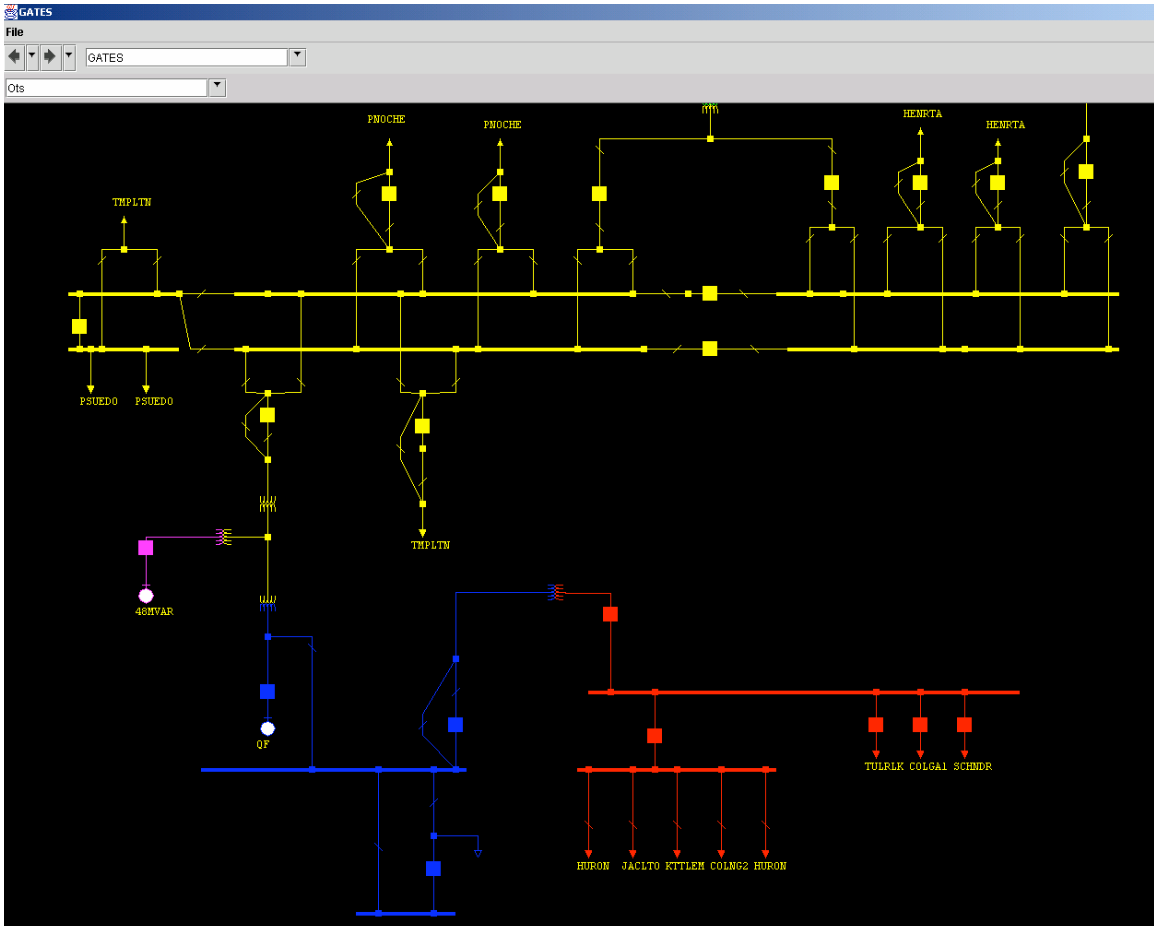


Figure 1-2b: Gates Station – Operating Model – 230KV, 115KV, 70KV Bays

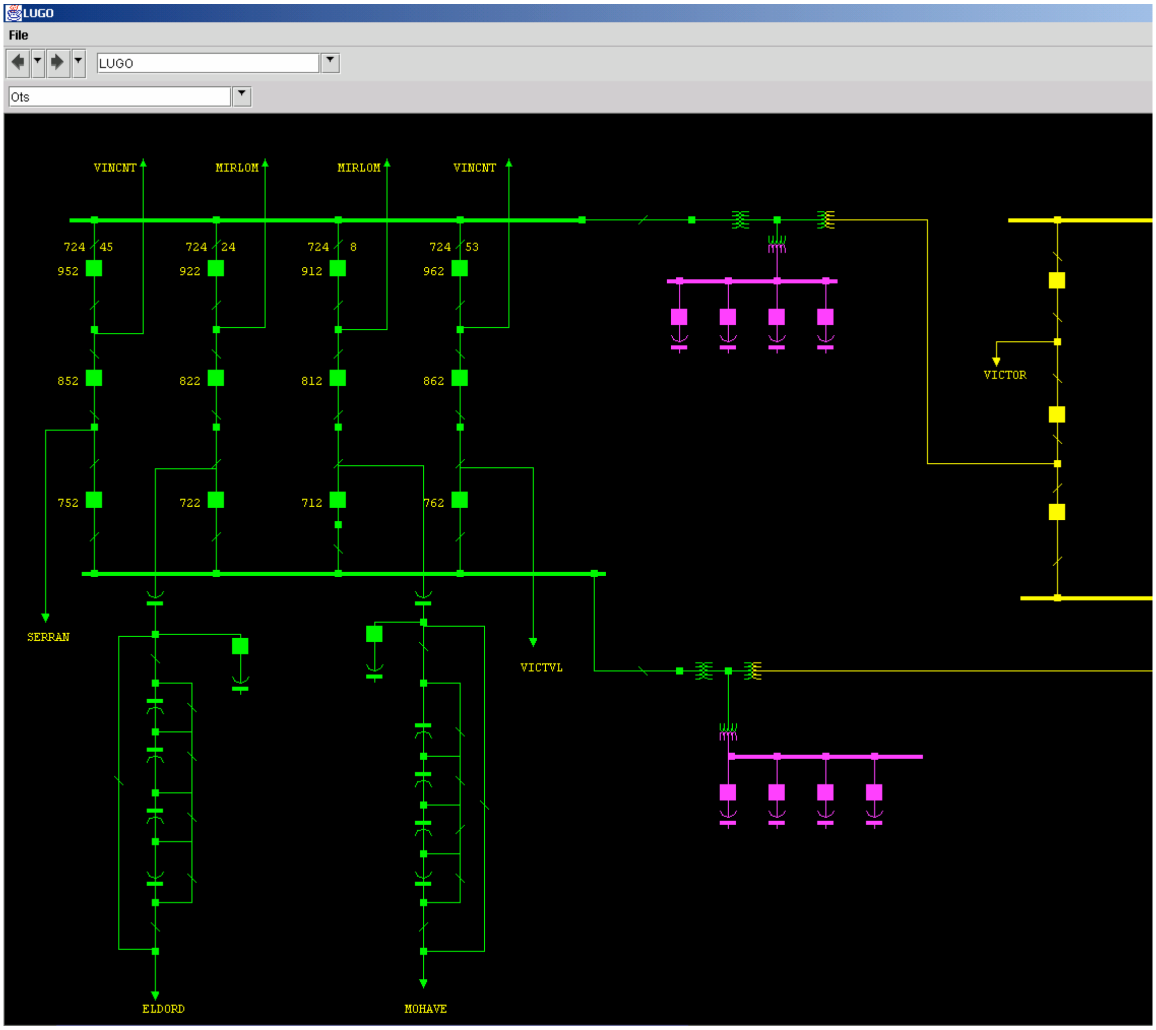


Figure 1-3a: Lugo Station - Operating Model – 500KV Bays

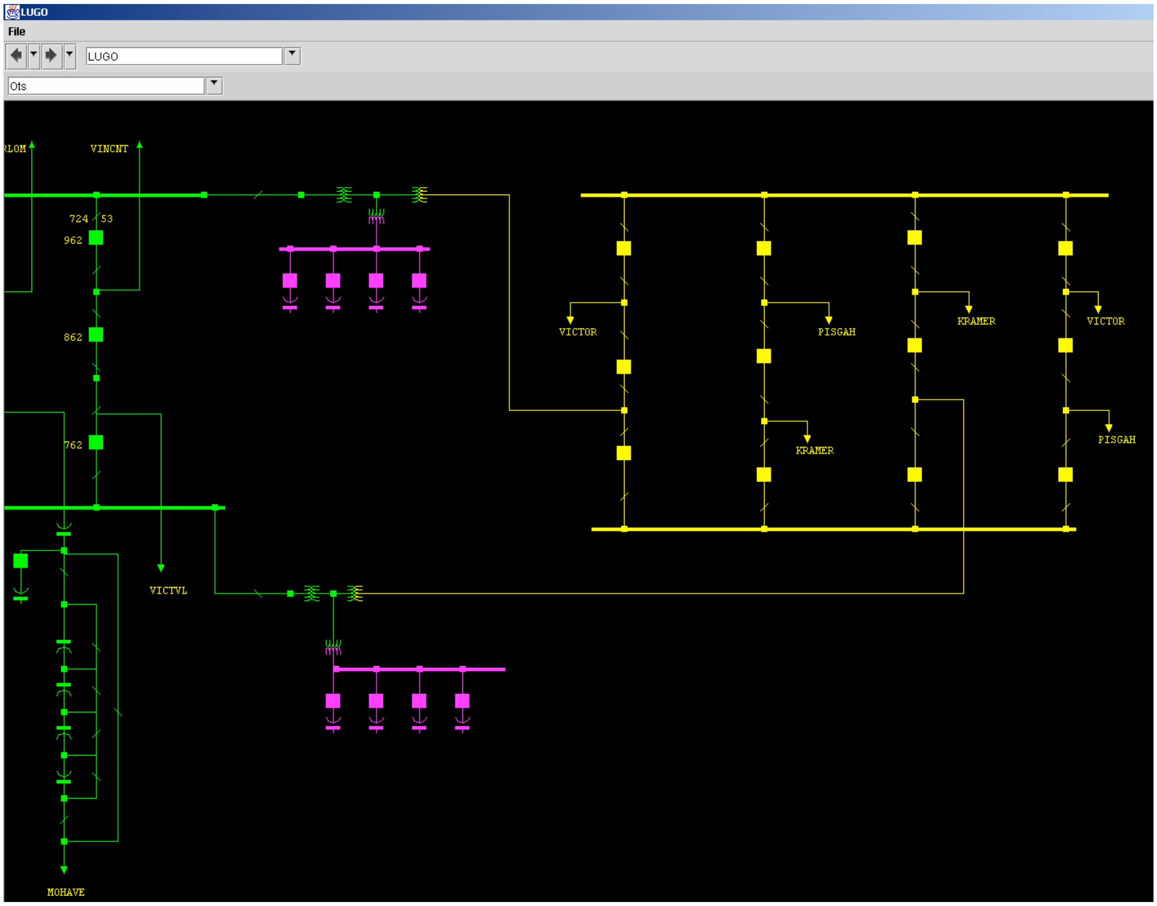


Figure 1-3b: Lugo Station – Operating Model – 230KV Bays

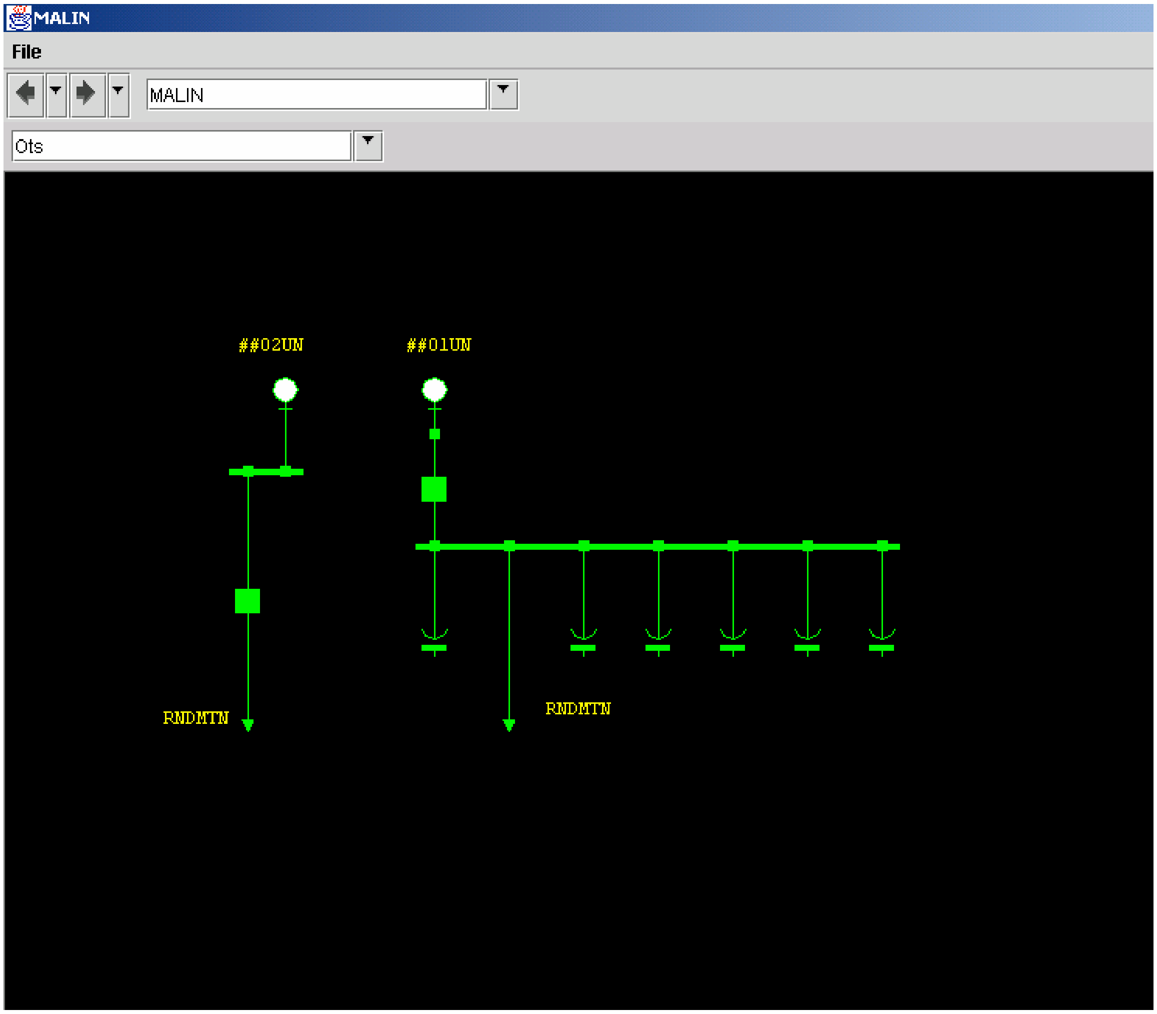


Figure 1-4: Malin Station – Operating Model

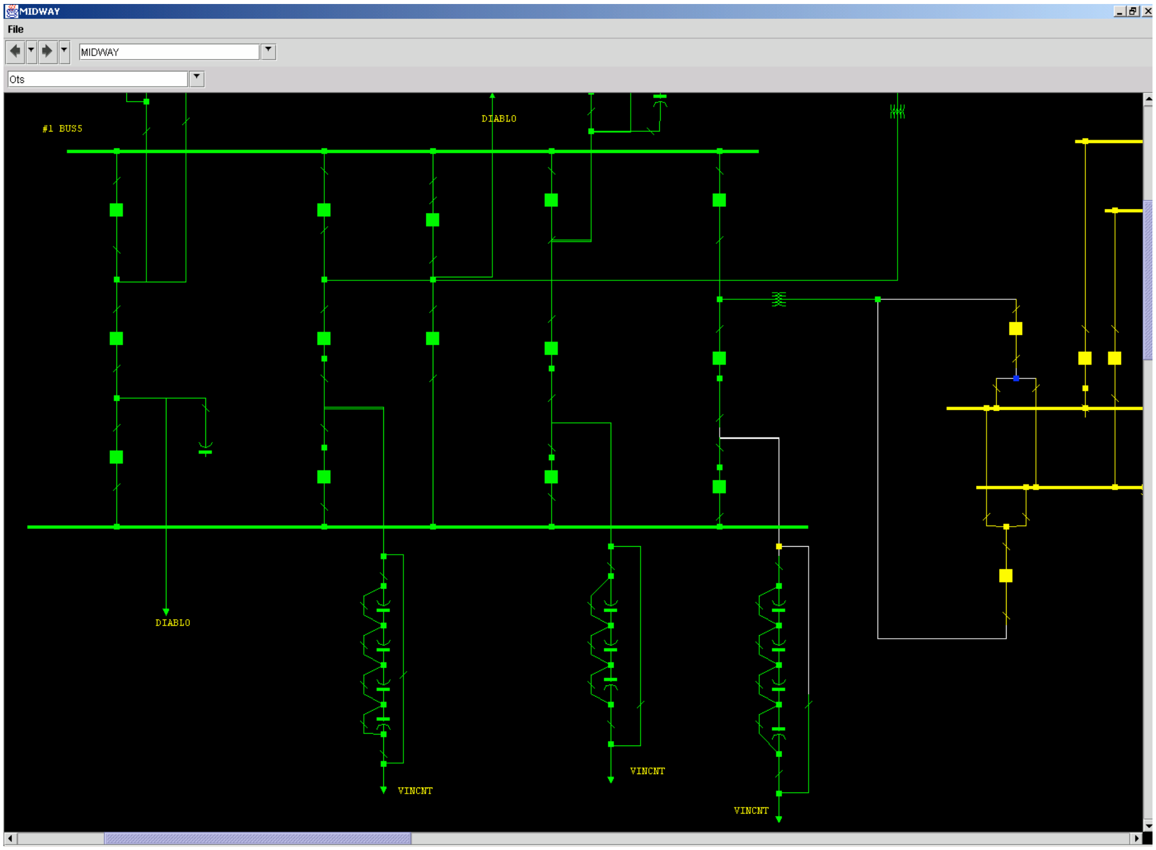


Figure 1-5a: Midway Station – Operating Model – 500KV Bays

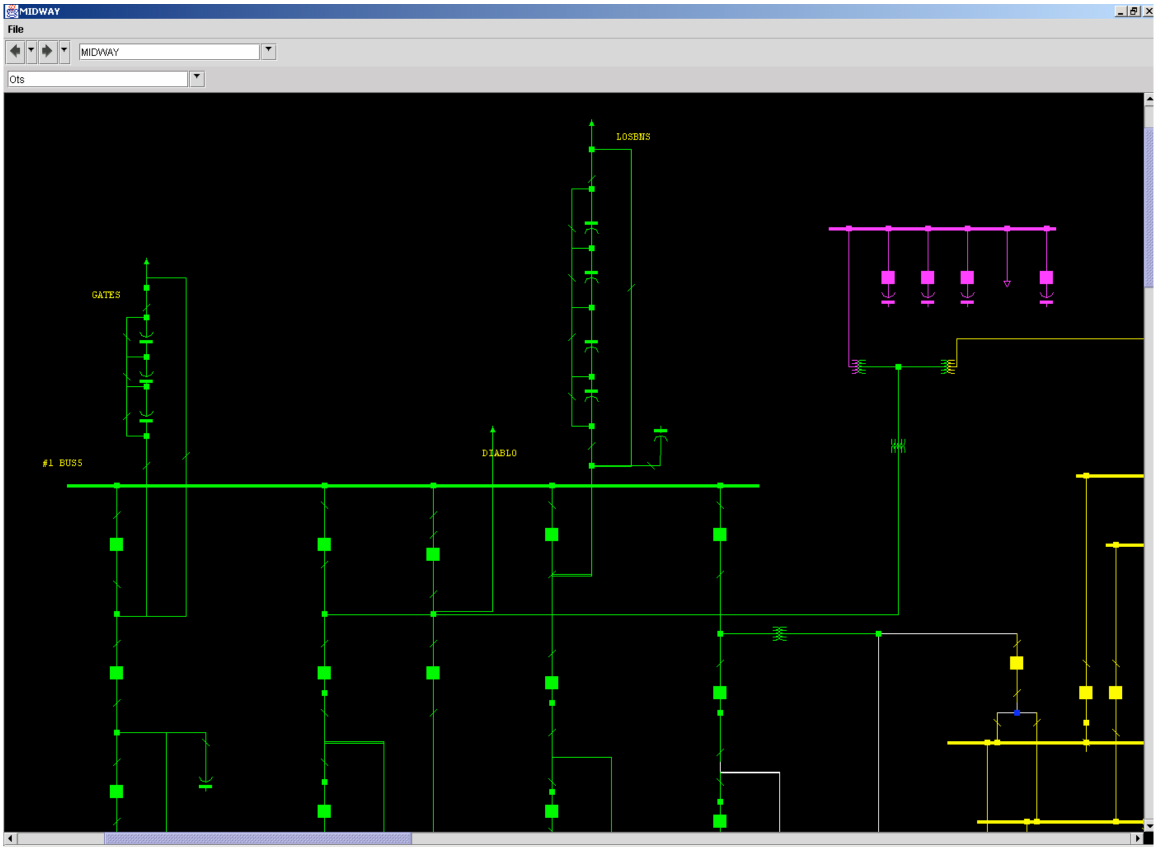


Figure 1-5b: Midway Station – Operating Model – 500KV Bays

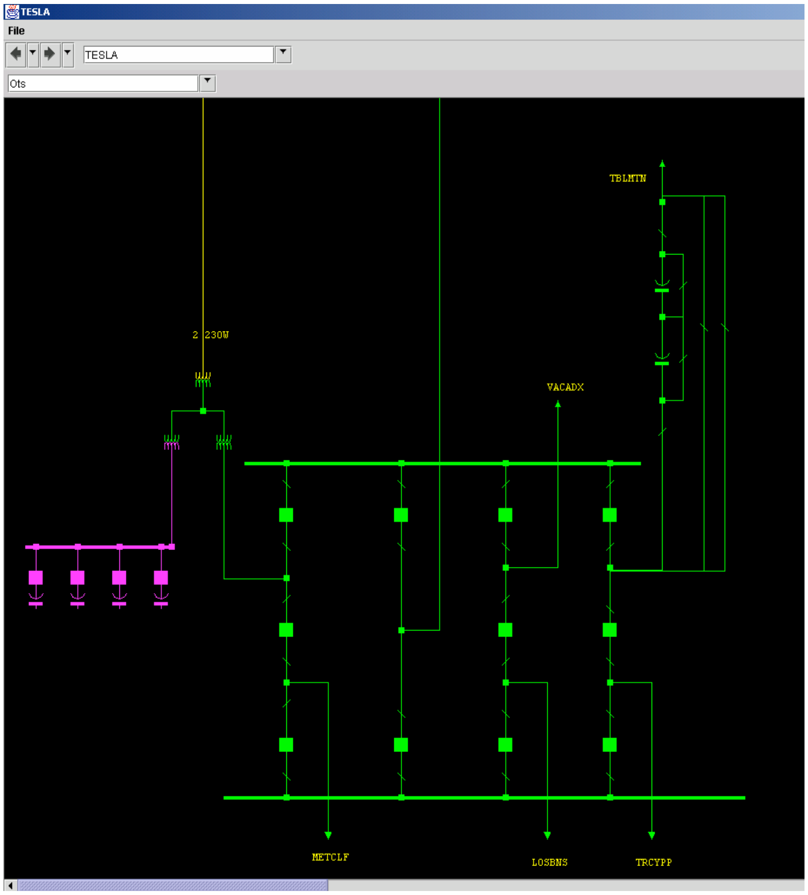


Figure 1-6a: TESLA Station – Operating Model – 500KV Bays

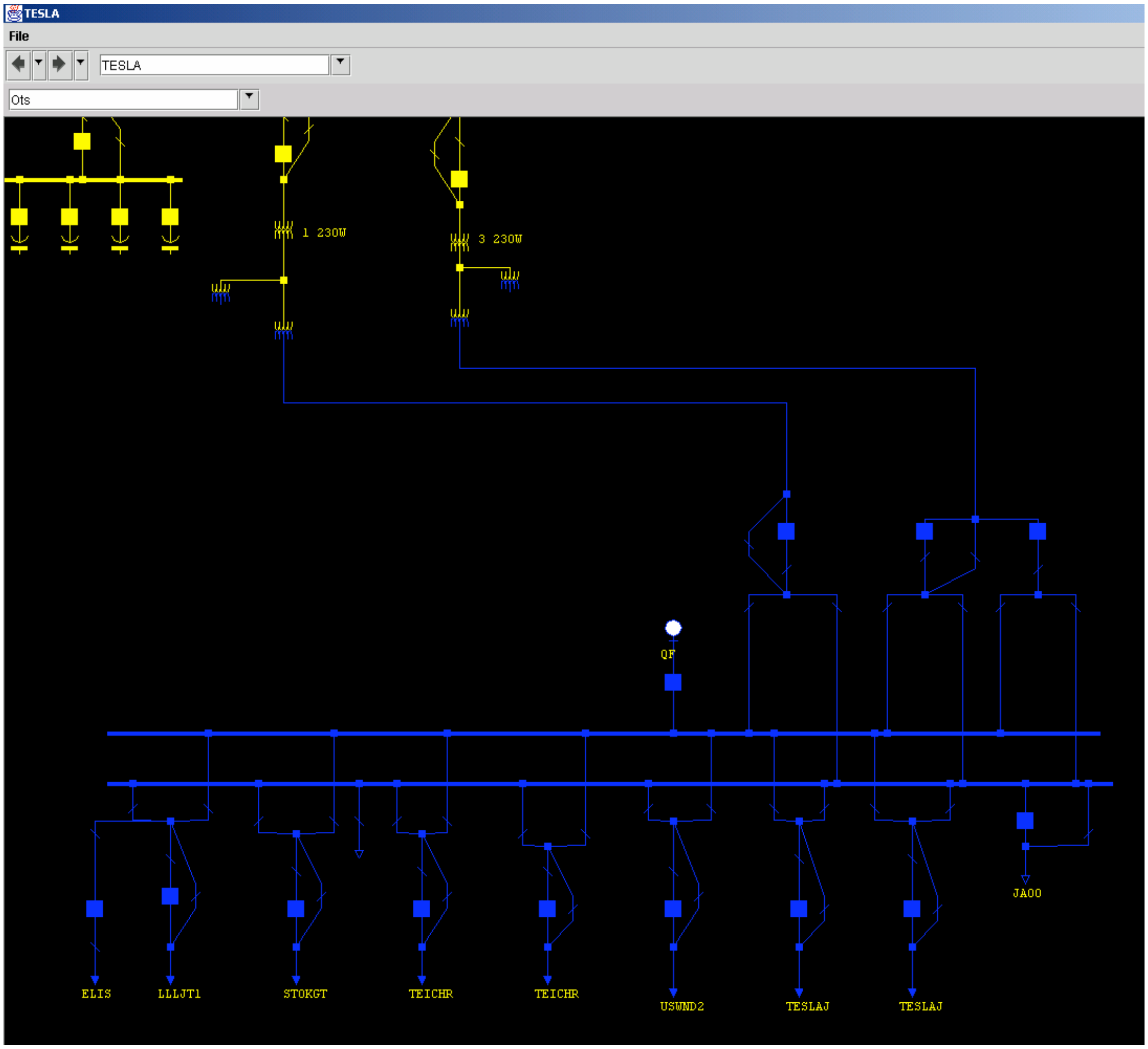


Figure 1-6b: TESLA Station – Operating Model – 115KV Bays

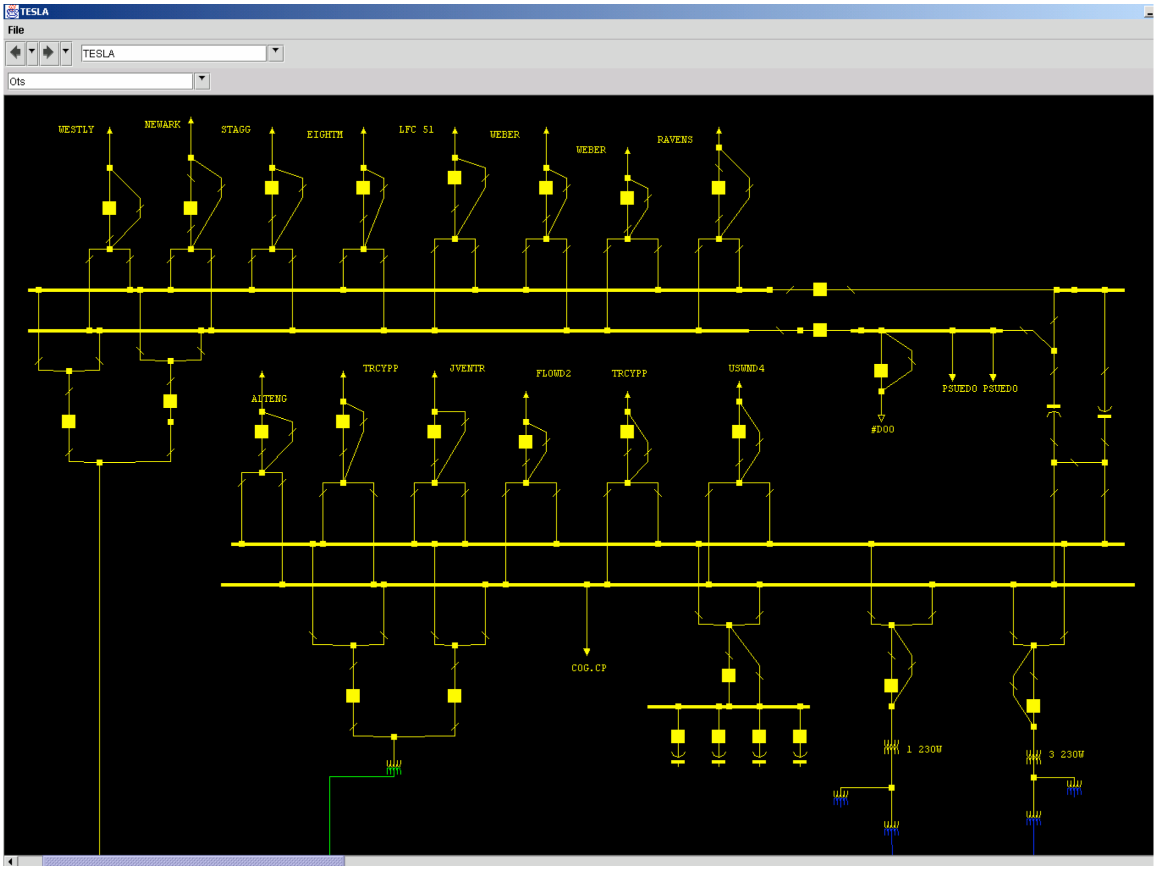


Figure 1-6c: TESLA Station – Operating Model - 230 KV Bays

Station Displays for WSCC Planning Model

This section describes the results of an effort to build station displays from the WSCC planning model. The WSCC planning model is used by the CAISO operations engineers to perform operational studies of the CAISO system.

The WSCC planning model, which is used with the GE Power System Load Flow (PSLF) was converted to the CIM database. The GE PSLF does not model the collection of equipment into substations. Therefore, in the conversion process, the buses were grouped into substations by applying the following rules:

- Any buses that are connected by series devices, or transformers are grouped into the same station,
- The name of the station is selected to be the name of the highest voltage bus with the most equipment connected.
- Equipment that may be electrically disconnected, but has the same station name will be collected into a single station.

The station diagrams were automatically generated and then arranged manually. The results for the Diablo, Gates, Malin, Midway and Tesla stations are shown in Figures 1-7 through 1-11.

The statistics for the WSCC Planning Model are as follows:

	Qty
Stations	8,022
Buses	13,123
Branches	11,619
DC Lines	3
Generators	2,331
Loads	7,712
Transformers	5,318
	40,106

The following differences were noted between the CAISO operating model and the WSCC planning model:

- The operating model uses six character station names. The planning model uses eight character station names.
- The operating model includes all the series capacitors as individual devices within the station. The planning model represents the series capacitors at one end of the line lumped together as an equivalent line segment.
- The operating model includes all the breakers and switches and auxiliary buses.
- The planning models three winding transformers as a single unit. The operating model converts them to three equivalent two winding transformers.

As an interim solution for OTS studies, the planning model could be enhanced to include the breakers, switches and auxiliary buses as shown in Figure 1-8 for the Lugo station. Breakers have been added using the Graphical Data Engineering tool.

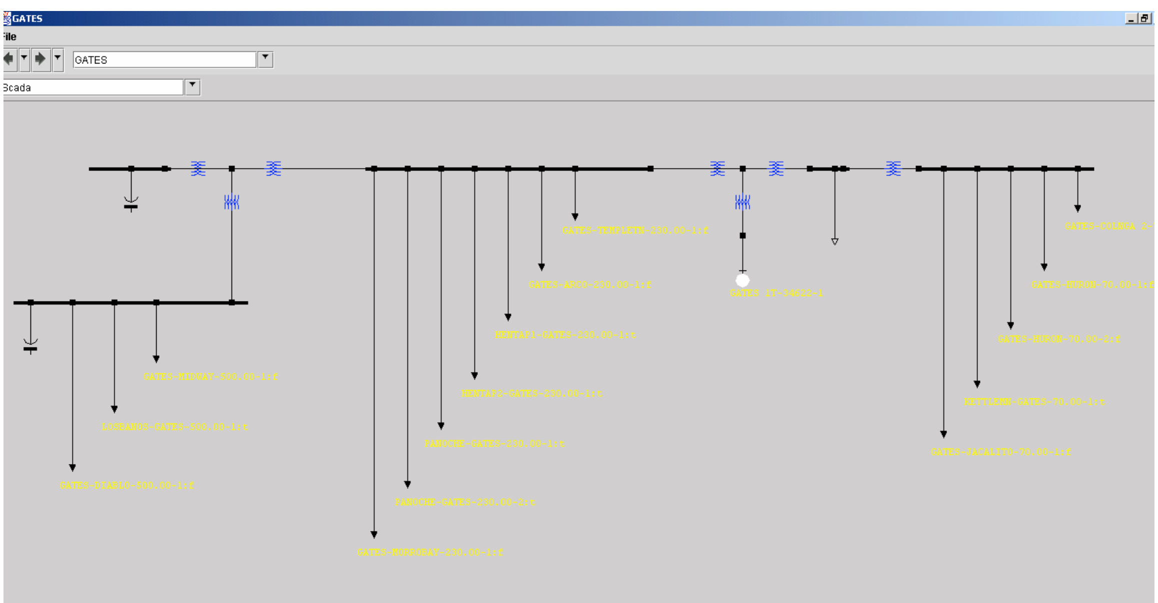


Figure 1-7: Gates Station – Planning Model

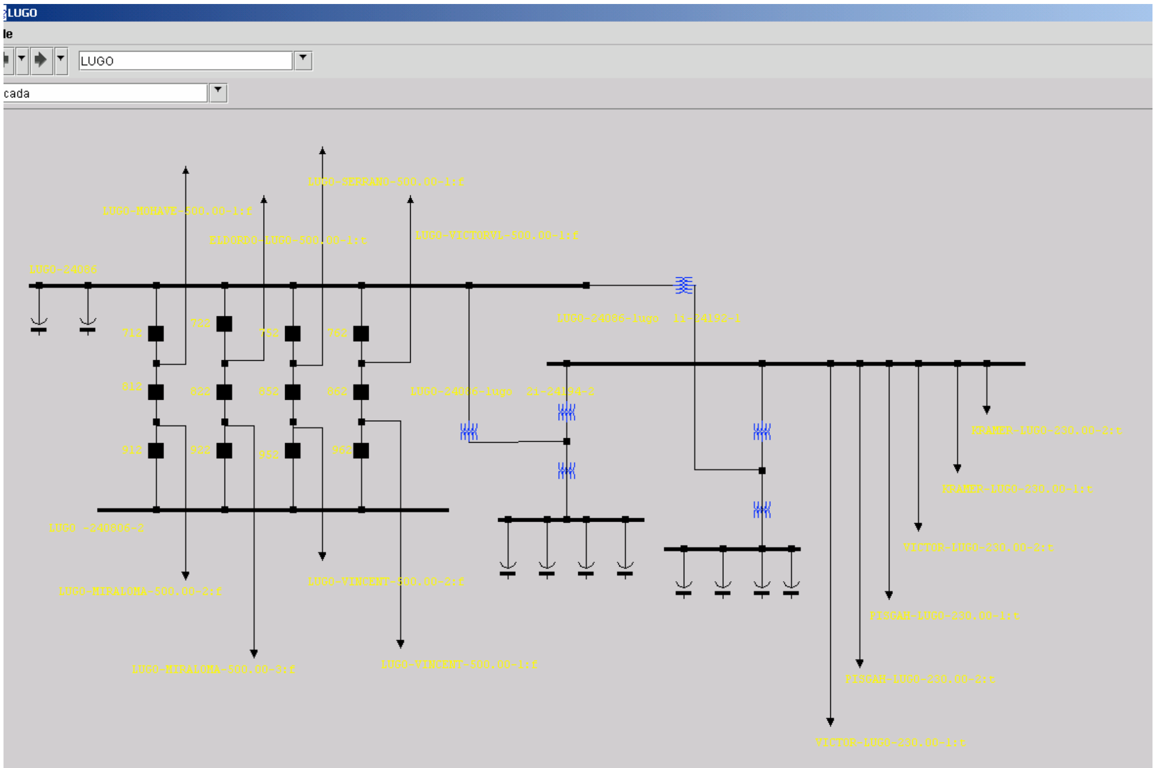


Figure 1-8: Lugo Station – Planning Model - with Breakers Added for 500 KV Bays

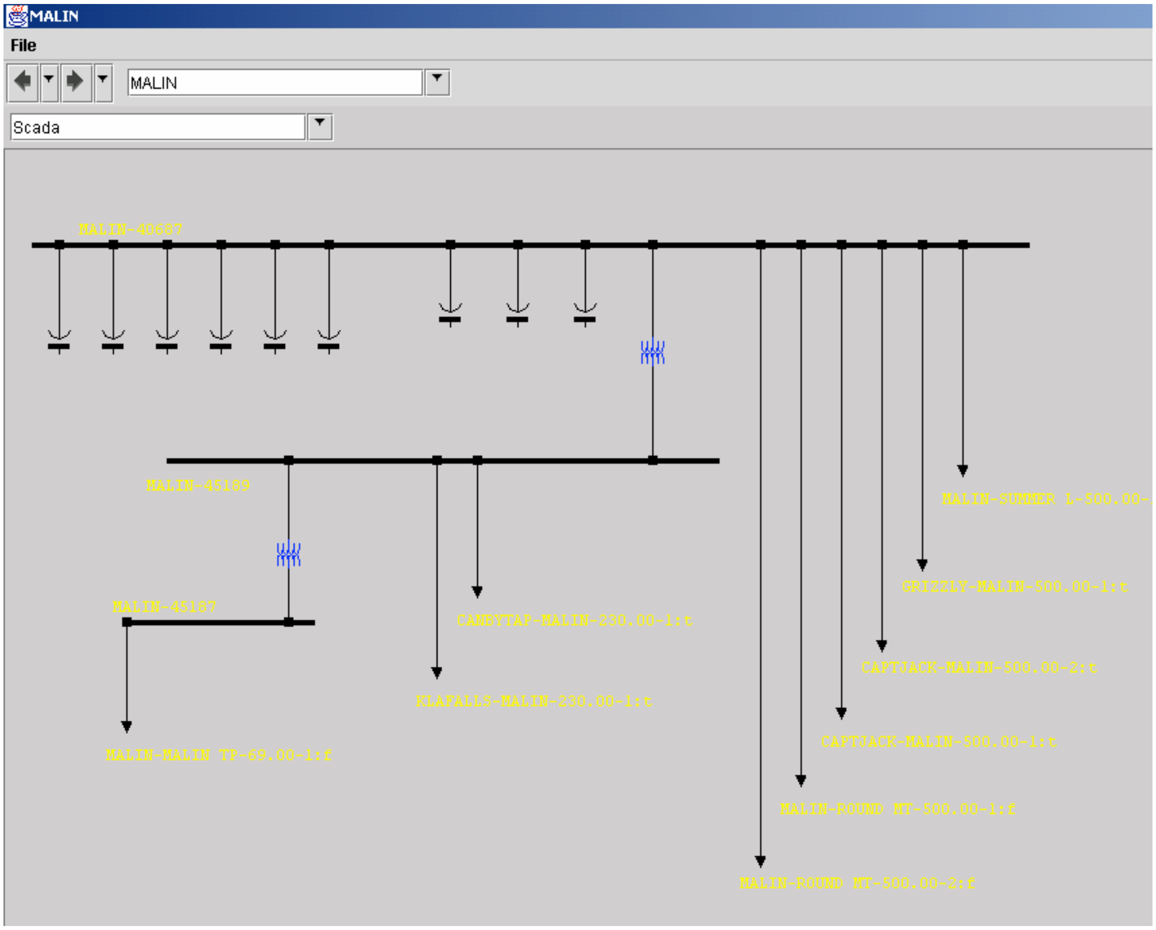


Figure 1-9: Malin Station – Planning Model

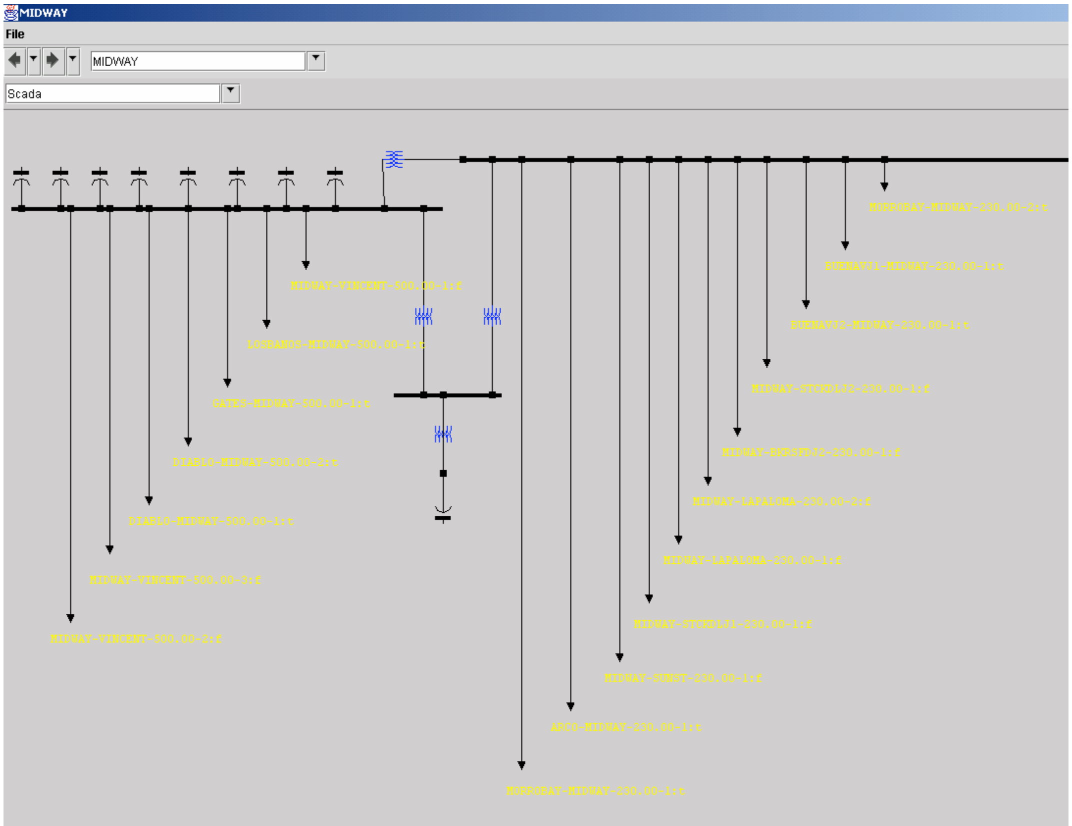


Figure 1-10a: Midway Station – Planning Model – 500 KV AND 230 KV Levels

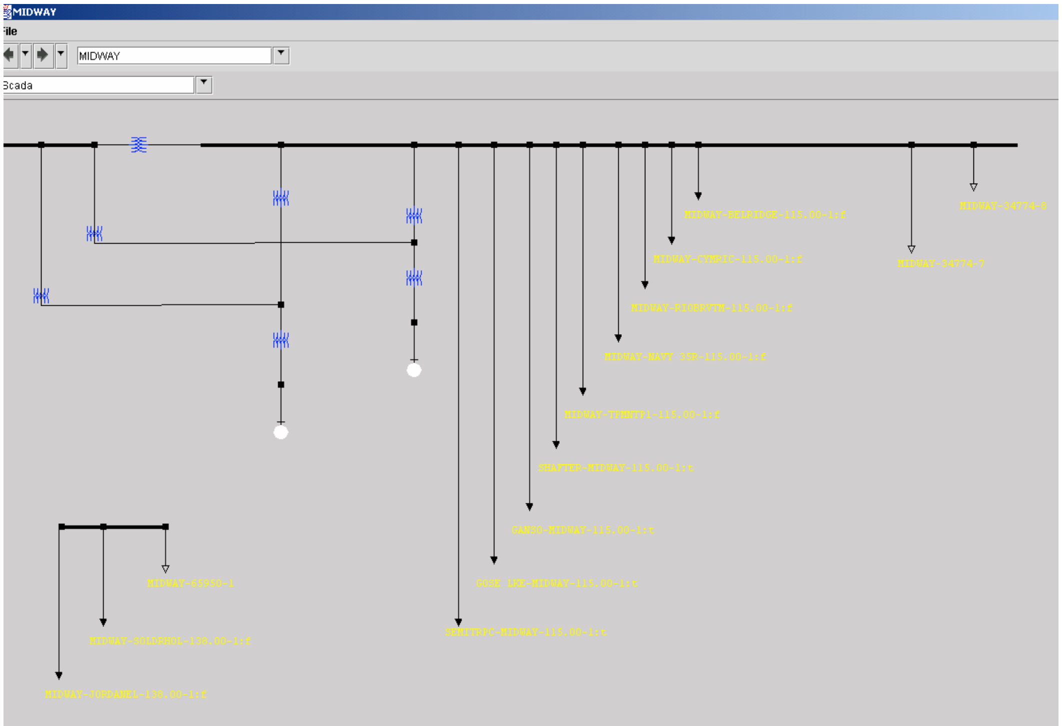


Figure 1-10b: Midway Station – Planning Model – 115 KV Level

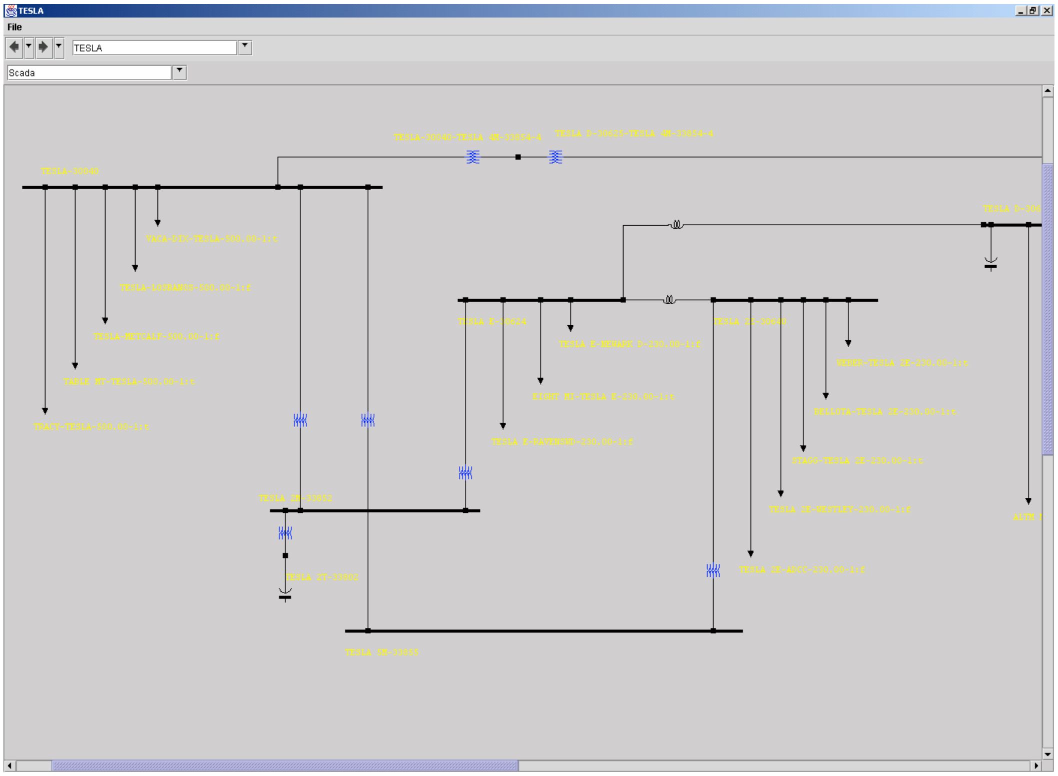


Figure 1-11a: TESLA Station – Planning Model – 500 KV and 230 KV Levels

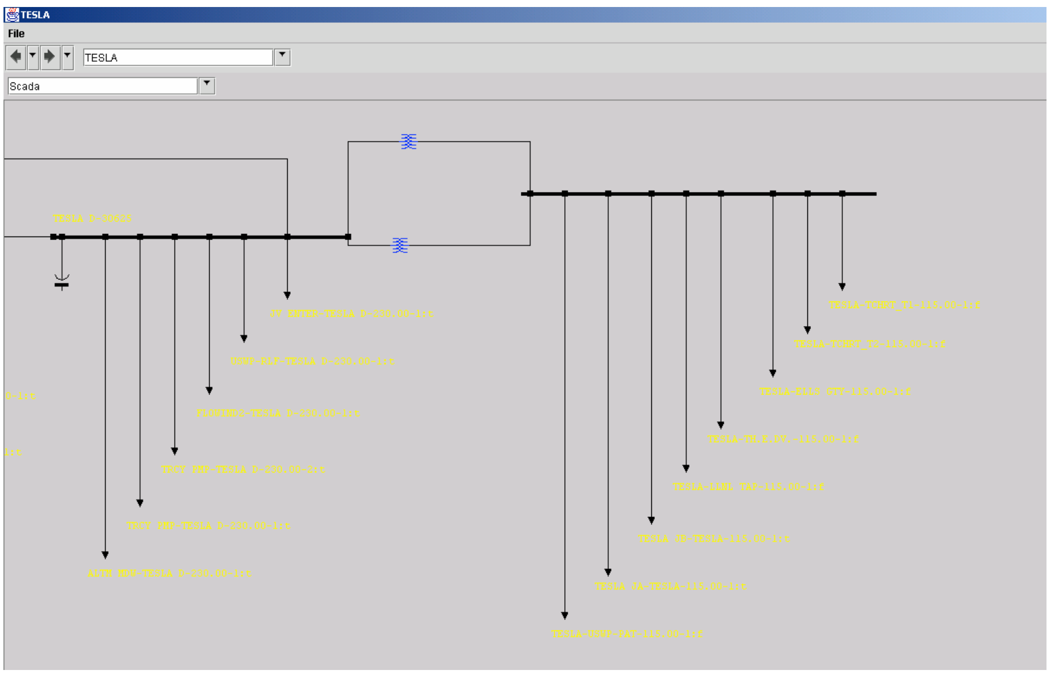


Figure 1-11b: TESLA Station – Planning Model – 230 KV and 115 KV Levels

The EPRI OTS was enhanced to support models with more than 10,000 buses and to support transformers as tie-lines.

A significant amount of CERTS project specific work would have been required to get the WSCC planning model to perform as an operational model. This work would have duplicated the work already being done by CASIO EMS project team. Since the CAISO EMS project staff were making good progress with calibrating the operational model using the tools on the ABB Ranger system it was decided to wait for the CIM XML operational model to support the EPRI OTS.

Station Displays for CAISO 2003 Operating Model

In early 2001, CAISO awarded a contract for a new Energy Management System to ABB Network Management. This contract required the construction of a network model which merged the CAISO operational model with a WSCC planning model.

In this system the network application model and the schematic displays are maintained using an ESRI Geographic Information System (GIS). The layout of the schematic displays is stored in an Oracle database. The display definitions in the ESRI GIS include embedded object information. The CAISO network application model can be exported in a CIM XML format.

Once the CIM XML model is made available, this will be imported into the PACE CIM compliant real-time relational database. The station one-line displays and system overview displays will be built. Coordinates of the equipment in the ESRI GIS network data model will be exported to assist with the layout of the PowerVisuals based station one-line and system map displays.

Summary and Conclusions

During the time frame of this project from mid 2000 to mid 2003, the CAISO EMS Project Team, the CASIO EMS supplier (ABB Network Management), the CERTS project team, and the industry in general have made significant advances towards developing Energy Management Systems that are more open and maintainable.

The biggest step is the wide spread acceptance of CIM XML for exchange of operational models. Network application models are no longer locked into vendor proprietary systems with onerous legal restrictions.

The other major step is that the EMS vendors are now offering graphical model maintenance tools and automatic display creation tools and they are embedding object information into their station displays. Changes in the network application database are being automatically reflected in the network one-line displays. Changes in the one-line displays are being automatically reflected into the network application database.

With the development of these standards and tools, it is now technically feasible for large ISOs such as the CAISO to support a parallel research and development effort on new operational power applications, while at the same time implementing a new Energy Management System.

The experiences with importing the CAISO 2000 operating model and the WSCC Planning Model have been used to enhance the PACE Power Application Computing Environment and the EPRI Operator Training Simulator software so that they can handle very large models with more than 10,000 buses in a robust, stable and efficient manner.

2

TECHNICAL APPROACH

PACE Power Application Computing Environment

The software to build and maintain the CAISO Station One-line displays is supported with the PACE Power Application Computing Environment as shown in Figure 2-1.

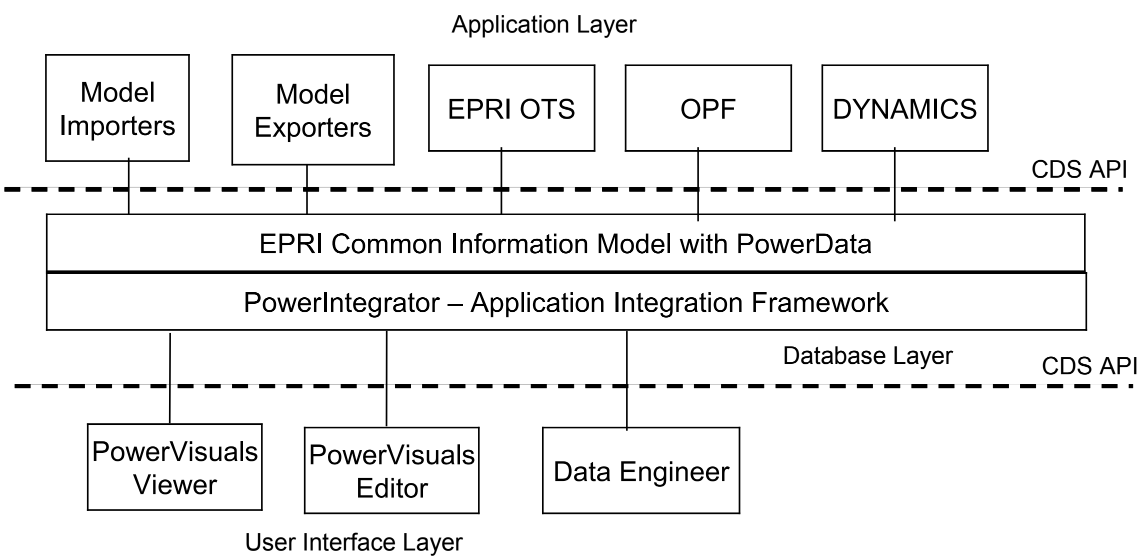


Figure 2-1: PACE Power Application Computing Environment

PACE has the overall objective of supporting the development and integration of power applications by the extended EMS and DMS software development community where this community includes EMS and DMS vendors, Independent Software Developers, Electric Utilities, Systems Integrators, Consultants, Universities and Research Institutes.

The foundation of PACE includes the EPRI Common Information Model with the PowerData real-time database, the PowerIntegrator Application Integration Framework and the PowerVisuals JAVA based graphical user interface.

The PowerIntegrator Application Integration Framework allows software applications written in a variety of languages, running on a variety of platforms, to successfully share information. By using the PowerIntegrator Application Integration Framework for exchanging information, multi-vendor systems and applications can be integrated in way that dramatically reduces maintenance costs and enhances their usefulness. In the ideal situation, model data is entered once and all the other systems that use the data can be updated automatically in near real time. To the end user the systems appear to be seamlessly integrated and all the required information is immediately available at his/her fingertips. The components can be database components, user interface components and application components. Any component can act as both a consumer and provider for data, events and methods. All components communicate with each other using the Common Data Source (CDS) Application Program Interface (API). Components can provide and receive information using either asynchronous publish/subscribe or synchronous request/response mechanisms.

The PowerData Real-Time Database includes:

- PowerData Real-time Relational Data Base Server. The PowerData RTDB Server is a high performance real-time relational database management system developed by PowerData Corporation to support real time processes and large scale mathematical models.

- PowerData Replication Server: Replicates a PowerData database on an event driven basis from a primary processor to one or more auxiliary processors. The auxiliary processors can be used as standby machines or for running additional applications.

- PowerData Event Server: In some real-time applications it is not practical to poll the database manager for changes to the data or to the database schema. The PowerData Event Server emphasizes push, not polling technology. The Event Server notifies an application of events for any database object for which the application has requested notification. These notifications indicate the operation that occurred and the time it occurred.

- Archive Server: Historical data recording and retrieval software.

The PowerIntegrator Application Integration Framework includes:

- CDS Libraries for PowerData: The CDS API adapter for PowerData allows PACE applications to run with the PowerData RTDB as the persistent store.

- CDS Adapter Libraries for Oracle: The CDS API adapter for Oracle allows PACE applications to run with an Oracle DBMS as a persistent store.

- CDS Adapter Libraries for Text Files: The CDS Adapter Libraries for Text Files allows the PACE applications to access data stored in text files using the CDS API.

- Network CDS Libraries: The Network CDS Libraries allows PACE applications and PACE data sources to share data across a network of computers.

- Join and Expression Engine: The Join and Expression Engine translates data access operations on view classes to operations on source classes, and translates events on source classes to events on view classes. It also allows attributes for view classes to be calculated on an event driven basis from attributes in the source classes.

PACE also includes the following general purpose utilities:

- PACE Process Manager: The Process Manager is used for defining and controlling the execution of programs under periodic conditions, when system events occur and when user requests are made.

- PACE Alarm and Event Manager: Manages generation, sorting, filtering, display, acknowledgement and archival of alarms and events.

- PACE Topology Processor: This is a general purpose utility and is used for line colorization.

- Generalized Model Importer and Exporter. The Generalized Model Importer program imports and merges models from different DMS and EMS vendors into a CIM based model. The Generalized Model Exporter can export models in the proprietary formats of major DMS and EMS vendors.

- PACE Data Engineer is used for updating the EPRI Common Information Model. Once Power Visuals Editor has been used to build a power system schematic diagram with topological connections, the CIM database is updated to reflect these objects and connections. With PACE Data Engineer engineers and operators can maintain a model using intuitive graphical tools.

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. The data dictionaries are openly published and accessible to all interested third party developers. When implemented with PowerData, the EPRI Common Information Model is an on-line real time application that stores the real time scanned analog/status data. It can also handle solutions for future applications such as operator training simulator and power flow.

The user interface for PACE is based upon PowerVisuals. PowerVisuals is a family of net-enabled graphical user interface products that can be used for monitoring and controlling real-time event driven processes as well as maintaining and accessing their underlying databases. PowerVisuals supports a very wide range of graphical user interface applications but has especially unique strengths for handling real-time systems that monitor networks with topological models as found in electric power, telecommunications, oil, gas, water and transportation industries.

PowerVisuals supports user defined displays types that are typically found in modern Energy Management, SCADA and process control systems including:

- System Map displays

- Substation one-line diagrams
- Alarm and Event displays
- Tabular (spreadsheet) displays
- Trend displays

With PowerVisuals diverse applications and databases can be integrated with a single universal user interface. PowerVisuals is based upon the Java programming language.

PowerVisuals is designed to provide the developer with a high degree of flexibility on how dynamic objects change in relation to the applications data. PowerVisuals provides an environment for accessing and maintaining information on topological models by means of schematic diagrams.

PowerVisuals includes three basic products:

- PowerVisuals Editor allows the existence and appearance of various pieces of information about the topological model to be controlled and changed.
- PowerVisuals Viewer manages commands, events, and data between users, and the applications. In Viewer mode, information on PowerVisuals displays updates dynamically as data in its supporting data bases changes. The result is a live graphical display that is updated in real time.
- PowerVisuals Synchronizer monitors changes to the EPRI Common Information Model database and keeps the PowerVisuals graphical display model up to date with these changes.

The Model Importer is a generalized program for importing various EMS files into the CIM database. On successive file imports, the program checks for differences. If an equipment object already exists in the CIM with the same parameters, no changes are made. If parameter differences are detected for existing equipment, these will be changed in the CIM. If a new equipment object is detected in the network file, this will be added to the CIM. The Model Importer has been configured to import the following models:

- EPRI OTS Network Description (NETD) File
- ABB EMSYS Network Application File.
- GE Power System Load Flow (PSLF) File.
- CIM XML Network Application File.

The Model Exporter program is a highly generalized export program, which is also configurable to handle different record formats. The Model Exporter has been configured to export an EPRI OTS network description file from the CIM.

The EPRI Operator Training Simulator (OTS) Power System Model (PSM) is an application that simulates the long term dynamic response of power systems under a wide range of normal, emergency and restorative conditions. During the initialization phase, the EPRI OTS reads the EPRI OTS Network description file to build its internal database. Changes to the underlying model, for example adding lines and transformers, are introduced by modifying and re-importing the network description file.

The OTS Power System Model calculates a new power flow, typically every one second. This powerflow reflects changes in load due to a specified daily load profile and random load noise, changes in generation due to AGC and governor actions and changes in network topology due to operator actions, relay actions and external events.

3

USER INTERFACE TOOLS

Overview

PowerVisuals is a Net-enabled graphical user interface development tool kit that can access multiple databases and can provide a universal graphical user interface for integrating a diverse range of distributed applications in mission critical, high performance, real-time event driven environments.

PowerVisuals supports a very wide range of graphical users interface applications but has especially unique strengths for handling real-time systems that monitor networks with topological models as found in electric power, telecommunications, oil, gas, water and transportation industries.

PowerVisuals supports user defined displays types that are typically found in modern Transmission Management, Distribution Management, SCADA and process control systems including:

- System Overview Schematic diagrams
- Substation one-line diagrams
- Transmission line diagrams
- Schematic distribution feeder diagrams
- Repeat tabular (spreadsheet) displays.
- Trend displays

PowerVisuals is designed to provided the developer with a large amount of flexibility on how dynamic objects changes in relation to the applications data. PowerVisuals provides an environment for accessing and maintaining information on topological models by means of schematic diagrams.

PowerVisuals includes the following products:

- PowerVisuals Viewer manages commands, events, and data between users, and the applications. In Viewer mode, information on PowerVisuals displays updates dynamically as data in its supporting data bases changes. The result is a live graphical display that is updated in real time.

- PowerVisuals Editor allows the appearance of various pieces of information about the power system model to be controlled and organized.

- PowerVisuals Synchronizer monitors changes to the EPRI Common Information Model database and keeps the PowerVisuals graphical display model up to date with these changes.

PowerVisuals Viewer

PowerVisuals Viewer is the program used for monitoring and controlling real-time applications. The viewer mode is different from the editor mode in the following ways:

- The displays are linked to a real-time database. Changes in the data values are shown on the display either as alphanumeric values or by changes in how an object is drawn.

- The user has a restricted ability to add or delete conduction equipment objects.

- The user can change the data in the database.

- The user can control devices.

The objective of PowerVisuals Viewer is to allow the user to access all the relevant information about an object just by pointing and clicking on the object. Even though this information may be scattered among different data bases residing on different computer systems.

PowerVisuals Viewer supports a range of user interface features:

- Symbols for power system objects can change their color, shape, size, fill and position based upon values in remote databases.

- Each symbol can be linked to multiple databases provided by different vendors.

- Objects on displays can be linked to call up other displays

- The standard Windows conventions can be used to move, size, and minimize the Viewer Display window as desired.

PowerVisuals is very flexible in how the user interface for an application can be configured. The following sections illustrate how the user interface for the power network applications is configured to work in the baseline product.

Substation Diagrams

The substation diagrams show details of the substation layout including the circuit breakers, units, loads, shunts and line terminations. The substation diagrams are used to perform all breaker switching actions. A number of windows with substation diagrams along with the System Map can be open and updated simultaneously on the same CRT. The sample diagrams in this product description are for a Transmission System. Similar diagrams will be made available with three phase currents and voltages to support distribution applications.

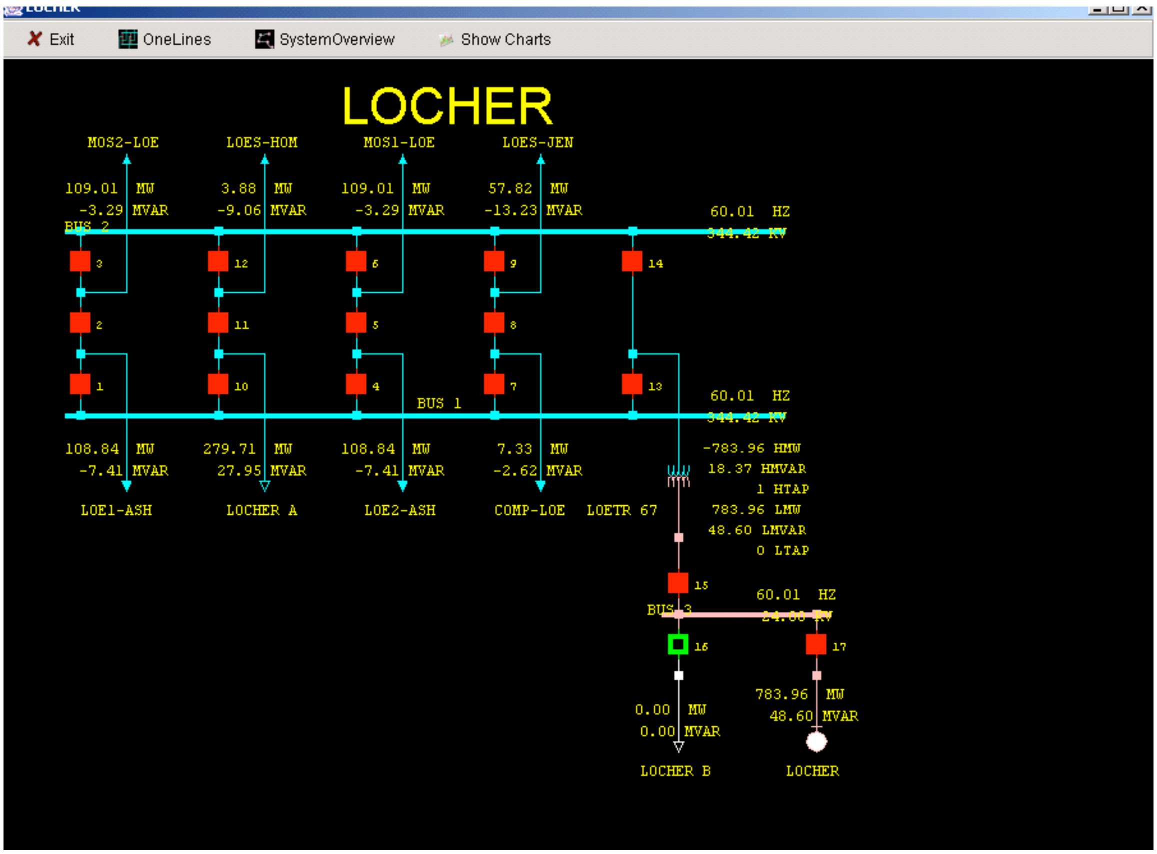


Figure 3-1: Example of Station Diagram

System Map

The System Map shows an overview of the system Substation and Transmission Lines. MW and MVAR flows are shown. Line colorization can be used to show de-energized circuits.

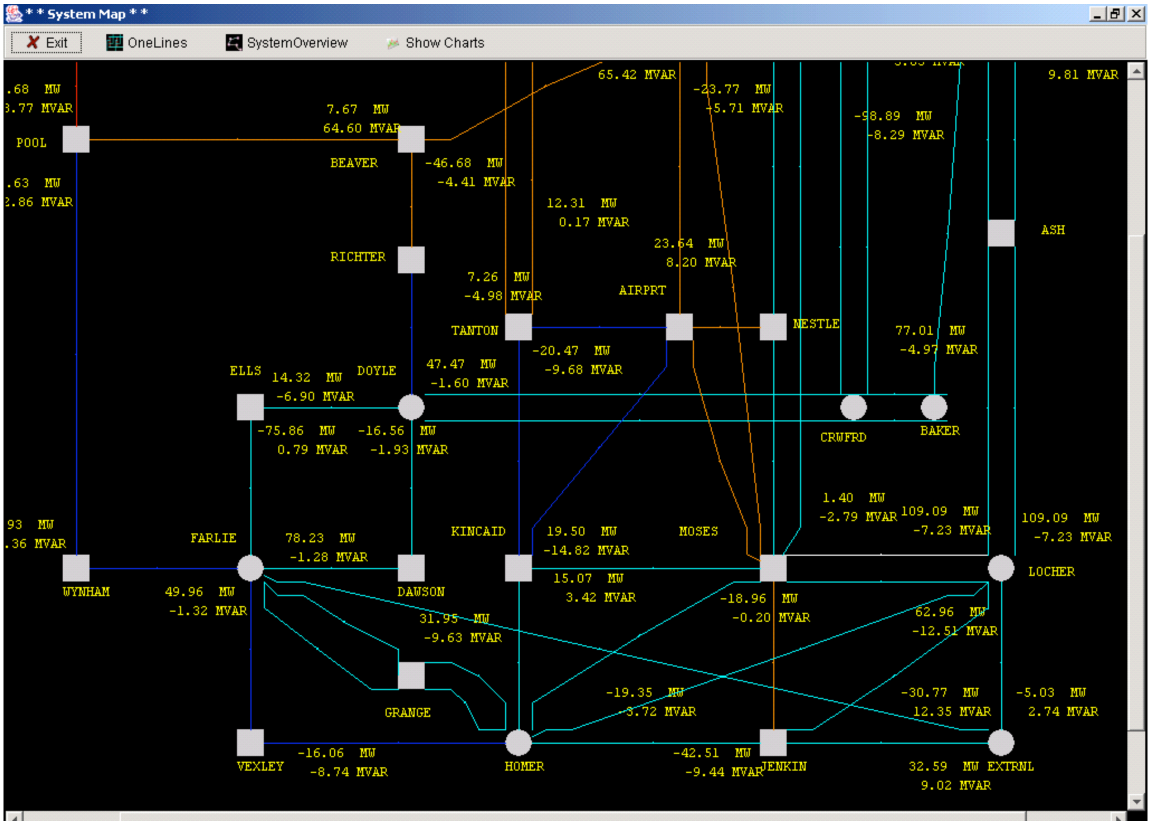


Figure 3-2: Example of System Map Diagram

Display Call-up Procedures

Action objects allow for the quick transversal of the display system.

- Calling a station diagram from a station diagram:
  The line-end object (an arrowhead) when clicked upon with the left mouse button opens the station map at the other end of the line.

- Calling the System Map from a station diagram:
  Clicking on a button or menu item, will call up the System Map.

Calling Displays from the Menu Bar:
Navigation includes a drop-down with all display names, plus an auto-search that matches the name as you type it.

Changing Contexts

Displays can be switched between different contexts by selecting the context from a drop down list. A typical set of contexts would be, SCADA, State Estimator, OPF-user#1, OPF-user#2. When the context is changed, the display is linked to a different set of real-time data in the CIM measurement value table. The background color of the display can be changed to indicate the different contexts.

Monitoring System Conditions

Monitoring of the system conditions can be accomplished via:

- System Map
- Substation one-line diagrams
- Repeat tabular (spreadsheet) displays.
-

The user could use the following typical procedure for analyzing a system problem:

- Entries in the abnormal summary display will alert the user that some abnormal system condition has occurred; e.g. circuit breaker trips, line overloads, voltage out of limits.
- The System Map will show the substations which have an abnormal condition.
- From the System Map the operator will open up windows for the substations that are in an abnormal condition.

The procedure for accessing information to analyze a system problem can be very straight forward by using the following guidelines:

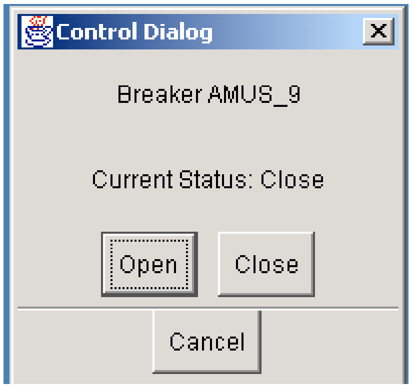
- Use the System Map for an overview
- Use the Substation diagram for the next level of detail
- Use tabular displays for lists of equipment attributes e.g. bus voltages, generator MWs, MVars.

Device Control Functions

The Device Control function allows the user to control predefined devices from substation one-line diagrams. This includes actions such as ON/OFF control for two-state devices, transformer tap changing, and set point control.

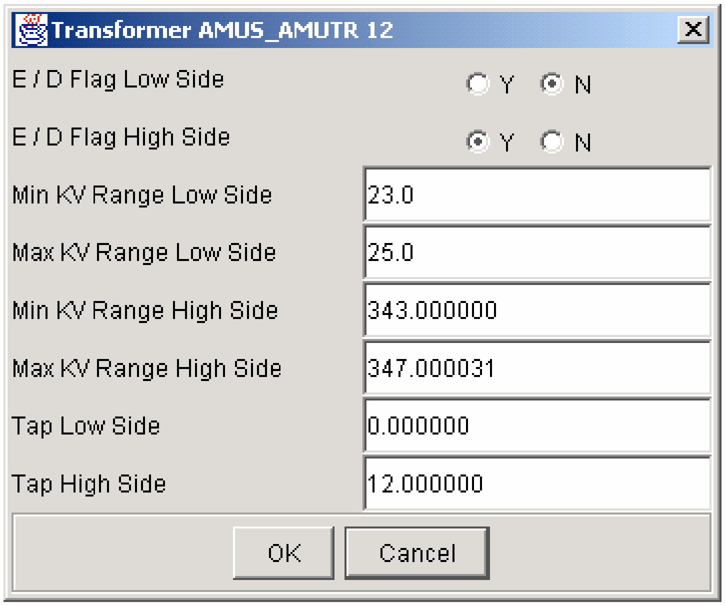
Opening & Closing Breakers

To operate a circuit breaker, the circuit breaker symbol is selected on the substation diagram. This results in a pop-up dialog box. From this pop-up dialog box the user can either open or close the circuit breaker. After a few seconds, the breaker changes status. A closed breaker is indicated as a solid square; an open breaker is a hollow square.



Controlling Transformers

To control a transformer, the user clicks on the transformer symbol. The following dialog opens:

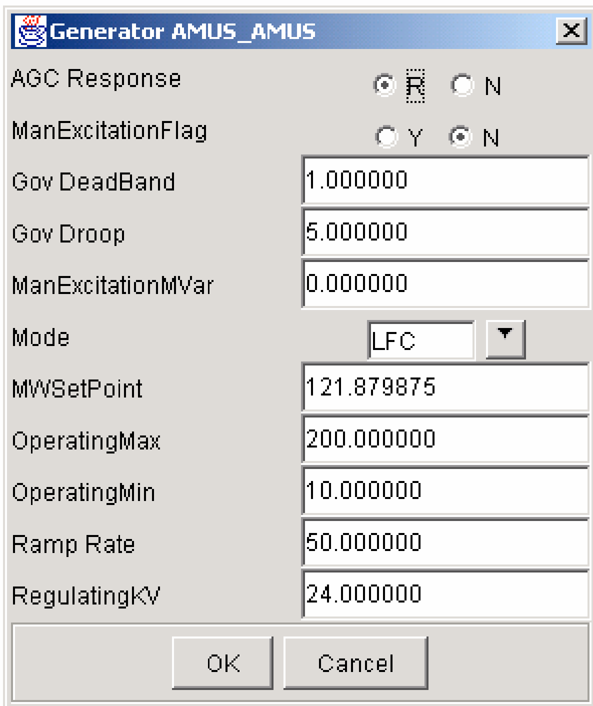


The Tap Low Side or Tap High Side value can be changed as desired. The number of High Steps, the number of Low Steps and the Normal Tap can be found in the DE Winding Display.

The Enable/Disable Flag for the transformer LTCUL can be selected. Information on whether the tap operates in Fixed or LTC mode can also be found in the DE Winding Display.

Adjusting Generating Unit Controls

The user clicks on the generator symbol to change unit parameters or controls. The following



Dialog appears.

The user can adjust the following generator parameters:

- MW: If the generator is in manual (MAN) mode, the user can specify the base point for generator output. The generator will ramp to the specified base-point (provided that limits are not exceeded).

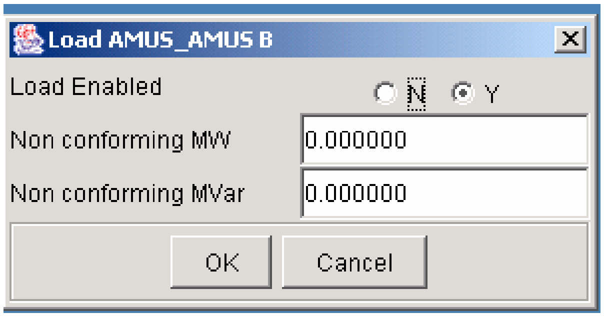
- Excitation (ManExcite): the user can select manual or automatic excitation.

- RegulatingKV: The user can specify the voltage at the output bus with or without Manual Excitation enabled.

- Mode: The user can select one of the following modes, by selecting the Mode List.

Controlling Loads

The user selects the Load Symbol. The following dialog will appear. The user can enter a value for the non conforming load portion.



PowerVisuals Editor

PowerVisuals Editor allows the user to create new one-line or tabular displays and to modify or delete existing displays. A screen shot of the PowerVisuals Editor Window is shown in Figure 3-3.

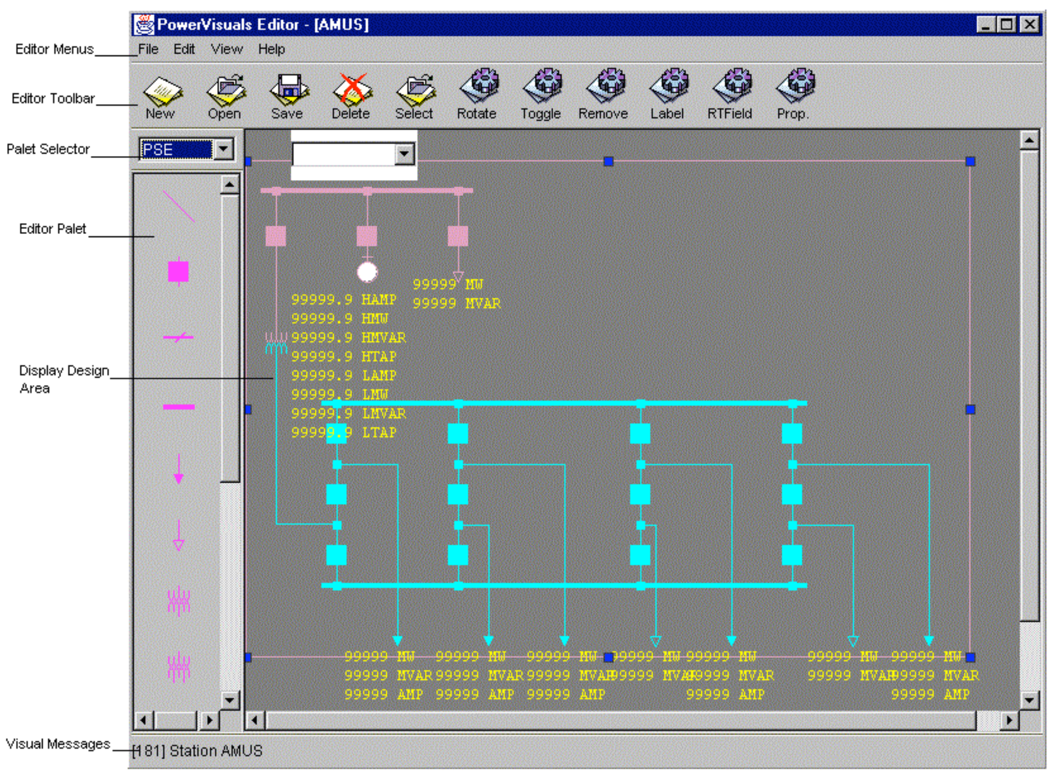


Figure 3-3: PowerVisuals Editor window with a populated display and real-time fields

When a display is built from scratch using PowerVisuals Editor, the user must drag and drop and connect all the individual visual objects. The user must also link all of the visual objects to the database.

PowerVisuals Editor displays contain visual objects that represent the equipment and connections in a power system station. Every construct shown on a display is a visual object, even simple lines and text, which would be considered "static" information on standard EMS displays.

What characteristics define a visual object?

Visual objects have a number of universal characteristics, among them:

- Each visual object may have one or more terminals which can be connected to terminals of other visual objects
- Each visual object has the ability to be associated with different data attributes and to change appearance based on the values of those attributes
- Each visual object has support for a Properties dialog
- Each visual object has the ability to have basic operations performed on it, including being selected, moved, sized, rotated, toggled, connected

How to select visual objects

To select a visual object, the user simply clicks on the visual object and its handles will appear. (Red, green and blue squares in Figure 3-4) The user can select visual objects individually or select them as groups and perform actions, such as moving or resizing, on them.

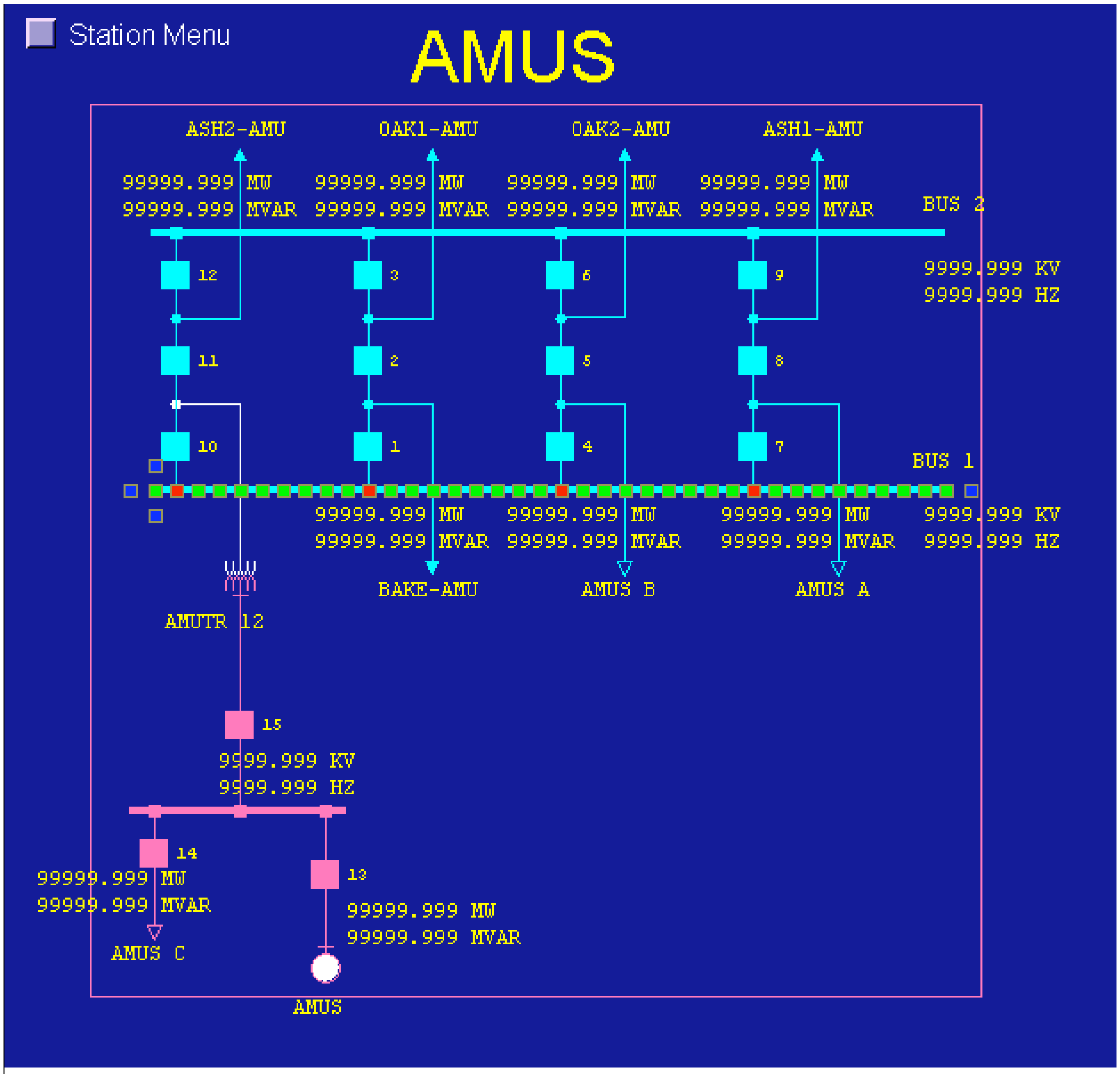


Figure 3-4: PowerVisuals Editor Display Design Area with Visual Object for BUS 1 Selected

How to move visual objects

PowerVisuals Editor allows the user to move visual objects to any part of the display, whenever necessary. A visual object can be moved simply by selecting it and dragging it to another location. Any connections to the visual object will be maintained. For example, if a breaker is moved from one side of the screen to the other, and the breaker is connected on each side by Connectors, the Connectors will stretch so that they stay attached to the breaker. The user can quickly and easily rearrange the layout of a one-line display while maintaining connectivity.

Connecting Visual Objects

The network topology is defined by connecting the terminals of the visual objects. Each visual object can have one or more terminals as shown by the green squares in Figure 3-6. All the terminals are shown when a connector is selected. (Busbars really only have one terminal but there are multiple points on a busbar where equipment can be connected.)

A connecting object is used for connecting terminals of devices. Different forms of the connecting object are shown in Figure 3-7.

When the connecting object is connected to the terminal of a visual object the color of the terminal is changed from green to red as shown in Figure 3-8 Figure 3-9 shows the result when all of the visual objects are connected. Figure 3-10 shows the result when the terminals are no longer highlighted. This is the display that the end user would typically see.

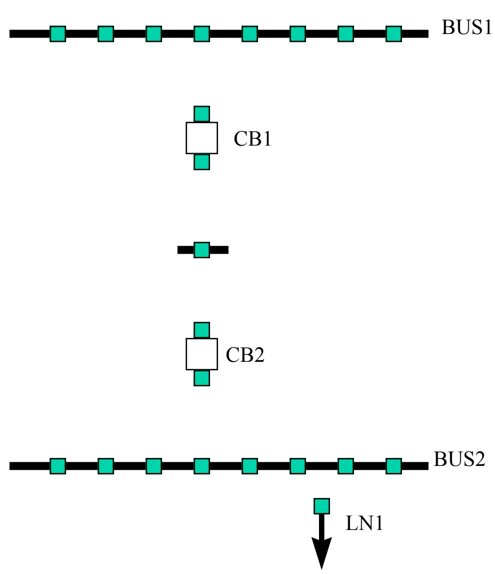


Figure 3-6: Visual Objects Created and Placed In Position

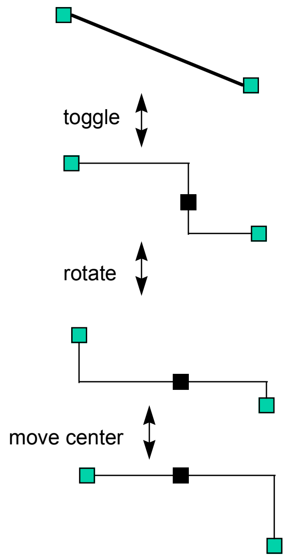


Figure 3-7: Different forms of the same connecting object

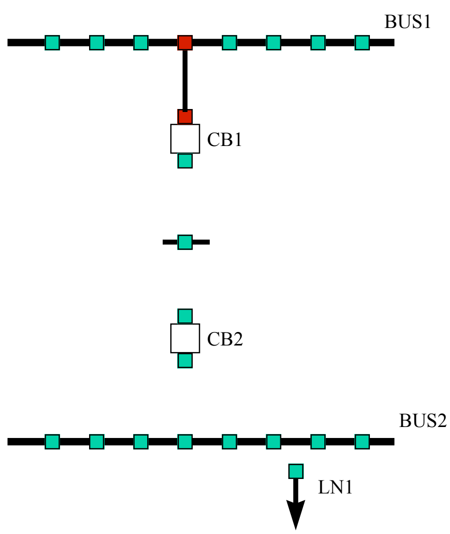


Figure 3-8: Bus BUS1 has been connected to breaker CB1

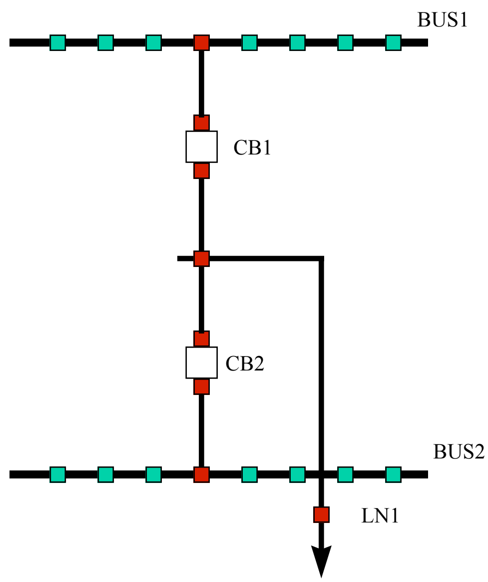


Figure 3-9: All visual objects have been connected using the universal connector objects

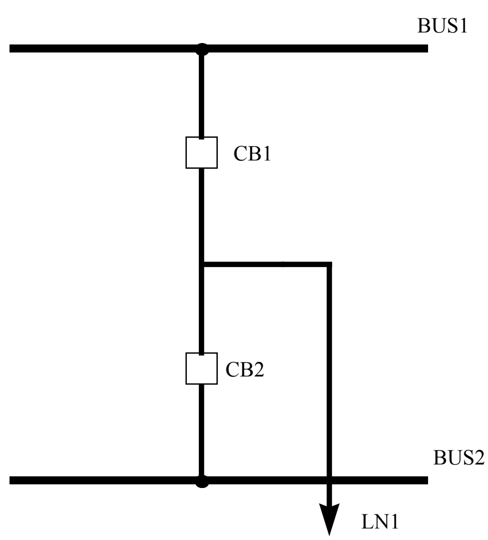


Figure 3-10: Connected visual objects without highlighted terminals

PowerVisuals Synchronizer

PowerVisuals Synchronizer is a graphical display building toolkit that simplifies the development of schematic displays that are required for monitoring, control and simulation of power system networks. In more and more situations, a customer has one or more existing Power Application databases with the network topology already defined, but there are no full graphic one-line diagrams available.

The PowerVisuals Synchronizer can be used to greatly simplify the process of building substation, transmission and system overview displays.

Synchronizer automatically generates all the display objects, connections. It also generates all the display to database linkages:

- Linkages to the name of the object in a database. The name field will be placed adjacent to the visual object.
- Linkages to the real-time fields associated with the object in the database. Measurement fields will be placed adjacent to the visual object.
- Breakers and switches will be linked so that their graphical attributes (e.g. color, fill) can change based upon status fields in the database.
- Synchronizer can generate poke points. When the user selects a line end symbol, the display for the substation at the other end of the line is called up.

The user can easily refine the one-line diagram generated by the Synchronizer by using the PowerVisuals Editor to move objects to the desired locations. When objects are moved, their connections with other objects are maintained and are not broken.

The advantages of using PowerVisuals Synchronizer in this manner include the following:

- The amount of labor to create the one-line diagrams is reduced. For the ERCOT ISO system one person was averaging 24 stations per day.
- One-line displays can be created and made available for use much earlier in the project timeline.
- Changing one-line displays to accommodate dispatcher feedback is faster, more efficient and easy to verify.
- Database to display linkage errors are eliminated.
- Network topology errors are more apparent.

- A more complete system is available for acceptance testing since a complete set of schematic displays can be ready for this milestone.

- The PowerVisuals one-line diagrams can be used to support Data Engineer, which allows the database to be updated with simple to use graphical editing tools.

About EPRI

EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

EPRI. Electrify the World

About PIER

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable and reliable energy services and products to the marketplace.

The PIER Program annually awards up to $62 million to conduct the most promising public interest energy research by partnering with RD&D organizations including individuals, businesses, utilities and public or private research institutions.

1008723

Printed on recycled paper in the United States of America

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com