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Space Craft Electrical System -- New Concepts in Protection and Control

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Introduction

Increased demands for more reliable circuit protection and power control in manned space craft electrical systems have resulted in a vigorous exploratory research program to develop a totally new "systems concept" of protection and control using solid-state logic in conjunction with either solid-state or electromechanical power switching.

The electrical power system currently used in manned space craft is patterned after those used in aircraft. It should be noted that, in many cases, the electrical system, in even our most modern aircraft, could stand a critical re-evaluation.

Present System

A present-day space craft electrical power system consists of power sources, loads, and the distribution grid that connects them. The present interconnecting distribution grid includes bus-bars, feeder wires, switches, circuit breakers, relays, contactors, and various types of sensors.

The functions of the several components of the interconnecting grid system are as follows: Switches are provided for on-off control of the circuit. Relays may be used to augment switching capability, to reduce switch size in a crowded location, to permit remote switching of a circuit, and to perform various logical operations. Circuit breakers are provided to prevent burnout or overload damage to both wire and power sources. Contactors are controlled by switches or relays and are used to switch relatively high current loads. Sensors may be used to detect over-voltage, over-current, over-temperature, and ice accretion. All of these functions must be provided for in any new system.

The trend in the larger and more advanced manned space craft is toward increased complexity in the circuit protection and power control areas. This has resulted in a larger number of circuit breakers, relays, contactors, switches, wires, and other devices. In an effort to conserve space and offset the increase in weight, designers have worked diligently to miniaturize these devices. In so doing, however, they have created many new problems which seriously threaten the reliability and operational performance of the space craft.

A cursory investigation of the present system produces a number of questions, a few of which are: Why run heavy power wire to the cabin and then back to a load near the power source? A circuit breaker is a switch as well, thus why cascade a switch or relay in series with a circuit breaker? Why perform circuit logic at power levels? Why provide a separate control switch for each circuit?

Total System Concept

In the development of the total system concept one must break with tradition and study the entire power system---i.e., sources, loads, switching, protection, control functions, and display and adjust the design to meet a set of system requirements. Any effort to simply replace electromechanical components with solid-state components, whether or not they perform logic or switching functions, will not meet with any real degree of success.

Important parameters in any space craft electrical system are reliability, survivability, maintainability, vulnerability, size, and weight. Consequently, to produce a system which has optimized the above parameters, one must perform an overall functional analysis in which there is no component equivalence with the electromechanical system. Figure 1 is a simplified block diagram of this proposed system.

Control Network

To reduce weight and size and to improve reliability, one would perform all logic at low signal levels. The control network or "brain package" performs signal processing and logical operations on information from the control panel, overload sensors, and switches to determine switch states and to display panel status. Since all logic will be performed at signal levels, the control circuit may be constructed using integrated circuits which allows for a much greater number of complex logical operations.

This concept should be compared with the present electromechanical system in which all logic is performed at power levels by switches and relay contacts in cascade which is understandably unreliable.

Power Switch

The power switch is a remotely controllable device which will serve the dual function of both a switch and a circuit breaker. This means the power switch must be able to open under short circuit conditions to perform as a circuit breaker and it must meet the on-off life cycle test of a switch. In addition to operate as a circuit breaker, the power switch must respond quickly to the application of a turn off signal. In the proposed system only one switch should exist per wire or load. Note that in any modern system one may find at least one circuit breaker, occasionally several, in addition to a switch in series in almost every circuit. Thus, the use of a single switch that can serve both circuit protection and switching functions leads to an improved system through weight reduction and higher reliability.

Control Panel and Display

The inputs to the control logic are handled through the control panel. In other words, the control panel is used by the operator to communicate with the system. In a conventional system the control panel is the multitude of switches and circuit breakers that are scattered throughout the space craft.

The display panel indicates the status of the electrical power system. This panel displays all circuits and indicates whether each is on, off, or tripped. The status of particular functions or groups of circuits can be displayed as well as that of individual circuits.

The display and control panels are located in the cabin or cockpit directly within the astronaut's view and reach, yet the control network, switches, sensors, and other elements may be remotely located. Connection of the cabin equipment to the remote may be accomplished by a single wire pair; however, several wire pairs using different routes are recommended to provide additional reliability and survivability by providing redundancy. This method, which requires signal coding, will not only reduce panel congestion but also reduce weight by a tremendous savings in wire. If a separate control wire were provided from the control panel to the remotely controlled devices, there would not be any great saving in wire unless there were an unusually large number of high current circuits in the system.

The proposed system opens up a large number of new possibilities for system functions, for example: (1) One switch on the control panel could be used to program all required circuits for any particular flight function. Flight functions are defined as lift-off, climb-out, orbiting, descent, landing, and a group of specified emergency conditions. The selection of a new function would automatically turn off those circuits which were used in the last function but are not required for the new function. (2) If a circuit trips because of an overload, the control network would automatically reset the circuit any desired number of times before tripping out permanently, indicating the fault condition to the astronaut. Although the trip action would be automatic and many nuisance trips would go unnoticed at the time, they would be read on the record printer during a routine maintenance check. (3) Continuous, sequential monitoring of all circuits becomes possible which means that the astronaut can pin-point impending trouble and perform any required preventive maintenance.

One of the major objectives in the system concept is to reduce cabin congestion and save valuable panel space and also improve operator access and supervision. Consider the possibility of using a control panel consisting of ten push buttons, very similar to the typical telephone touch tone system. (See Figure 2). All switch circuits and selected functions could be controlled by simply dialing a number.

Each astronaut could have his own control panel providing him with access to all power system switches. The operational capability of the proposed system is far in excess of the present system. Since a number of switches could be controlled by dialing a specific function, the access time to the system is greatly reduced. Specific functions again might set all circuits for takeoff or operate all cabin lights. Audio tone coding allows all information to be transmitted over a single wire pair.

In the total system concept, the display is similar to the present circuit breaker panels with a caption description of each function and with related functions associated together. The panels, however, are only display units in which conventional circuit breaker panels may also be input units. An area of 3/4 inch by 1 inch, or less, would be required per function as compared to an area of 1 inch by 2 inches, or more, for a conventional circuit breaker panel. A portion of a typical full size panel is shown in Figure 3.

For each function in the system, a caption is presented describing the function and giving each function an identification number. The state of a function is indicated by (1) No Light - Circuit Off, (2) Green Light - Circuit On, (3) Red Light - Circuit Tripped.

Substantial panel space could be saved with a digital fault display using three digit read-out. With this technique, a number which indicates the tripped circuit is digitally displayed. If more than one circuit is tripped, the circuits may be displayed in sequence. It seems that a combination of the two display techniques might be desirable.

The proposed total system display permits the operator to determine the status of the entire power system at a glance, while the digital portion will quickly direct the astronaut's attention to any fault on the system and permit him to take action very quickly.

In addition to these displays, a tape printer is provided to record all system operations for future operational and maintenance records.

Conclusions

Theoretical considerations and actual tests on a prototype system indicate that the control logic when used with either the electromechanical or solid-state switch permits a measure of reliability in protection and power control functions not previously feasible using standard switches, circuit breakers, and relays. Through the use of the logic package, many desirable new functions can be performed either manually or be programmed by using any of the standard methods.

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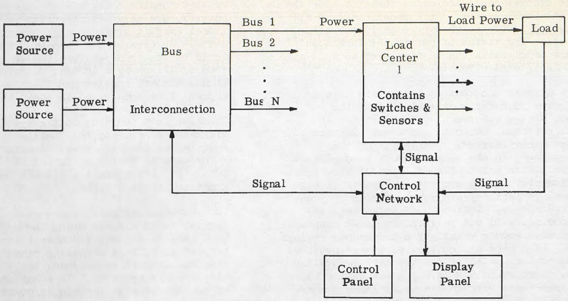


Fig. 1. Total System Concept Block Diagram

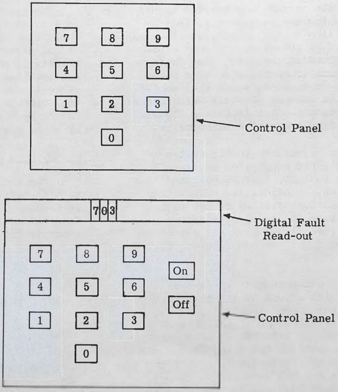
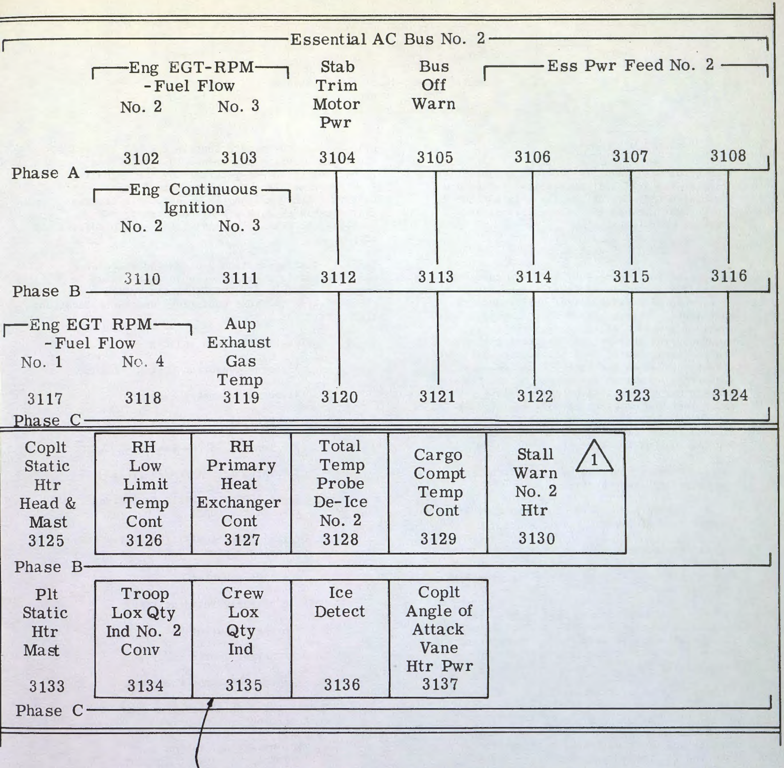


Fig. 2. Control Panels.
-- Full Size



3/4 x 3/4 area behind panel may be green for on; red for tripped; nothing for off.

3/4 x 1 area for each function to be indicated. This compares with about 1 x 2 for present circuit breaker panel.

Panel is edge lighted plexiglas with engraved captions and a frosted back.

Fig. 3. Display Panel