# Visualization for Shipboard Power Systems

Karen L. Butler-Purry N.D.R. Sarma
Power Systems Automation Laboratory
Department of Electrical Engineering
Texas A&M University, TAMUS 3128
College Station, TX-77848-3128, USA
Email: klbutler@ee.tmu.edu, ndrsarma@ieee.org

## Abstract

*Shipboard Power Systems (SPS) are geographically spread all along the ship. It consists of various components such as generators, cables, switchboards, circuit-breakers, bus transfer switches and loads, all interconnected with each other and located at various places (decks) on the ship. Geographical information on these components is required to assess the impact of faults caused due to battle damage or material casualties. Information regarding faulted components is required for the Automation methods such as failure assessment, restoration and reconfiguration. Good Visualization and information retrieval tools are required to assess the effect of battle damage on the shipboard power systems so that failure assessment and restoration can be quickly done to as many loads as possible. This paper presents the details of visualization for SPS.*

**Keywords:** Shipboard Power Systems, Visualization Tool, GIS

## 1. Introduction

A typical shipboard electrical power system (SPS) consists of various components such as generators, cables, switchboards, load centers, circuit breakers, bus transfer switches and loads. Fig. 1 represents a simplified SPS that contains each type of component found in a typical SPS but reduced number of these components. A SPS consists of three phase generators that are delta connected in a ring configuration using generator switchboards. Bus tie circuit breakers interconnect the generator switchboards that allow for the transfer of power from one switchboard to another. Load centers and some loads are supplied from generator switchboards. Further, load centers supply power to some loads directly and supply power to power-panels to which some loads are connected. Feeders supplying power to load centers,

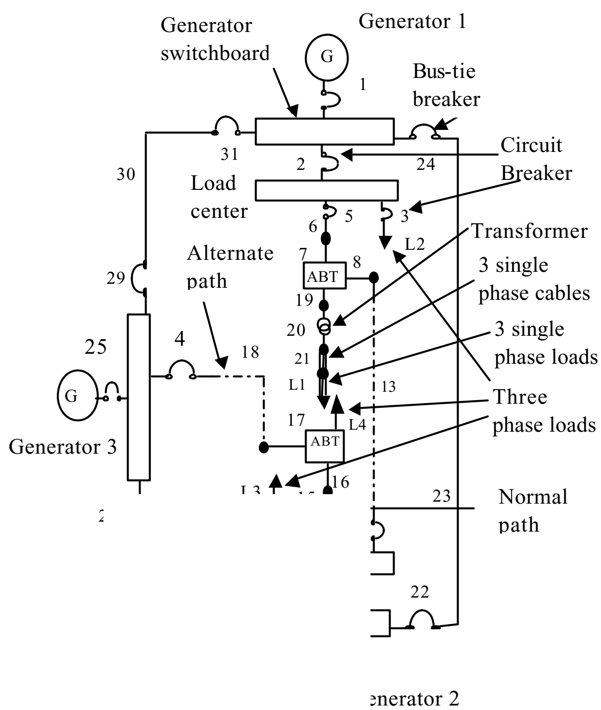


Fig. 1. Example System

power panels and loads are radial in nature, meaning each load is supplied by only a single source at any given time. The radial nature of the system is important for ease of fault location and isolation, and coordination of the protective devices. Loads are categorized as either vital or non-vital and are either three phase or single phase. For vital loads, power is available thru two separate paths (normal and alternate supply paths) via automatic bus transfers (ABTs) or manual bus transfers (MBTs). Normal path is the preferred path. The ABTs are normal path seeking and the alternate path is used only when the normal path is not available.

Circuit breakers (CBs) and fuses are provided at different locations for isolation of faulted loads, generators or distribution systems from unfaulted portions of the system. These faults could be due to widespread system fault resulting from battle damage or material casualties of individual loads or cables. After occurrence of faults and subsequent isolation of faults, there will be unfaulted sections that are left without supply. Fast restoration of supply to these unfaulted sections of the SPS is necessary for system survivability. During this restoration, the capacities of the generators and cables must not be violated and voltage magnitudes at each node should be within tolerable limits.

Shipboard power systems are very similar to isolated finite inertia utility systems in that the available generators are the only source of supply for the system loads. There are, however, several differences between utility and shipboard power systems, such as ships have large dynamic loads relative to generator size and a larger portion of nonlinear loads relative to power generation capacity, and transmission lines are not nearly as significant as for utilities because of their short lengths [1].

Automation methods for shipboard power systems, such as failure assessment, restoration and reconfiguration, require good visualization and information retrieval tools to assess the effect of battle damage on the electrical systems. This paper presents details of various visualization aspects developed for automation methods for shipboard power systems. Section II explains the use of some methods of visualization for representing the SPS. Section III gives the illustration on a typical SPS based on a typical surface combatant ship. Conclusions are given in section IV.

## 2. Visualization for shipboard power systems

It is important to have good visualization tools for SPS for various purposes such as visualization of impact of battle damage, to display the results of automated methods such as failure assessment, restoration and reconfiguration. This section explains some of the approaches of visualization tools that are developed for SPS.

Display of SPS can be viewed from two perspectives as follows:

- Geographical layout
- Electrical connectivity layout

In geographical layout the SPS has the details of the special layout of the components of the ship electric system in a 3 dimensional view. Electrical connectivity layout of the system gives the details on the electrical connectivity layout of the system.

### 2.1. Geographical layout of SPS

A Geographic Information System (GIS) is a computerized system designed to capture, store, process, analyze and manipulate characteristic and spatial data. The GIS consists of two parts: digital map and database. Basically a GIS integrates digital diagrams such as computer-aided design and drafting (CADD) diagrams with information systems such as relational database management systems (RDBMS). GIS is used to model a Shipboard Power System based on the geographical 3 dimensional layout profile of the surface combatant ship.

A three-dimensional CADD map of the SPS was constructed with an information database containing the electrical parameters of the SPS. The 3D map of the electrical layout contained the various SPS elements located according to their spatial position within the ship. Fig. 2a shows an isometric view of the 3-D map of the SPS. It shows different sides of the ship. The “FORE” and “AFT” represent the front and rear of the ship, respectively. The “PORT” is the side of ship that is closest to the port when the ship is harbored at the port. The “STARBOARD” is the side of ship that is on the farther from the port when the ship is harbored on the port. Each component was placed on the drawing using X, Y and Z coordinates. Each different component was drawn in a different color. Fig. 2b shows a magnified square section of 3-D map of the SPS containing labels for various elements of SPS. The magnified section shows various electrical elements such as Circuit-Breakers, Bus Transfers, Loads, Switchboards and Generators.

The drawing elements were linked to the attribute database. The database consisted of tables that store data for the elements of SPS. Each element had a connectivity table, a real time and a static table. The connectivity table contained information about “to” and “from” nodes for various components, which basically gave the connectivity scheme of the elements in the system. The real time measurement tables stored the real time electrical values of the elements for a given time step. The static parameter tables store various static information such as rating, resistance, inductance and capacitance of the elements.

Queries are written to extract the data that is required for various automation methods from these tables.

### 2.2 Electrical connectivity layout of SPS

In addition to geographical layout diagrams, electrical connectivity diagrams are also very useful when one requires to visualize only the connectivity details of the system. These connectivity diagrams show how various components are electrically connected without any emphasis on the geographical aspects such as length and layout of the components. These diagrams are also often referred to as line diagrams.

Two types of visualization formats have been developed for electrical connectivity layout of SPS, static and dynamic formats.

#### 2.2.1 Static format of electrical layout of SPS

In static format of electrical layout, the information that is displayed is static in the sense that there is no information that changes. Such line diagrams can be drawn using any word processing package such as MS Word.

#### 2.2.2 Dynamic format of electrical layout of SPS

Some of the information of the components that are displayed in line diagrams can change dynamically based on system conditions. For example, the status of a particular CB may be open or closed. Components may be energized or de-energized and faulted or non-faulted. These attributes should be displayed in the diagrams. Display of such dynamic information gives a good visualization picture of the system under different conditions. Such displays in real-time represents the operational status of the system.

These layouts can also be used to display the output of a particular automation method. For example, the output of a failure assessment method consists of information of faulted components and affected loads. This information is displayed on the line diagram and gives good visualization of this fault scenario. For service restoration method, the output is switching actions (opening/closing of switches) required to restore service to as many affected loads as possible. When these switching actions are implemented, we get a reconfigured network. This reconfigured network information is displayed on the line diagram. In this work, MicroStation[2] has been used to display the dynamic information.

## 3. Illustration

In the present studies a typical SPS model based on a typical surface combatant ship has been developed. MicroStation[2] has been used to draw the 3D diagram and dynamic format of the electrical layout of the SPS. This system has the following components: 3 Generators, 3 Switchboards, 5 Load Centers, 11 Transformers, 23 constant impedance type Loads, 19 Induction motors loads, 28 Bus transfers, 83 Circuit-breakers, many three-phase and single-phase Cables. This system has been used to illustrate the visualization concepts discussed in the previous section.

### 3.1 Geographical layout of SPS

Fig. 2(a) shows the 3D diagram of this system. This system shows the outline of the ship hull. Inside the hull are shown the geographical layout of the various components such as cables, and loads of the SPS. It is possible to zoom-in to see more details of the components. Fig. 2(b) shows a magnified (zoomed) view of a part of the SPS.

Such geographical layout will be useful to have good visualization for SPS. For example, during a battle damage scenario, it is required to connect the damage with the location of equipment so that we can visualize the impact of the damage and know the components that are affected due to the damage. Fig. 3 shows the visualization of a battle damage scenario for the example SPS. Here it is assumed that the impact of a battle damage is in the form of a sphere and the location of the damage is as shown in the figure. By superimposing the sphere on the geographical layout it is possible to identify the damaged components for this battle damage. In this case, because of the battle damage, the cables C2312, C1105, C1213, C1214, C2303 will be damaged as shown in Fig. 3.

### 3.2 Electrical connectivity layout of SPS

This sub-section illustrates the electrical connectivity layout of the example SPS whose geographical layout is as shown in Fig. 2.

#### 3.2.1 Static format of electrical layout of SPS

Fig 4 shows the static format of the electrical layout of the example SPS. Since this has only the static information, this has been drawn using MS Word. This shows the electrical connectivity of all the components in the system. We can see from this diagram that all the generators are connected in a ring configuration and all the components below are in radial configuration. We can also visualize the normal and alternate paths available for some vital loads since normal path is represented as a solid line and the alternate path is represented by a dotted line. Such a diagram gives the information of the electrical connectivity of the system.

#### 3.2.2 Dynamic format of electrical layout of SPS

Fig 5 shows a part of the overall SPS. This illustrates how the dynamic information of various components can be displayed. This has been drawn using MicroStation [2]. Each of the components is designed as a cell and placed on the diagram. Depending upon the status of the component, the display attribute of the component (such as color, filled/unfilled) is changed. For example, in Fig 5(a), the circuit-breaker CB2 is closed (shown as a filled box) and the load LOAD1 is supplied thru the cable CABLE1. LOAD1 is normally supplied thru CB2 and bus transfer ABT1. ABT1 is shown as two switches (one open and the other closed). Now due to some fault on CABLE1, CB2 is opened (shown as unfilled box) and the status of ABT1 is changed as shown as Fig. 5(b). LOAD1 is now supplied thru CB3 and CABLE2. CABLE1 is also shown as faulted.

Thus with the visualization tools one can display the information effectively and this helps the user to quickly get a feel of what is happening in the system under various scenarios.

## 4. Conclusions

Visualization aspects for shipboard power systems are presented in this paper. Two perspectives of display of SPS, geographical layout and electrical connectivity layout have been presented. Further in electrical connectivity layout, two types of visualization formats, static and dynamic formats, have been presented. They form a good tool to display the results in a visual form for different automation methods such as failure assessment, service restoration and reconfiguration for shipboard power systems.

## 5. References

[1]. Karen Butler, N.D.R. Sarma, Cliff Whitcomb, Hyder Do Carmo and Haibo Zhang, “Shipboard Systems Deploy Automated Protection”, *IEEE Computer Applications in Power*, vol. 11, no. 2, April 1998, pp 31-36.

[2]. Bentley Systems, Incorporated, *MicroStation95, Version 05.05.08.11*, 1999.

## 6. Biographies

**Karen L. Butler-Purry** is an associate professor in the department of electrical engineering and assistant dean of the College of Engineering at Texas A&M University. She received the B.S. degree from Southern University -- Baton Rouge in 1985, the M.S. degree from the University of Texas at Austin in 1987, and the Ph.D. degree from Howard University in 1994, all in electrical engineering. In 1988-1989, Dr. Butler was a Member of Technical Staff at Hughes Aircraft Co. in Culver City, California. Her research focuses on the areas of computer and intelligent systems applications in power, power distribution automation, and modeling and simulation of vehicles and power systems. Dr. Butler is a senior member of IEEE, IEEE Power Engineering Society (PES), and the Louisiana Engineering Society. She is a registered professional engineer in the States of Louisiana, Texas, and Mississippi.

**N. D. R. Sarma** received the B.Tech (electrical) and M.Tech (power systems) degrees from Regional Engineering College, Warangal, India in 1983 and 1986 respectively, and the Ph.D. degree from the Indian Institute of Technology, Delhi, India in 1995. From February 1992 to October 2000, he was with the R&D division of CMC Limited, Hyderabad, India. From October 1997 to June 1999, (on sabbatical leave from CMC) and since November 2000, he is working at Texas A&M University, College Station, TX, USA, as a Post Doctoral Research Associate. His areas of interest include Load Dispatch and Distribution Automation Systems for power utilities. He is a Senior Member of IEEE and IEEE Power Engineering Society.

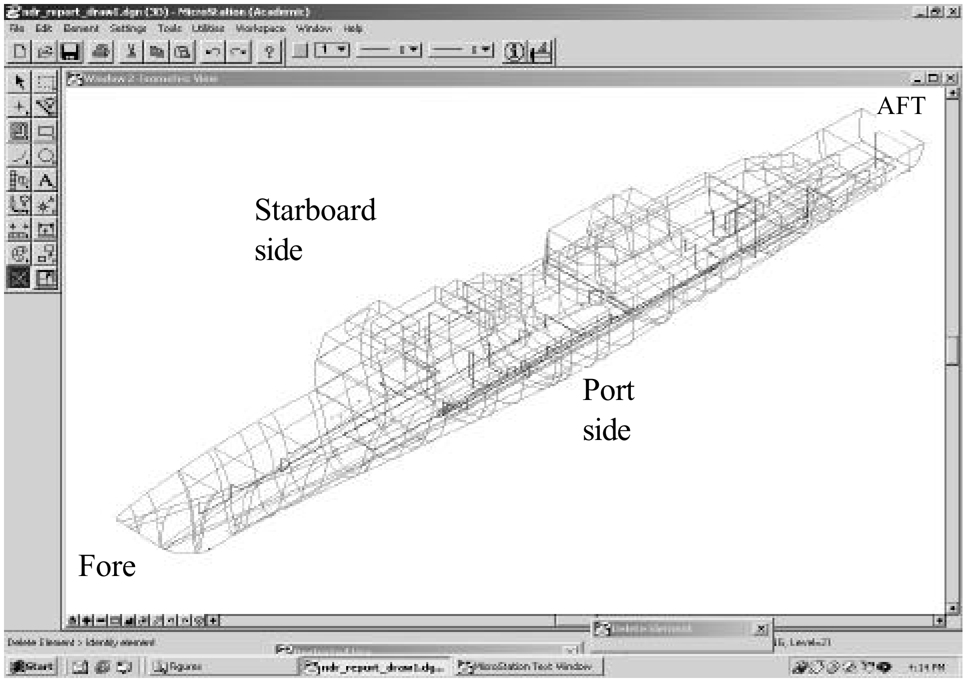


Fig 2(a). Geographical Layout of a SPS based on a typical Surface Combatant Ship

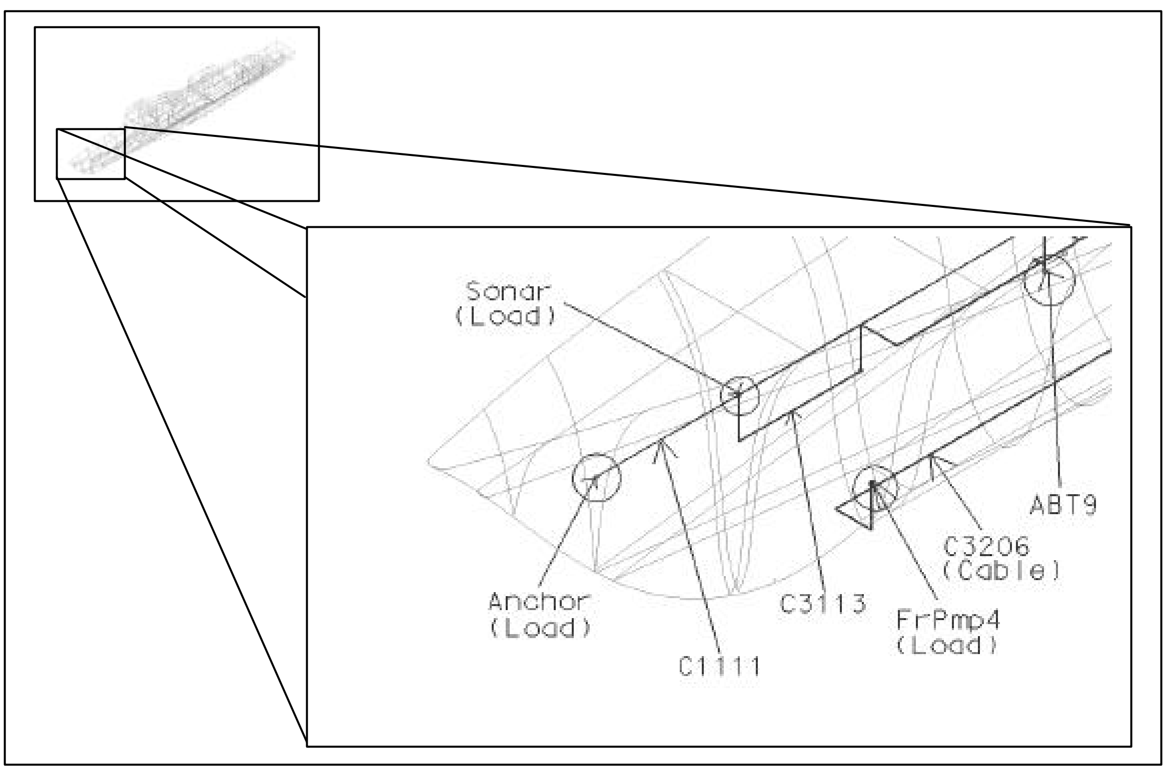


Fig 2(b). Magnified view of a Section of the Geographical Layout of the SPS

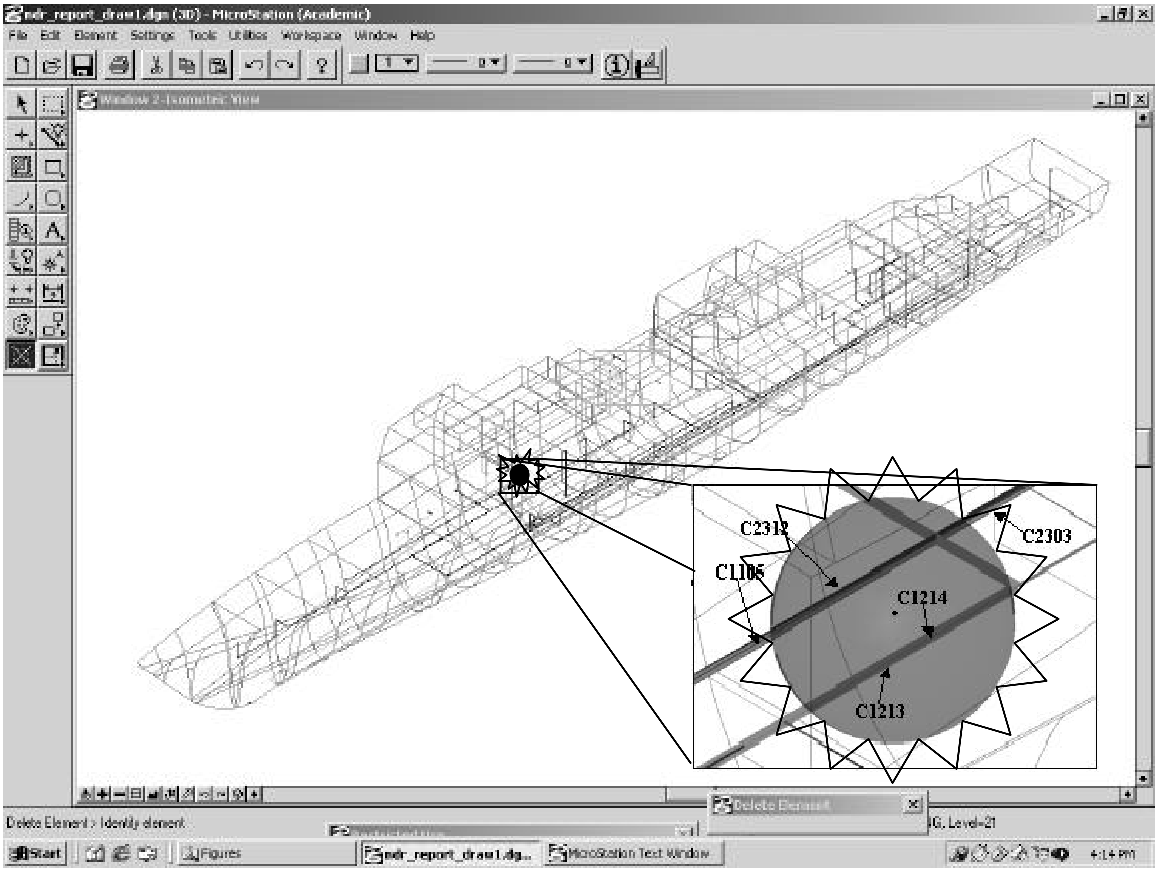


Fig. 3. Visualization of an Impact of the Damage on SPS

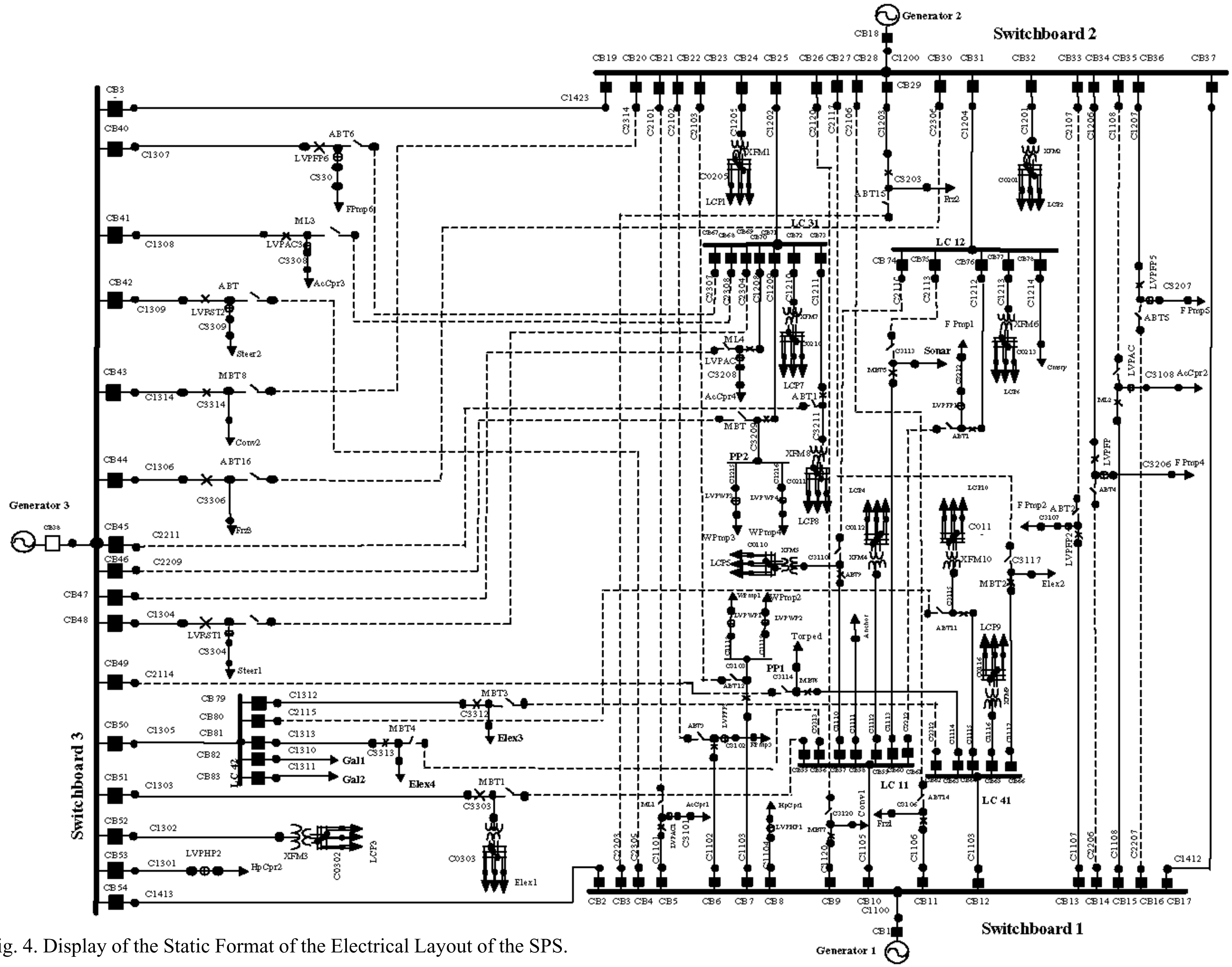


Fig. 4. Display of the Static Format of the Electrical Layout of the SPS.

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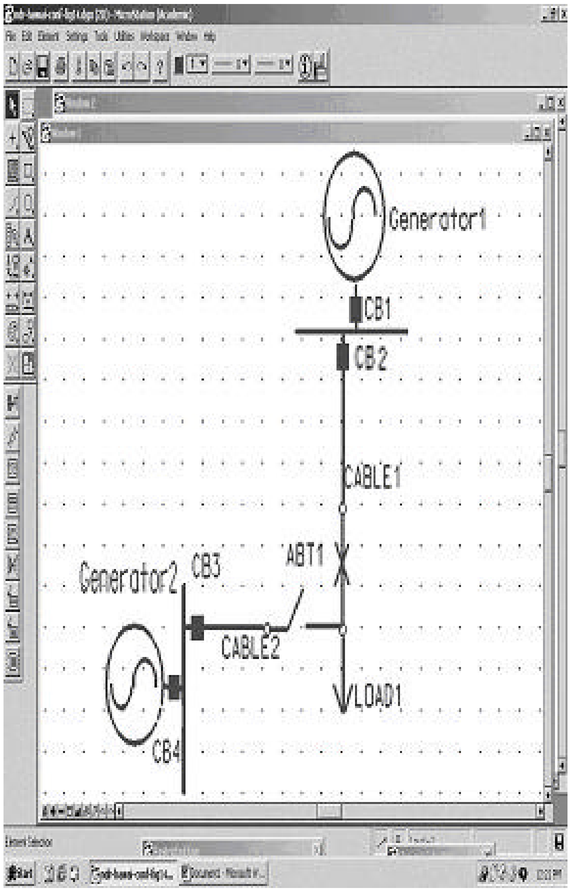


Fig 5 (a).

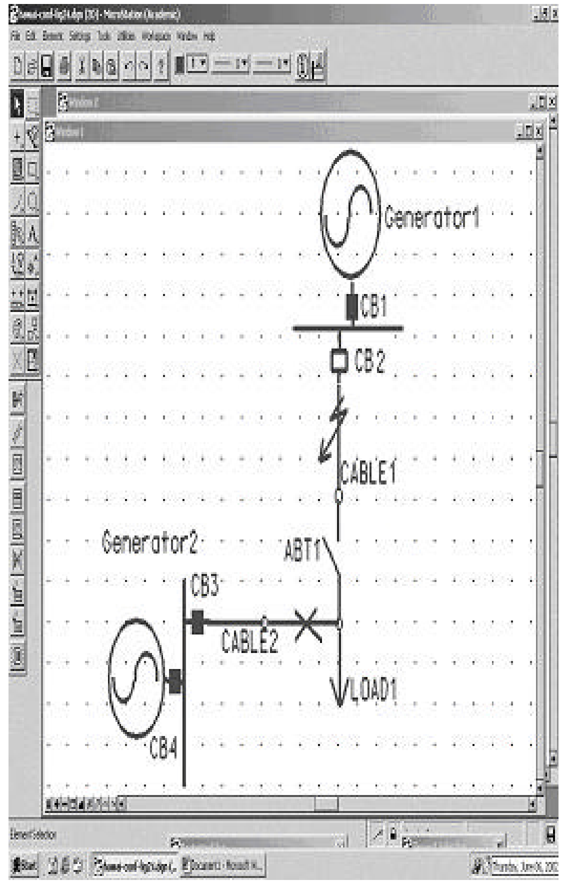


Fig. 5(b)

Fig. 5. Display of the Dynamic Format of the Electrical Layout of SPS