PRELIMINARY DESIGN OF AN ADVANCED INTEGRATED POWER AND AVIONICS INFORMATION SYSTEM

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Abstract

Under Air Force contract F33615-80-C-2004, an advanced electrical system has been developed for a 1990s era two-engine tactical fighter. The system takes advantage of advances in solid state power switching and computer control technology to produce an integrated electrical power and avionics information system for managing the distribution of electrical power to the aircraft loads. A critical element in the design is the intelligent electrical load management center containing solid state power controllers. In this paper, power generation, distribution, control and load management for this advanced power system concept is discussed.

I. Introduction

The Air Force Wright Aeronautical Laboratories (AFWAL) Aero-Propulsion Laboratory is sponsoring a research and development program directed toward applying advanced solid state power switching and computer control technology to aircraft electrical power systems. Present day operational aircraft power systems use mechanical switches, thermal circuit breakers, and switch logic to distribute and control power from source to load (See Figure 1). The system lacks modularity and is difficult to modify for avionics and weapons changes. It is very inflexible to power failures in that a short on a main power feeder may disable enough loads that the mission has to be cancelled. The system has little tolerance to faults.

In order to correct some of the above deficiencies, The Boeing Company has designed, under contract to the Aero-Propulsion Laboratories, a new system architecture and power system control concept which is integrated with the avionics systems and takes advantage of common multi-purpose hardware and advances in computer technology. This advanced electrical system has been designed to meet the requirements for a 1990 time-frame, two-engine tactical aircraft with multi-mission capability.

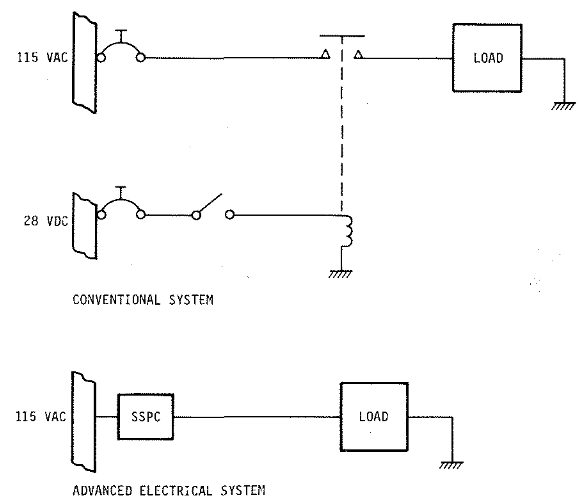

Figure 1. System Switching Comparison

The key characteristics of this system are: 1) Digital Avionics Information System (DAIS) standard elements (MIL-STD-1750 processor, MIL-STD-1553B data bus, controls and diplays), and remote terminals (RT); 2) Intelligent Electrical Load Management Centers (ELMC) capable of controlling power to loads; 3) Built-In-Test (BIT) capability to isolate faults to the module level (BIT includes both circuit and data monitoring checks); 4) Solid State Power Controllers (SSPC) to replace circuit breakers and power control switches; 5) generator control, protection and status monitoring by a Generator Control Unit (GCU) compatible with DAIS hardware and software; 6) multi-mission data information system through programmable system processors and standard DAIS elements, and 7) automatic load management for increased aircraft survivability and probability of mission completion.

In the following section, we shall elaborate on this electrical system concept.

II. Power Generation and Distribution

As shown in Figure 2, primary electrical power is provided by two main AC generators . To insure maximum fault isolation, these generators are never paralleled. A tie bus between the main AC buses allows either generator to power the other generator's main bus if the latter is not operating. The tie bus also connects the auxiliary generator and external power to the two AC buses. Three transformer rectifier units (TRU) provide DC power for the system. A TRU is connected to each AC bus. The third TRU is connected to a relay which selects either AC bus. A battery provides emergency power to DC loads (until the auxiliary generator comes on line) and provides power to the flight critical buses during switching outages.

Electrical power is distributed to the loads from load centers strategically located throughout the aircraft. These load centers are called Electrical Load Management Centers (ELMC). From the ELMCs both AC and DC power is distributed. Within the ELMC is a local power distribution center depicted in Figure 3 that provides for the automatic selection of power sources for the ELMC AC and DC buses.

For each AC or DC power source shown within the Distribution Center, one source is designated the primary source and the other is designated the secondary source. Under normal operating conditions, power to each bus is supplied by the primary source. If the primary source fails, power is automatically provided by the secondary source. Precautions will be taken to insure that two sources are not connected to a particular bus at the same time. Selection of

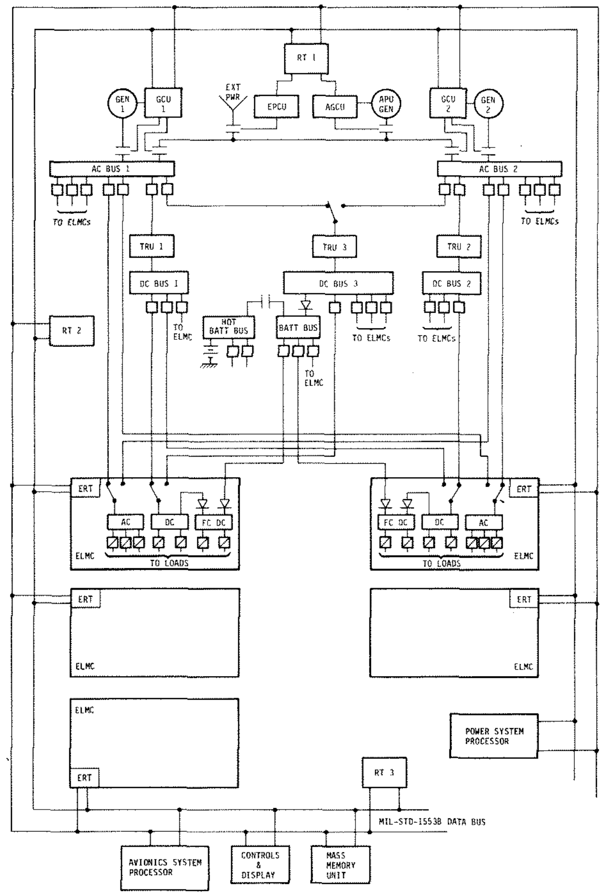

Figure 2. Aircraft Electrical System Configuration

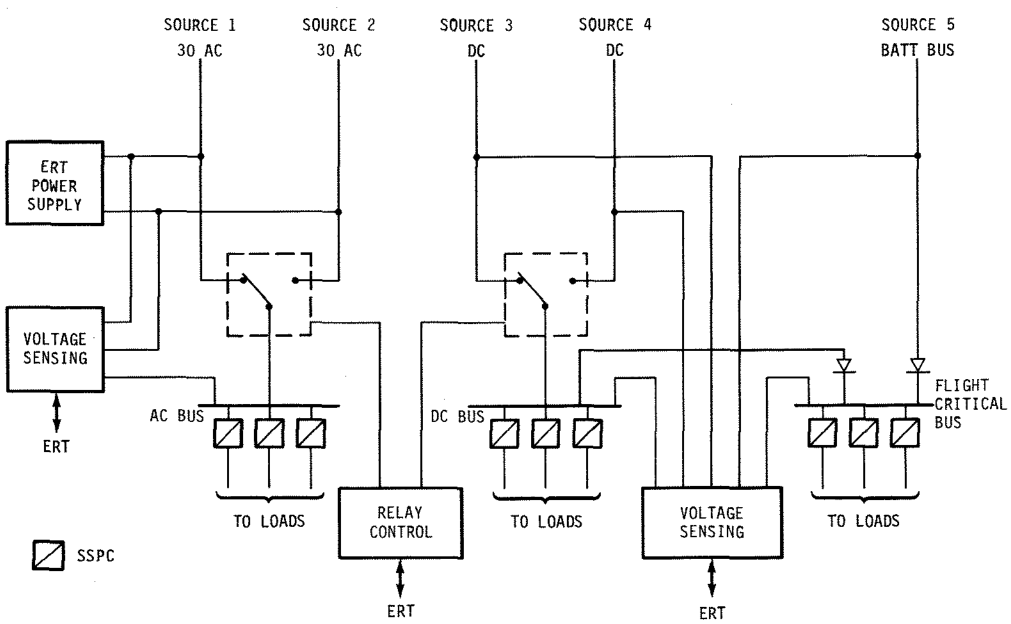

Figure 3. ELMC Power Distribution Center

power sources can also be done by control of the processor within the ELMC. In the case of the flight critical bus, the primary power source is the DC bus which is powered by either its own primary or secondary source, and the secondary power source is an emergency battery. This battery is diode-paralleled with the primary source to insure that the battery is isolated from faults in the main DC system.

Power is finally distributed to the loads via the solid state power controllers (SSPC), located in the ELMCs. The SSPCs are used to switch power on and off to the loads and also to provide load feeder fault protection. They replace conventional power system thermal breakers, switches and relays shown in Figure 1.

III. Electrical Power Control

Electrical power control is accomplished by the use of the integrated power and avionics data network, also shown in Figure 2. It consists of an avionics processor, power system processor, (PSP), 5 ELMCs, mass memory unit, 3 Remote Terminals (RT), 2 Generation Control Units (GCU), and multi-purpose controls and displays. These elements are tied together by a single dual redundant MIL-STD-1553B serial data bus. A functional description of each of these elements is shown in Figure 4.

Figure 5 shows a comparison between a conventional system and the advanced electrical power system in the solution of a Boolean equation to enable a landing gear door solenoid. In the conventional system, the Boolean equation is solved via a series of switch closures starting with the landing gear handle up switch. By contrast, the advanced electrical system solves this equation and enables the landing gear door solenoid with software in the electrical power system processor (PSP) and the ELMC. The Boolean equation, which must be solved is located in the PSP. The variables A, B, C, and D, which are switch position discretes are transmitted to the PSP via the power system information data bus through the various remote terminals. Once all necessary switches have been closed, the Boolean equation to request gear door closure becomes true and this equation result is then sent to an ELMC to activate the appropriate solenoid via a SSPC.

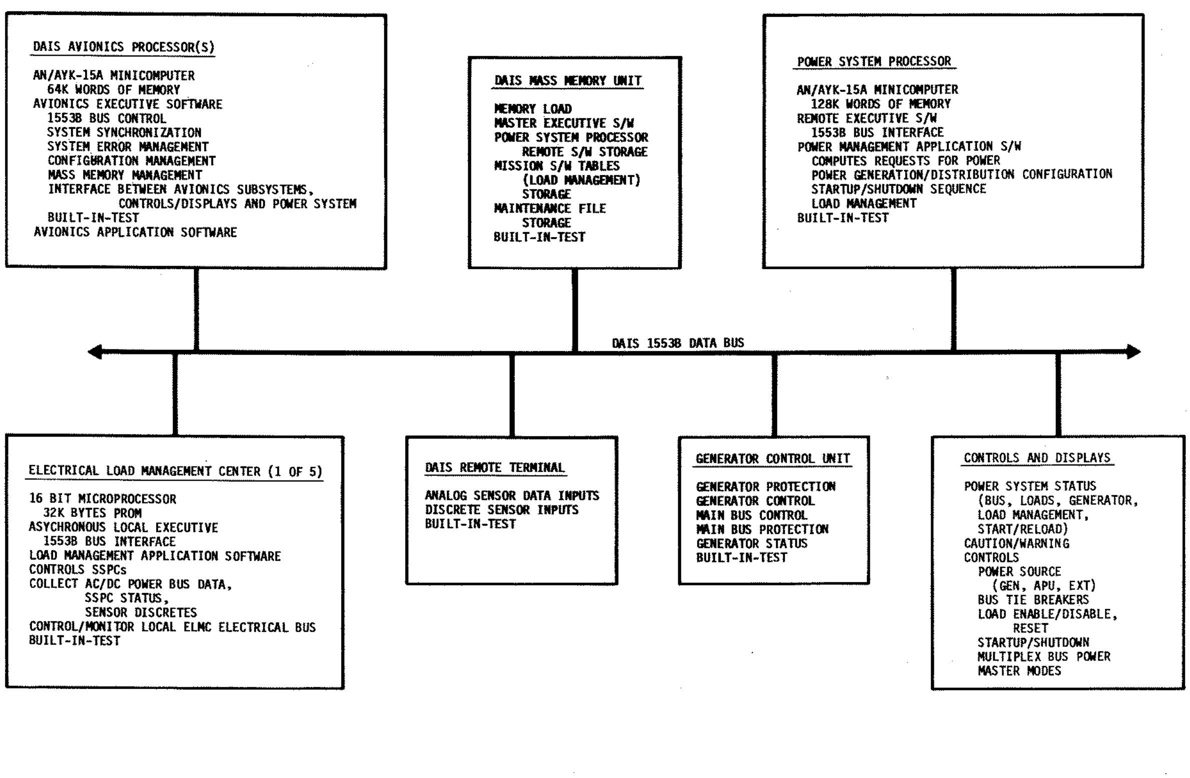

Figure 4. Integrated Avionics and Electrical Control System Functional Diagram

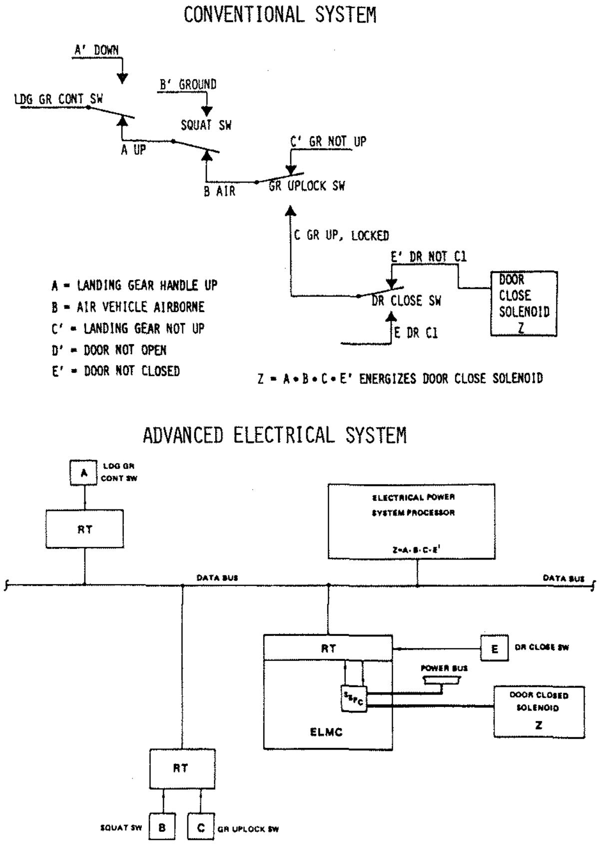

Figure 5. Power Request Equation

IV. Hardware Description

Following is a brief description of the major hardware elements in the advanced integrated power and avionics information systems.

Multiplex Data Bus Characteristics

The multiplex data bus used in the integrated avionics and power information system conforms to MIL-STD-1553B requirements. The bus operates at a maximum data rate of 1 megabit/second. The data transferred over the bus is coded as Manchester II bi-phase levels. Data words are 16 bits plus the sync waveform and the parity for a total of 20 bit times as shown in Figure 6. Also shown in Figure 6 are the three types of word formats used: command, data, and status. Sole control of information transmission on the bus resides with the bus controller which initiates all transmissions.

The multiplex data bus provides the interface between the avionics system and the electrical control system. The avionics processor controls the data bus and as a result, provides overall system synchronization and timing. Information exchanged between the avionics system and the electrical control system includes electrical system startup and shutdown commands issued by the avionics processor, controls and diplays data, and avionics sensor data. Data that is received from aircraft controls is first interpreted by the avionics system, and if this data requires processing by the electrical control system, it is transmitted to the power system processor. Similarly, electrical control system data that needs to be placed on aircraft displays is sent to the avionics processor by the power system processor.

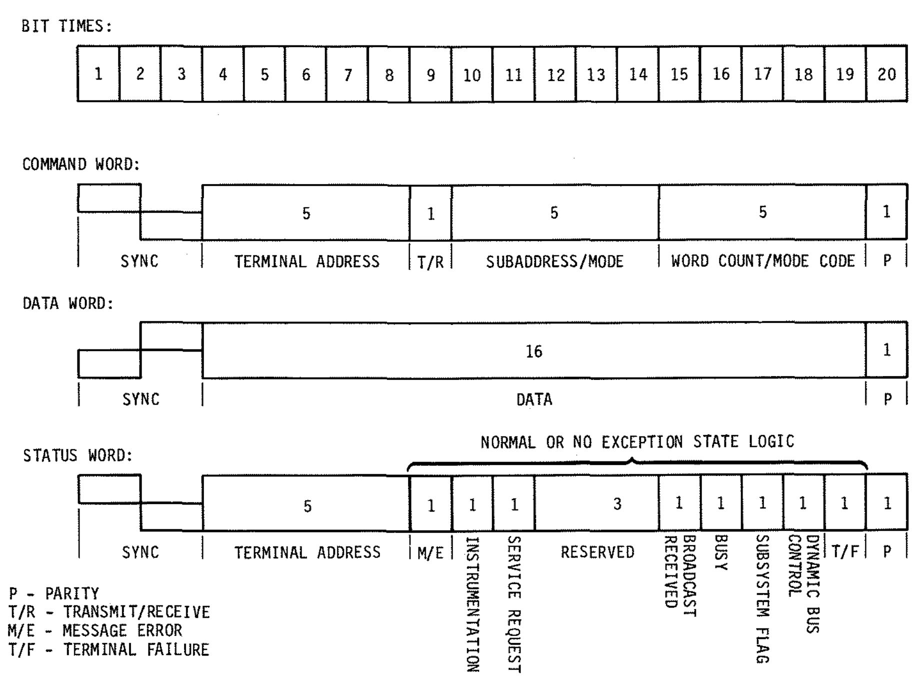

Figure 6. 1553B Bus Message Word Formats

Power System Processor

The power system processor (PSP) provides control and management of the electrical system. The PSP is an AN/AYK-15A digital processor with 128K 16 bit words of memory. Functions performed by the PSP include the following: 1) power system startup/shutdown, 2) electrical load priority establishment, 3) electrical power request equation processing, 4) ELMC status processing, 5) power system configuration control, and 6) controls and displays data handling.

In order to perform its functions, the PSP communicates with other elements of the aircraft electrical control system. The relationship and data flow between the PSP and the other system elements is shown in Figure 7.

Electrical Load Management Center

The ELMCs provide control and management of the electrical power distributed to the loads connected to each ELMC. The ELMCs contain SSPCs from which it receives status information and sends control information. The ELMCs interface with the power system processor, via the MIL-STD-1553B data bus. Each ELMC contains an embedded electrical remote terminal (ERT). Control of the ELMC, its I/O subsystems, and bus interface is handled by a microprocessor within the ERT portion of the ELMC. The ELMC design is modular and flexible to allow signal handling to be incrementally expanded or contracted in order to accommodate the requirements of a particular load configuration. Figure 8 is a block diagram of the ELCM showing the three major subassemblies: Power Distribution Center, SSPC control unit, and ERT.

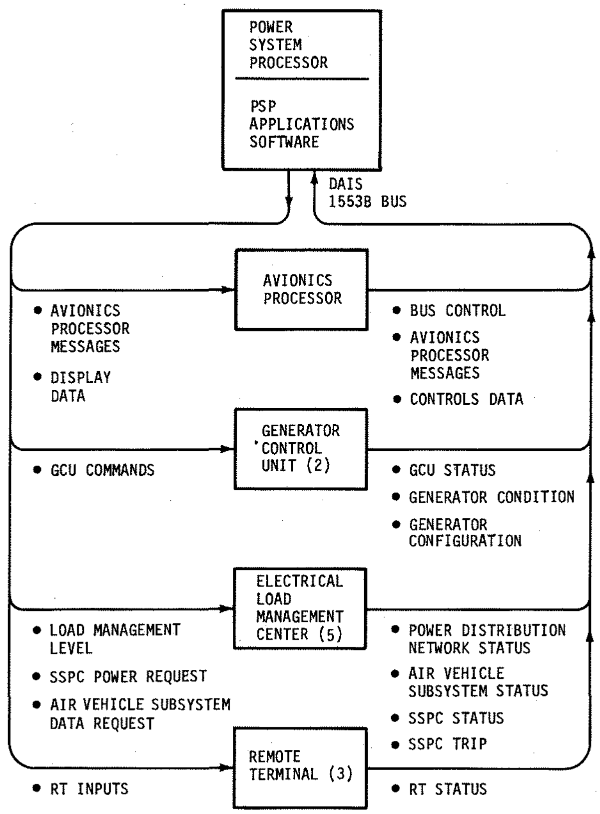

Figure 7. Electrical System Data Flow

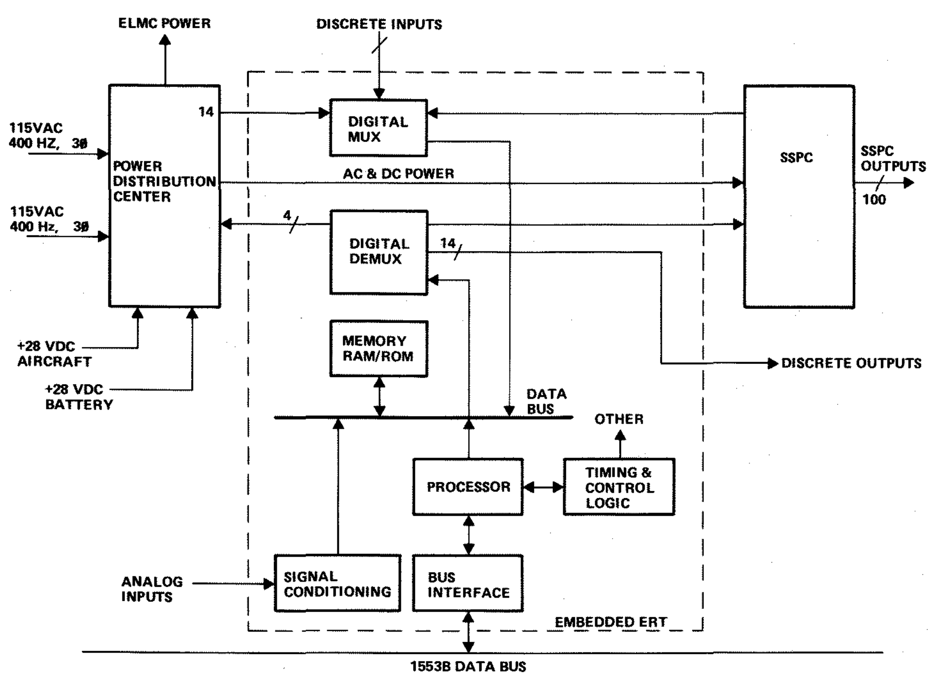

Figure 8. ELMC Hardware Block Diagram

The Power Distribution Center has already been described but it should be noted that the selection of power sources can be done under software control by the ERT processor. The SSPC control unit receives control inputs from the ERT, outputs SSPC status to the ERT, and controls the power supplied to various aircraft loads with SSPCs. Each SSPC is controlled by a single ON/OFF signal and provides a TRIP signal for over current conditions and an ON/OFF status signal. The ERT provides the primary interface between air vehicle subsystem equipments, SSPCs and a MIL-STD-1553B data bus. It consists of an embedded microprocessor and associated interface logic.

Generator Control Unit

To provide the necessary response time and reliability for control of an aircraft generator, control and protection of the generator is accomplished by the GCU as shown in Figure 2. The GCU also provides control and protection for the main AC bus. The GCU is connected directly to the data bus; however, the generator control and protection functions operate independently of any bus service functions. This isolates the generator system from data bus failures. during system powerup, the GCUs bring the power system on line before the control system is functioning.

V. Electrical System Software

All electrical system software is coded in Jovial (J73) higher order language. Both executive and application software programs exist in the avionics, power system processor, and ELMCs. The avionics executive software handles the synchronization of communications on the 1553B data bus as well as configuration and error management. The executive software in both the ELMC and power system processor functions to provide the interface to the 1553B data bus.

One of the most important applications software programs and the one to which we shall restrict our discussion here is that of load management. This software program is found in the power system processor. It is the purpose of load management to provide maximum available power to the aircraft loads. A top level flow diagram for the load management task is given in Figure 9.

Overload and under utilization situations are first corrected through reconfiguration of the power distribution network (See Figure 2). Hence, if a generator overload or under utilization situation exists, the power distribution network configuration is evaluated and if possible, commands may be issued to change the position of one or more network switching elements such as bus tie breakers, TRU3 or ELMC feeder selectors. Only when this fails to resolve the situation is a load management level scheme employed.

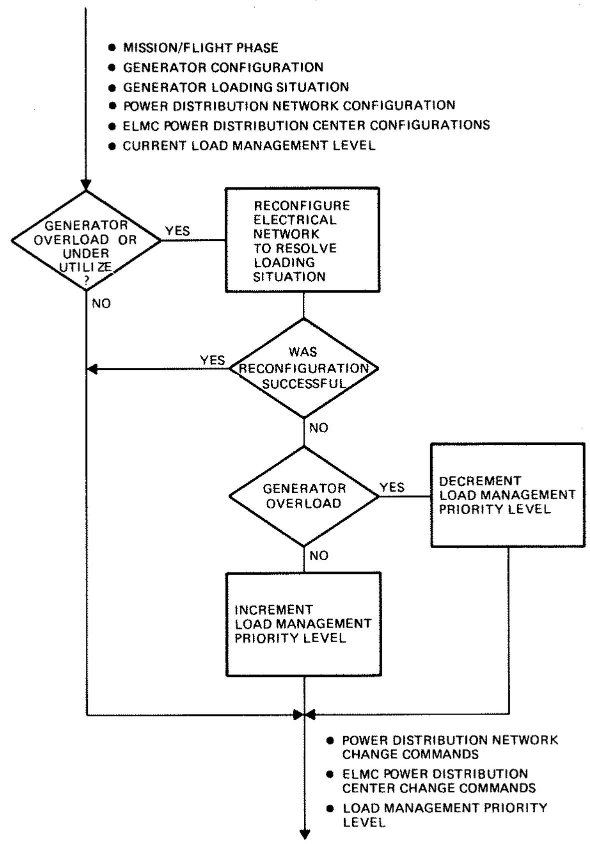

Figure 9. Load Management Flow Diagram

The available load management levels are described in Table 1. Normally, the load management level will be set to 1, i.e., all loads enabled for flight operations. As can be seen from Table 1, there are 3 levels of degradation for take-off/climb, landing, and there are 5 levels of degradation for combat. In addition, there is one load management level for ground maintenance. When load priority levels must be changed, they are change either up or down only one level at a time according to the current aircraft flight phase.

LEVEL	DESCRIPTION	LEVEL	DESCRIPTION
1	Normal	9	Intermediate Cruise
2	Maximum Takeoff/Climb	10	Minimum Cruise
3	Intermediate Takeoff/Climb	11	Maximum Combat, Maximum ECM (Electronic Countermeasures)
4	Minimum Takeoff/Climb	12	Intermediate Combat without ECM
5	Maximum Landing	13	Intermediate Combat without ECM
6	Intermediate Landing	14	Intermediate Combat without ECM
7	Minimum Landing	15	Minimum Combat without ECM
8	Maximum Cruise	16	Ground Maintenance

TABLE 1. LOAD MANAGEMENT PRIORITY LEVELS

VI. Summary/Conclusions

An advanced aircraft electrical system has been designed which meets the requirements for a 1990 time-frame two-engine tactical aircraft with multi-mission capability. Its modular design and use of intelligent electrical load management centers with solid state power controllers results in a greatly enhanced aircraft electrical system over that currently available today.

Acknowledgements

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