

**AUTOMATIC DETECTION OF ELECTRIC POWER TROUBLES**

**(ADEPT)**

**Caroline Wang, Hugh Zeanah, Audie Anderson, Clint Patrick**  
Information and Electronic Systems Laboratory  
Marshall Space Flight Center, NASA  
Huntsville, Alabama

**Mike Brady and Donnie Ford**  
University of Alabama in Huntsville

**ABSTRACT**

ADEPT is an expert system that integrates knowledge from three different suppliers to offer an advanced fault-detection system, and is designed for two modes of operation: real-time fault isolation and simulated modeling

Real time fault isolation of components is accomplished on a power system breadboard through the Fault Isolation Expert System (FIES II) interface with a rule system developed in-house. Faults are quickly detected and displayed and the rules and chain of reasoning optionally provided on a Laser printer.

This system consists of a simulated Space Station power module using direct-current power supplies for Solar arrays on three power busses. For tests of the system's ability to locate faults inserted via switches, loads are configured by an INTEL microcomputer and the Symbolics artificial intelligence development system. As these loads are resistive in nature, Ohm's Law is used as the basis for rules by which faults are located.

The three-bus system can correct faults automatically where there is a surplus of power available on any of the three busses. Techniques developed and used can be applied readily to other control systems requiring rapid intelligent decisions.

Simulated modeling, used for theoretical studies, is implemented using a modified version of Kennedy Space Center's KATE (Knowledge-Based Automatic Test Equipment), FIES II windowing, and an ADEPT knowledge base. A load scheduler and a fault recovery system are currently under development to support both modes of operation.

## INTRODUCTION

Marshall Space Flight Center (MSFC) is involved in design and development of the Automation of Electrical Power Systems project. This demonstrates the feasibility of using computer software to enhance fault-diagnosis techniques and develop fault-recovery techniques for the Space Station. To accomplish this, prototype software was developed to automate such tasks as detecting and isolating faults and monitoring and reasoning status.

The ADEPT system includes:

- (1). Real time fault isolation through a breadboard modeling the power components.
- (2). A local simulator which uses the theoretical models and will eventually support the fault recovery system.

## HISTORY BACKGROUND

In 1985, Martin Marietta Denver Aerospace delivered to MSFC the Fault Isolation Expert System including a two-rack, 350-watt, three-channel electrical power system breadboard.

MSFC was experimenting with various software techniques to improve performance and speed. ADEPT was built with the MSFC rule system utilizing the existing FIES II breadboard and software interface and KATE as a tool for the local simulator.

The real-time fault isolation version was implemented in LISP, because of its ability to search for a fault, display fault data, and automatically print out the fault reasons and current data along with the steady-state data for comparison.

The University of Alabama in Huntsville is also involved in this project. They have already converted the software into Symbolics system genera 7.1, and also will be conducting a future study of load management and scheduling.

## THE ADEPT SYSTEM

ADEPT is composed of a Symbolics 3670 computer linked to the modified FIES II system. The Symbolics 3670 includes a high-resolution graphics terminal, eight megabytes of memory, a 474 megabyte hard disk, Laser graphics printer, and a LISP environment. The FIES II breadboard is built into two side-by-side racks containing the host computer, its memory storage devices and I/O support equipment; the relay board subrack, its power supplies and related controllers; communications boards, ports, and cables; housekeeping power supplies; control switches and lighted displays.

Figure 4 outlines the components in the ADEPT system and the interactions of these components with one another.

Data transfer scheduling and control are provided by the host computer, an Intel System 86/380. Based on the iRMX86 operating system, the 86/380 contains the iSBC 86/30 Single Board Computer board, a thirty-five megabyte Winchester hard-disk, a one megabyte eight-inch flexible disk drive, and a multibus expansion rack with slots containing not only controllers for the computer itself, but also communication and data conversion boards discussed below. Software run on the 86/380 is written in Intel's ASM86 assembly language.

Three dual-sided power supplies provide charge to the batteries or electricity to drive the system's load resistances, or both, depending upon the configuration into which the busses' relays are set. Representing the Space Station's solar arrays, these supplies are capable of up to fifty volts and nearly two amperes output on each of the six available channels. Each supply has independent current-limiting adjustment, allowing simulation of various solar array lighting conditions.

At the heart of the breadboard is the relay board subrack, comprised of six boards containing forty-eight relays along with related support components. In addition to its function as the system's switching center, the relay subrack provides attach points for most of the sensor lines, by which A/D converters sample system conditions, and all of the fault insertion lines. The fault insertion logic, used to introduce various abnormalities at nodes along the power busses, sends its outputs directly to the relay boards where the "support components" mentioned effect conditions of open or closed relay faults and resistive or direct shunt faults. Configurations may be inserted either manually, using toggle switches on the front panel of the FIES II racks, or remotely, from the Symbolics terminal or the debugging monitor. In the event that a switch is offset from the normal mode, the corresponding relay cannot be controlled remotely, but a fault will exist and should be detected and isolated.

The system integrates software from three different suppliers to offer an advanced fault detection system, designed for the two modes of operation outlined in Figure 1.

Real-time fault isolation of components on the power system breadboard through the FIES II interface is made possible with the MSFC rule system. Faults are quickly detected, displayed, and reasoning provided. The FIES II interface and MSFC rules system were written in Common Lisp (Figure 2).

The simulation version uses a frame-based system, describing all system components and the relationships among them. A constraint system analyses these relationships and compares theoretical to actual measured values, thus identifying constraint failures (Figure 3).

## FAULT ISOLATION

When an initial configuration of loads is selected and downloaded from the Host Computer, and steady-state condition is achieved, all the sensor points' voltages and currents are read continuously and any significant change at any sensor point indicates a fault has been inserted. This Fault condition is then flagged to the Host computer to initiate the isolation program.

Fault Type: OPEN RELAY

Open circuit conditions are indicated by a sudden drop in the values of current read at the sensors while the voltage values remain the same or perhaps higher. Isolation is done by searching for a sensor point where the voltage is zero. The location of the inserted fault lies between the sensor points where there was a voltage and was not a voltage.

#### Fault Type: DIRECT SHUNT

A direct shunt, or short-circuit, fault causes a sudden increase in the sensor readings of current values and a decrease in voltage values on sensors nearest the power source. When this occurs, the fault type is identified and a search begins for a sensor point where the current is higher than the steady state current and following points have current readings of approximately zero.

#### Fault Type: RESISTIVE SHUNT

Resistive shunt causes a sudden increase in current readings on the sensors nearest the power source. A decrease in the voltage may also occur where the load plus the resistive shunt causes the current to exceed the capacity of the solar cells being simulated. Isolation of the resistor shunt fault is done by identifying the first sensor reading with a significant decrease in current. The fault is between this sensor and the last one back toward the power source with a high current reading.

#### REFINEMENTS

Refinements in the rules are made using Ohm's Law to further identify the type of fault being experienced. This is done by considering the ratio of the values of currents and voltages between steady-state and fault conditions.

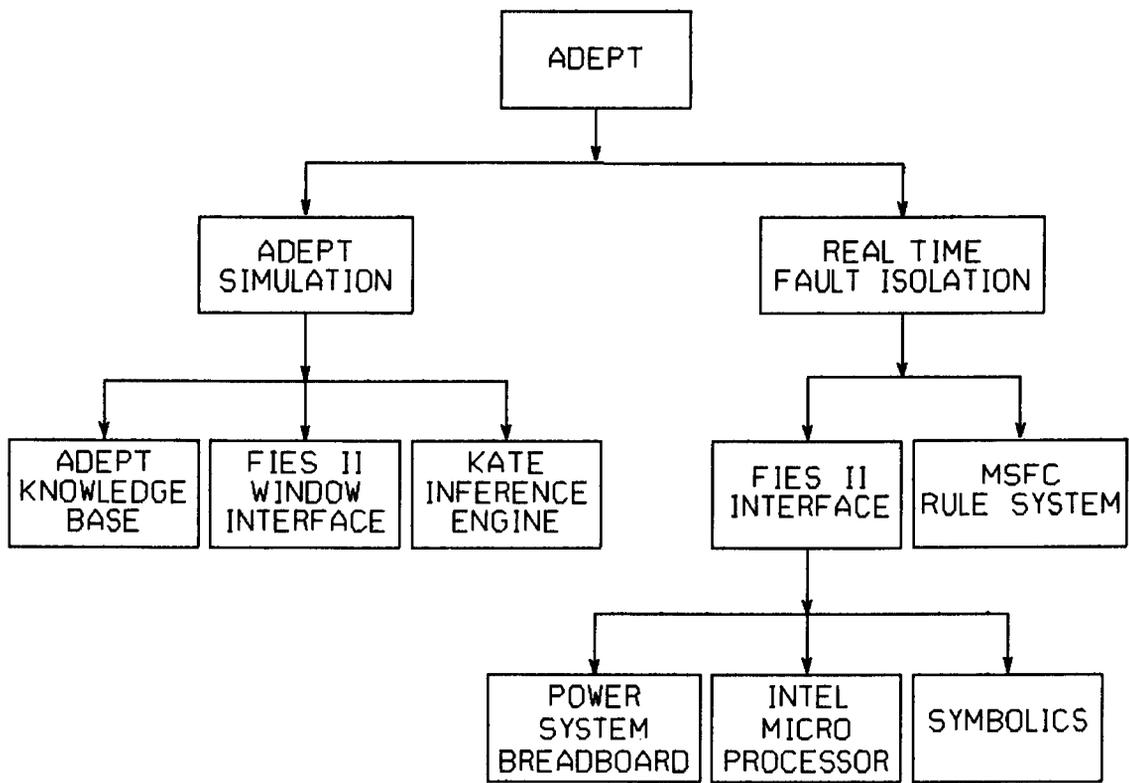


Figure 1. ADEPT system flow diagram

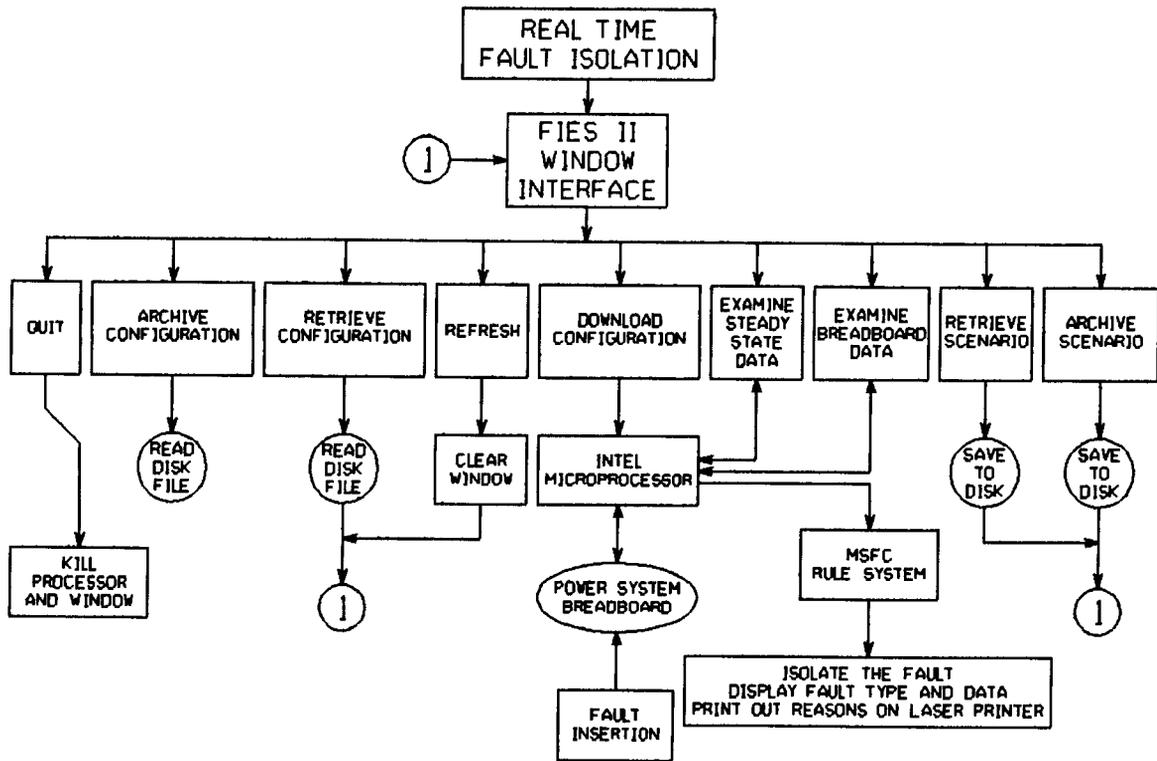


Figure 2. ADEPT real-time fault isolation flow diagram

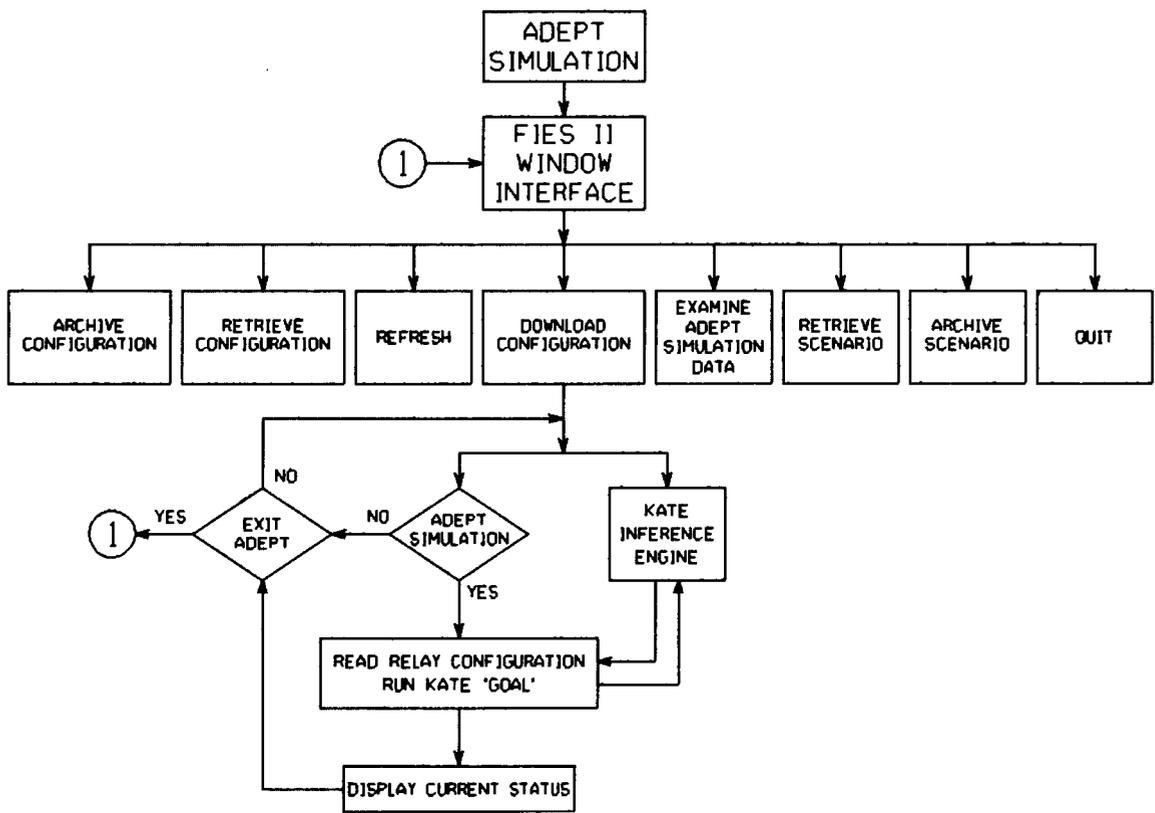


Figure 3. ADEPT simulation flow diagram

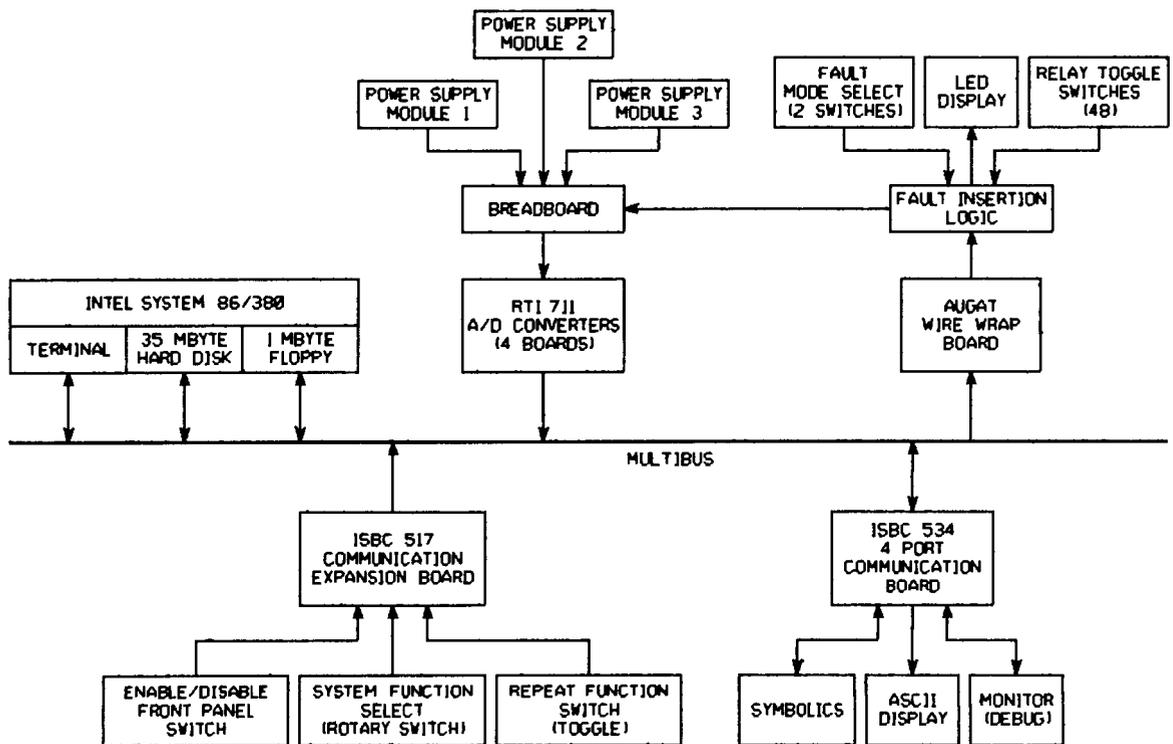


Figure 4. Hardware flow diagram