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SPACE STATION ELECTRICAL POWER DISTRIBUTION ANALYSIS USING A LOAD FLOW APPROACH

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ABSTRACT

The Space Station's electrical power system will evolve and grow in a manner much similar to our present terrestrial electrical power system utilities. The initial baseline reference configuration will contain more than 50 nodes or busses, inverters, transformers, over-current protection devices, distribution lines, solar arrays, and/or solar dynamic power generating sources. The system is designed to manage and distribute 75 KW of power single-phase or three-phase at 20 KHz, and grow to a level of 300 KW steady state, and must be capable of operating at a peak of 450 KW for 5 to 10 minutes.

In order to plan far into the future and keep pace with load growth, a load flow power system analysis approach must be developed and utilized. This method is a well known energy assessment and management tool that is widely used throughout the Electrical Power Utility Industry.

This report will discuss and document the results of a comprehensive evaluation and assessment of an Electrical Distribution System Analysis Program (EDSA). Its potential use as an analysis and design tool for the 20 KHz Space Station electrical power system will be addressed.

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1.0 INTRODUCTION

An orbiting Space Station employing a hybrid autonomous ac electrical power system will require an extensive computer aided analysis procedure for determining several operational characteristics of the system during transient and steady state conditions. A thorough analysis and smart control of earth based electric power systems have been achieved to a great degree by utilizing the "load flow" concept. Since the Space Station's electrical power system will evolve in a manner much like our own terrestrial electrical power system, the load flow approach should provide useful information in regard to the system present and future state of operation and load performance reliability.

2.0 LOAD FLOW CONCEPTS

Load flow is a computer-aided analysis procedure aimed at determining the actual power flow patterns (watt, vars) in a given system, and ways of controlling these patterns (1) J. Ward and Harry Hale of Iowa State University are are often credited with the first formulation of the power flow problem. Several other early and recent authors, such as G. Kron, R. L. Parks, G. W. Stagg, A. H. El-Abiad, J. R. Neuenswander, W. D. Stevenson, P. M. Anderson, K. C. Kruempel, and A. A. Fouad have made significant contributions directly or indirectly because of their interest in electric power systems.

2.1 OBJECTIVE OF LOAD FLOW ANALYSIS (LFA)

In order to determine the best ways of operating a given power system and plan for future load growth, it is necessary to analyze the steady state solution of the network and achieve the following objectives.

- Determination of real and reactive power flow in the transmission line of a system based on certain prior assumptions regarding loads and generation.
- Computation of all system voltages.
- Identify all overloaded transmission lines. (Operating too close to the transmission line limit which could cause cable overheating).
- Rerouting of power in case of emergencies.
- Determine which load flow pattern will results in "optimum dispatch".

2.2 CONTROL OF REAL AND REACTIVE POWER FLOW

In order to successfully manage the transmission and distribution of electrical energy. The following objective must be met in a normal ac power system.

- Maintenance of real power balance (1)
- Control of frequency
- Maintenance of reactive power balance
- Control of voltage profile
- Maintaining an "optimum" generation schedule
- Maintaining an "optimum" power routing scheme.

2.3 "LFA" NOT A STANDARD CIRCUITS PROBLEM

Although load flow concept involves the use of many conventional circuit analysis methods, it is not a standard circuits problem for several reasons. Some of these are:

- More often non-linear than linear due to the product of voltage and current being equal to power.
    - Additional non-linearities arise from the specification and use of complex voltage and current, and transmission components such as tap changing transformers in which the tap is adjusted to keep the bus voltage magnitude fixed.
    - Load impedance can never be represented by a constant due to a wide variety of load variations.
    - A typical load flow analysis involves network equations written in terms of voltages and powers (inherently non-linear and thereby demanding a numerical solution in most cases.)
    - A simple two bus one-line load flow diagram is shown in Figure 1 depicting the variable of interest in a load flow analysis.

3.0 SPACE STATION LFA

Space Station load flow analysis in theory will demand the same principle requirements as earth-based system. However, the practical control aspects of this second generation multisource hybrid power system will require considerable attention. Some of these include generation and frequency control of large area solar arrays and solar dynamic generating sources.

Other areas of concern are:

- Accurate modeling of all system components (i.e., transmission and distribution lines, transformers, etc.)

- Resonance conditions observed when using litz cable for a 20 KHz power system (2).
- Variable network topology due to a random distributed load mixture.
- Hybrid load flow numerical methods development.

The reference configuration electrical distribution system is shown in Figures 2 and 3.

4.0 ELECTRICAL DISTRIBUTION SYSTEM ANALYSIS (EDSA)

EDSA is an integrated collection of computer programs for electrical distribution systems analysis and design. The program is written to assist the engineer in the design and analysis of electrical power transmission and distribution systems of public utilities and large installations using 60 Hz power.

The programs are menu driven, interactive, and requires an IBM PC computer, 640 KB of memory capacity, and a 2.1 DOS or greater disk operating system.

Calculations are based on NEMA, ANSI, NEC, IEEE, Beaman, Stevenson, GE, and Westinghouse T&D reference books.

The complete EDSA software package includes the following programs:

- Short circuit analysis loop/radial/utility/multi-generating source. 185/300 bus system
- Load flow analysis 185/300 bus system
- Motor starting voltage dip load flow method
- Ground mat analysis

- Protective device coordination
- Shielding effectiveness
- Motor torque simulation
- Generator set sizing
- Wire and conduit sizing
- Transformer sizing
- Symmetrical ampere to withstand rating conversion factors
- Motor starting voltage dip impedance division method (on generator/utility)
- Panel, MCC, primary SWG, unit substation, automatic transfer switch, bus duct schedules
- Capacitor reactor starting of large synchronous motors
- Calculating zero-sequence resistance and reactance R(0), X(0)
- Load flow multi-source and loop
- Computer graphics interface
- Build, edit feeder and transformer master data files
- Build, edit fuse relay and MCP data files
- Build circuit breaker data files

The data generated by the load flow and short circuit analysis programs are shown in Figures 4 and 5.

5.0 CONCLUSIONS

The Space Station electrical power system will be a complex, high power, multisource system operating with a high degree of autonomy. The simulated management and control of this second generation system will require a number of artificial intelligence and expert system software modules. Some of these are: load flow analysis, state estimation, generation control, and energy storage.

The load flow analysis component of the EDSA package proved to be very useful for analyzing a 20 KHz electrical distribution system. This software package is considered by many to be the most complete analysis and design tool available.

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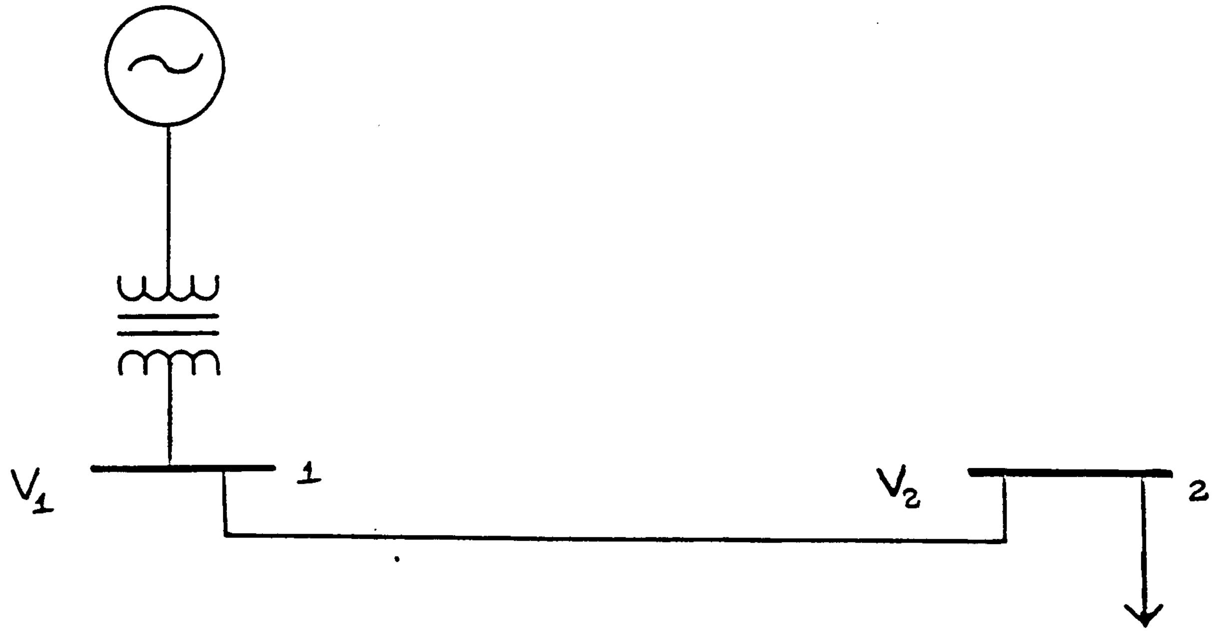

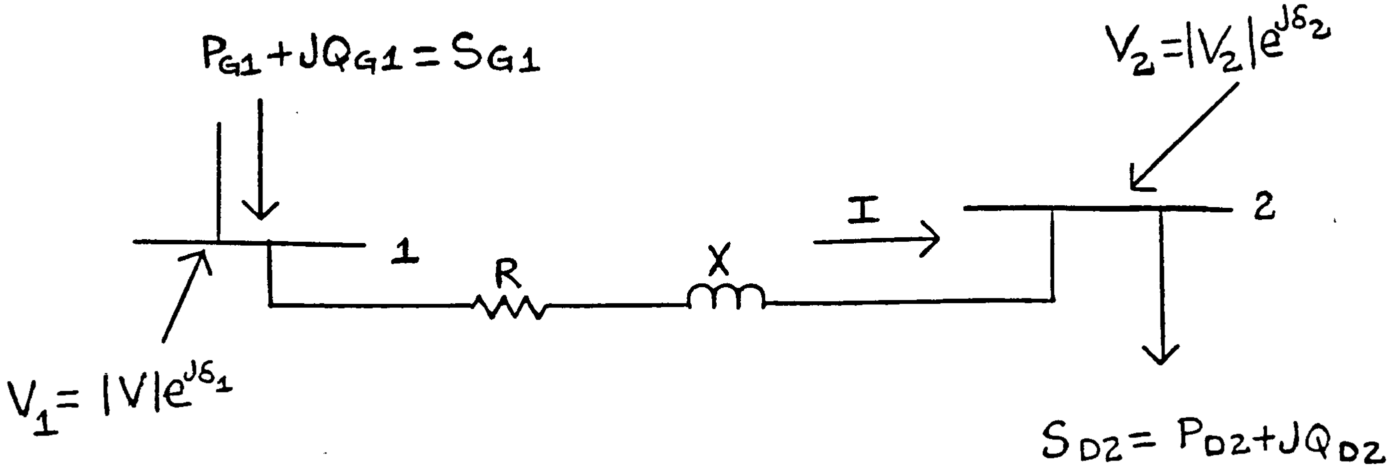

FIGURE 1. ONE LINE LOAD FLOW DIAGRAM

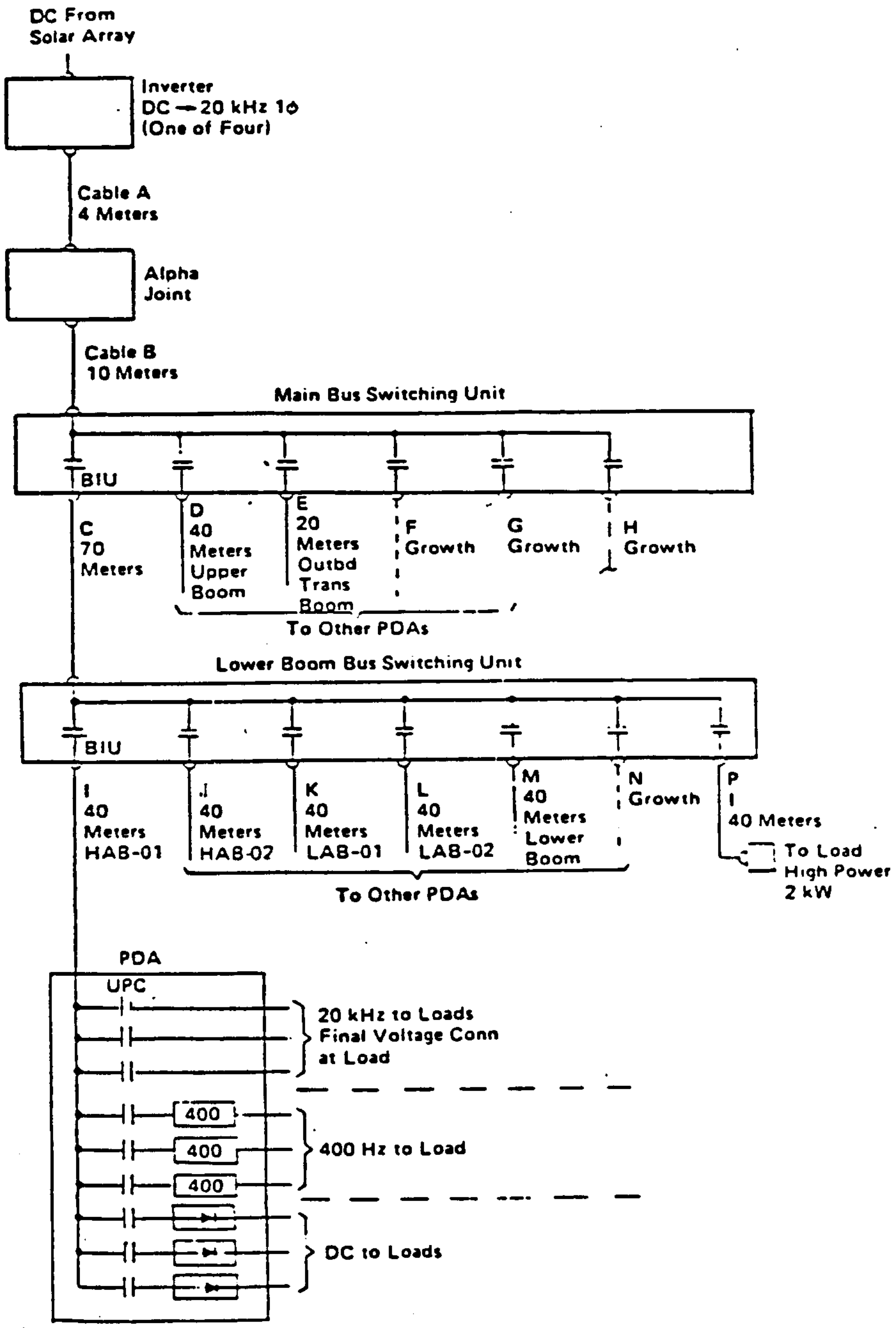

FIGURE 2. REFERENCE CONFIGURATION ELECTRICAL DISTRIBUTION SYSTEM

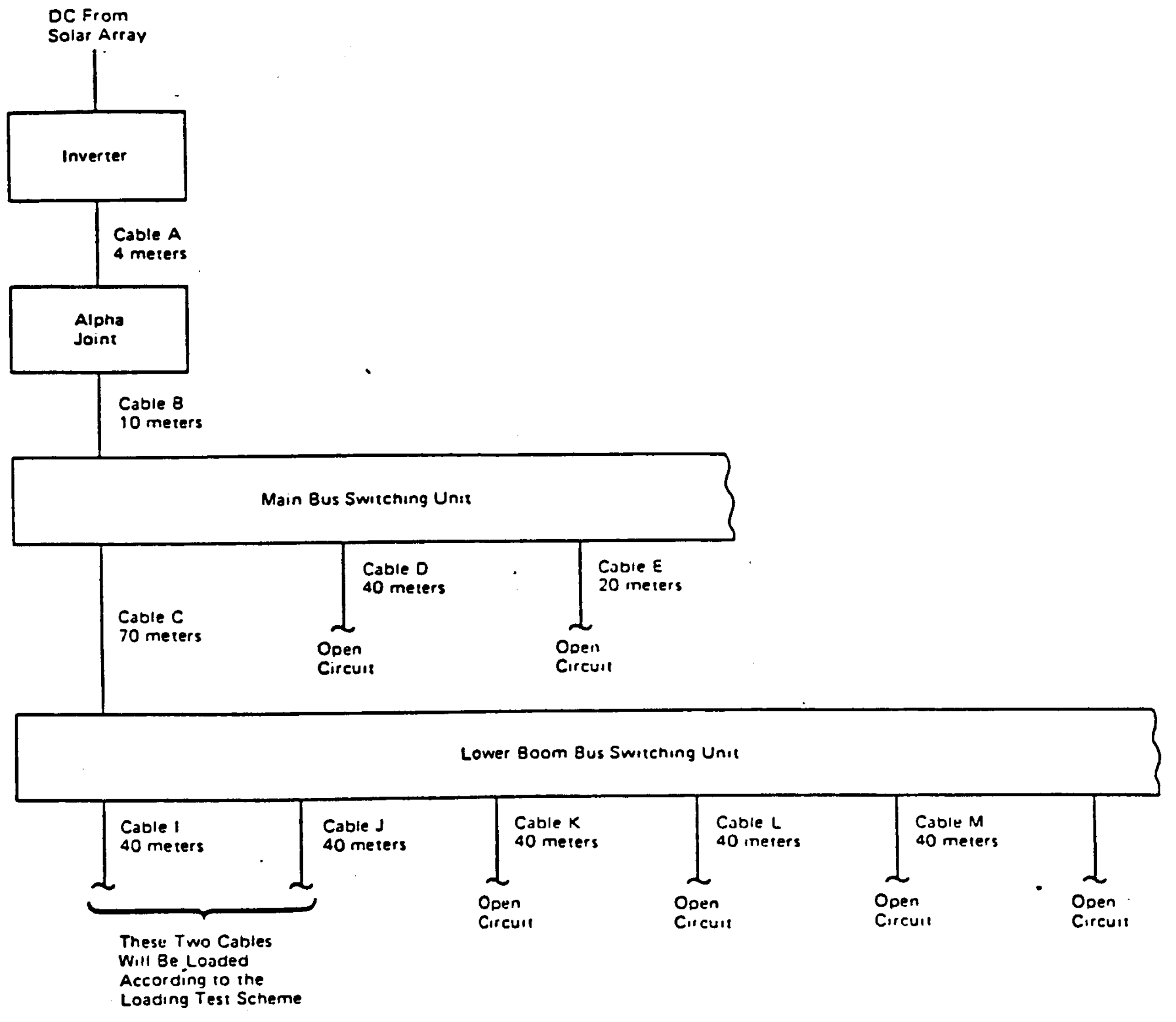

FIGURE 3. DISTRIBUTION SYSTEM BLOCK DIAGRAM