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An Advanced Supervisory Indication, Control & Data Acquisition System

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AN ADVANCED SUPERVISORY INDICATION, CONTROL & DATA ACQUISITION SYSTEM

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ABSTRACT

Electric Utility systems in the United States double in growth every ten years. This growth necessitates the construction of substations in new areas and expansion of substations in existing areas.

Troubles quite often cannot be quickly and accurately diagnosed until a sufficient number of calls have been received from customers to establish a pattern.

This paper will describe an advanced supervisory system utilizing latest state-of-the-art electronic equipment interfaced with digital computers to provide the trouble dispatcher with a rapid update as to the status of his system at all times. He will also be able to remotely control his system as well as receive essential operating data.

INTRODUCTION

Union Electric is an investor-owned utility with corporate headquarters located in St. Louis, Missouri. It serves over 700,000 industrial, commercial and residential customers in the states of Missouri, Illinois and Iowa; an area of some 19,000 square miles. In addition, Union Electric provides gas service to 43,000 customers in the Alton, Illinois area as well as steam heating to over 600 businesses in the downtown St. Louis area.

Union Electric's 1973 net integrated system peak was in excess of 5,000 megawatts. Its generation facilities consist of fossil fuel steam plants, combustion turbines, run-of-the-river hydro, conventional hydro and pumped storage hydro for a total nameplate capacity of 6,097 megawatts. 1200 megawatts is planned for in service in the near future at the new Rush Island Plant, presently under construction 30 miles south of St. Louis and a 1100 megawatt nuclear plant located near Fulton, Missouri is planned for an in-service date of 1981.

It became apparent by the mid-sixties that some means of rapidly and accurately alerting the distribution dispatchers to 4 and 12 kV feeder lockouts in the St. Louis City and adjacent areas was vital for improved service restoration. For example, on June 28, 1969, a severe storm disrupted service to some 17% of our customers in the metropolitan area; about 50 distribution feeders were locked-out.

In the fall of 1970, Union Electric's management initiated a formal study and throughout the following year, manufacturers of supervisory equipment were contacted to gather information that would ultimately lead to a bid specification. It was decided that this specification would be conceptual in nature in order to take advantage of the latest state-of-the-art developments in the supervisory field. Bids from a carefully selected list of manufacturers were requested in March, 1972 and in June of that same year, after an in-depth technical evaluation, the contract was awarded to Control Data Corporation of Minneapolis, Minnesota.

It is significant to point out that this system is the first major one of its kind anywhere in terms of magnitude, both initial and ultimate. The initial contract calls for 196 remote terminals with an ultimate of 300 terminals within the next 10 years. These remote terminals are located throughout St. Louis City and County as well as the regional areas of E. St. Louis, Alton, St. Charles, Jefferson and Franklin counties.

SYSTEM CONFIGURATION

The master station, which will be located in the Company's Distribution Dispatching Office in St. Louis, consists of two SC-1700 computers operating in a back-to-back arrangement via a data coupling channel. Each CPU is equipped with such peripherals as a teletype and a cartridge disk drive subsystem for mass storage of data. A line printer and paper tape reader/punch is connected to the secondary CPU for data retrieval and software development. Six process interface controllers (PIC's) are connected to both CPU's for redundancy so that the secondary CPU can assume full process control upon failure of the primary processor. Each PIC, in like manner, is redundantly connected to other PIC's thereby providing backup in case of a PIC or channel adapter failure. Six channel adapters together with their modem and line switch are located in each PIC. Each modem/line switch combination is capable of handling up to six 4-wire leased telephone circuits.

At the start of this project, "telegraph-grade" telephone circuits for interconnecting the remote terminals with the dispatching office were considered because of their attractive low leasing costs. However, this idea was abandoned early in the game as Bell engineers advised that such circuits were difficult to make up on a party-line basis and have reliability problems. A major criteria was the fact greater speeds than could be accommodated by telegraph-grade circuits were needed for handling the vast amount of data transmission required for this supervisory system. The Company's own microwave system will be utilized to augment the Bell leased lines wherever possible.

The communication circuits will be half-duplex, full period, 600 ohms balanced, Bell designation 3002 and unconditioned. This allows us to utilize a transmission speed of 600 baud and maintain a 15 second scan time on all data acquisition and a 5 second scan time of all status devices.

Should each of the substations be brought into the master terminal via a leased telephone line, the cost would be prohibitive. Therefore, a "party-line" arrangement, where more than one substation is coupled

to any one line was chosen. Much study was given to the number of substations that should be placed on any one circuit. Here leased line costs must be weighed against the impact of having a number of substations out of service at any one time. Union Electric decided that no more than 6 substations should be party-lined on any telephone circuit. It is recognized that this philosophy will vary greatly from any one company to another.

Because the communications link would be one of the most vulnerable and exposed elements in the supervisory system, a rather sophisticated error detection scheme is required in the coding. Bose-Chaudhuri error detection is used because these codes were available in most vendor's systems. They possess good efficiency and a high degree of confidence required in remote-to-master communications.

In order to protect this telephone circuitry from failure due to rise in ground potential due to fault conditions, it is mandatory that all telephone circuits leaving or entering a substation property be provided with neutralizing or isolating transformers. Under Bell's new tariff provisions, this protection can be provided by either the telephone company or the power utility. For economic reasons, Union Electric decided to provide this feature ourselves.

Control Data type 44-500 remote terminals are at each of the substations in the supervisory system. This is a high-speed continuous scanning unit that communicates with and is controlled by the computer master. It provides status and set-point output to control a broad range of digital or analog devices. Also, it provides an indication of device status and numerical values of pulse accumulators and analog quantities.

Union Electric placed stringent demands upon the physical location and environmental conditions under which the remote terminal equipment must operate. While the master and the remotes may be separated by great distances, the remote terminal, must of necessity, be located adjacent to the substation equipment it is supervising and/or controlling. Little space is available within the metal-clad switchgear at a distribution substation in which the remote terminal is to be installed. When installed, the terminal cannot infringe upon the space required to draw out breakers. Remote terminal equipment is normally contained in a 30 inch (76 cm) square cabinet 72 (183 cm) to 90 inches (230 cm) in height. This cabinet was redesigned to fit in a space only 14 inches (36 cm) deep by 24 inches (61 cm) wide by 80 inches (210 cm) in height. Also, the enclosures had to be weatherproof, (as some are mounted outside of the switchgear) and capable of operating within temperature ranges of -20°C to 70°C and at humidity of 0 to 90 percent, non-condensing.

The remote terminals are also designed to be readily expandable as more control points are added in the future. As new bays of equipment are added at a substation, additional points must be added in the remote terminals. The basic design of the remote terminal is such that only additional cards must be inserted into prewired baskets to accommodate this expansion. No external wiring is required at the remote terminals. For the most part, all that is required at the master terminal is a software change.

The large number of remotes scheduled for the system also presents a documentation problem. If each of the remote terminals were designed individually, nearly 200 sets of different documentation would be required initially. However, we have been able to reduce the different number of remotes to 4 basic types, each similar differing only in the number of control points required. This grouping allows the manufacturer to take advantage of the economies inherent in common parts and production.

Back at the master terminal is where the CPU's and their associated peripherals are located. In the Distribution Dispatching Office (DDO) at this location, four supervisory operating positions will be installed. These are the "man/machine interface" positions. Each position consists of a communication turret housing, all telephone and radio control facilities, two cathode ray tubes (CRT's) for display purposes, operating keyboard and logging typewriters. The CRT's are 19" (diagonal measurement), 7-color and capable of limited graphics display.

There are 5 such control consoles. Four are located in the DDO and one is located in the Load Dispatching Office (LDO). The LDO's console is slightly different in that the communications portion is not included as the LDO has its own communications set-up. One control position is provided for all remotes in the "Central" (city) area, another the "North County" area, another the "South County" area and another the "regional area". By button selection, a console can assume operation in any of the above-mentioned areas or can be made to operate in parallel with any other console. The LDO console's operation is slightly different in that it will handle only the substations for which the LDO is responsible.

The supervisor's keyboard associated with each console position is used for any supervisor selection or entry. The keyboard has two "channel select" buttons which allow it to be switched between the two CRT's, thus allowing control or selection from either CRT; but not simultaneously. The two CRT displays at each supervisor's console have separate display memories so that they can operate independently and the CPU can, therefore, write separate formats on each display with no interaction between the CRT's.

The substation is the basic unit for display. Each substation is represented by a one-line diagram showing the position of all controllable devices and data quantities obtained from that station. All information obtained from the on-line data base (software) is up-dated dynamically on the one-line diagrams. Selection of a station for display is based on the "menu approach". There is a menu corresponding to each of the operation areas; i.e., Central, Regional, North County, South County and LDO. A menu will be displayed at any CRT not being used for other purposes. The particular menu being displayed will depend on which of the operational area keys has been depressed. The LDO console will always present the LDO menu.

A room, contiguous to the DDO, will house CPU's, peripherals and engineer's console. The engineer's console will consist of a single CRT and full keyboard and will be used by the engineer for program development and modification to one-lines, etc. This engineer's console will be used not only in the programming effort; but also to train new personnel and to implement maintenance procedures. The engineer's console has the same capability as an operating console for selecting, displaying and controlling a remote terminal. It can, however, also be utilized in a training mode where a trainee can select and display any remote terminal on the system. It may also be used to control a remote terminal, provided that the key interlock to the

control section of the engineer's console has been enabled.

The software associated with this supervisory system can be divided into 3 basic categories -- (1) standard operating system, (2) standard driver packages, and (3) special application software. The standard operating system, such as the Mass Storage Operating System (MSOS), enables the user to begin a system design within the framework of already existing statements, instructions and functional capabilities. The MSOS was selected because it is real-time oriented and interrupt driven. Other standard software packages such as scan, control, alarm, display and logging are also used, each tailored to fit Union Electric's system. Special application software designed for the system includes such things as logging, method of displaying and alarming and coordination of the data base with the man/machine interface. Two unique software packages are provided with our system. One is the On-Line Display Generator and the other is the On-Line Data Base Manager.

The On-Line Display Generator permits the engineer at his console to draw a one-line on the CRT and enter it into the on-line system. There, it is automatically linked to data previously entered into the data base via another unique software package called the Data Base Manager routine. The On-Line Display Generator is a mass memory resident program that executes upon demand in the SC-1700 CPU. The primary function of this program is to provide the means of building and maintaining the current file of CRT displays which contain both fixed and dynamic information.

The On-Line Data Base Manager Program is mass memory resident executed on demand in the SC-1700. The primary purpose of this software package is to provide a means of updating and expanding the software system. It is not intended that this program be used by the console supervisors; but rather it be used by the engineer using the teletype as the input media. The On-Line Data Base Manager Program allows the engineer to:

(1) Enter new points and/or stations to the system.

(2) Modify previously defined points and/or stations in the system.

(3) Enter system data files which have previously been punched in binary format.

(4) Dump system data files in binary format on paper tape.

Complementing the On-Line Data Base Manager Program is the Library Editing Routine (LIBEDT). This program allows the addition, modification or deletion of functions to the system. LIBEDT can make the following changes to either the system library or program library:

(1) Add a program.

(2) Remove a program.

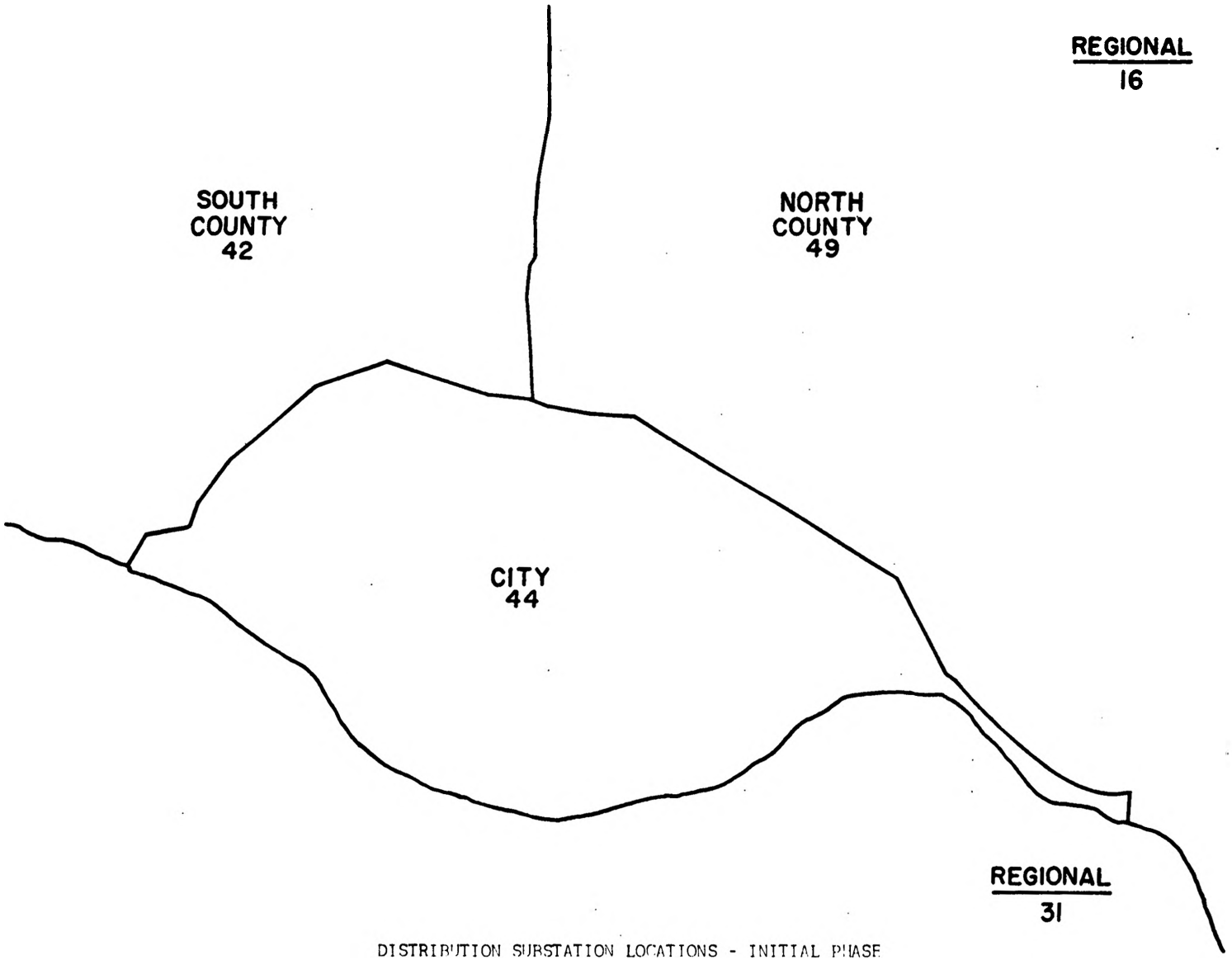
(3) Replace one program with another.

(4) Combine several relocatable programs from the library program or from an input device into an absolute format and then output them as a binary record on the binary output device.

CONCLUSION

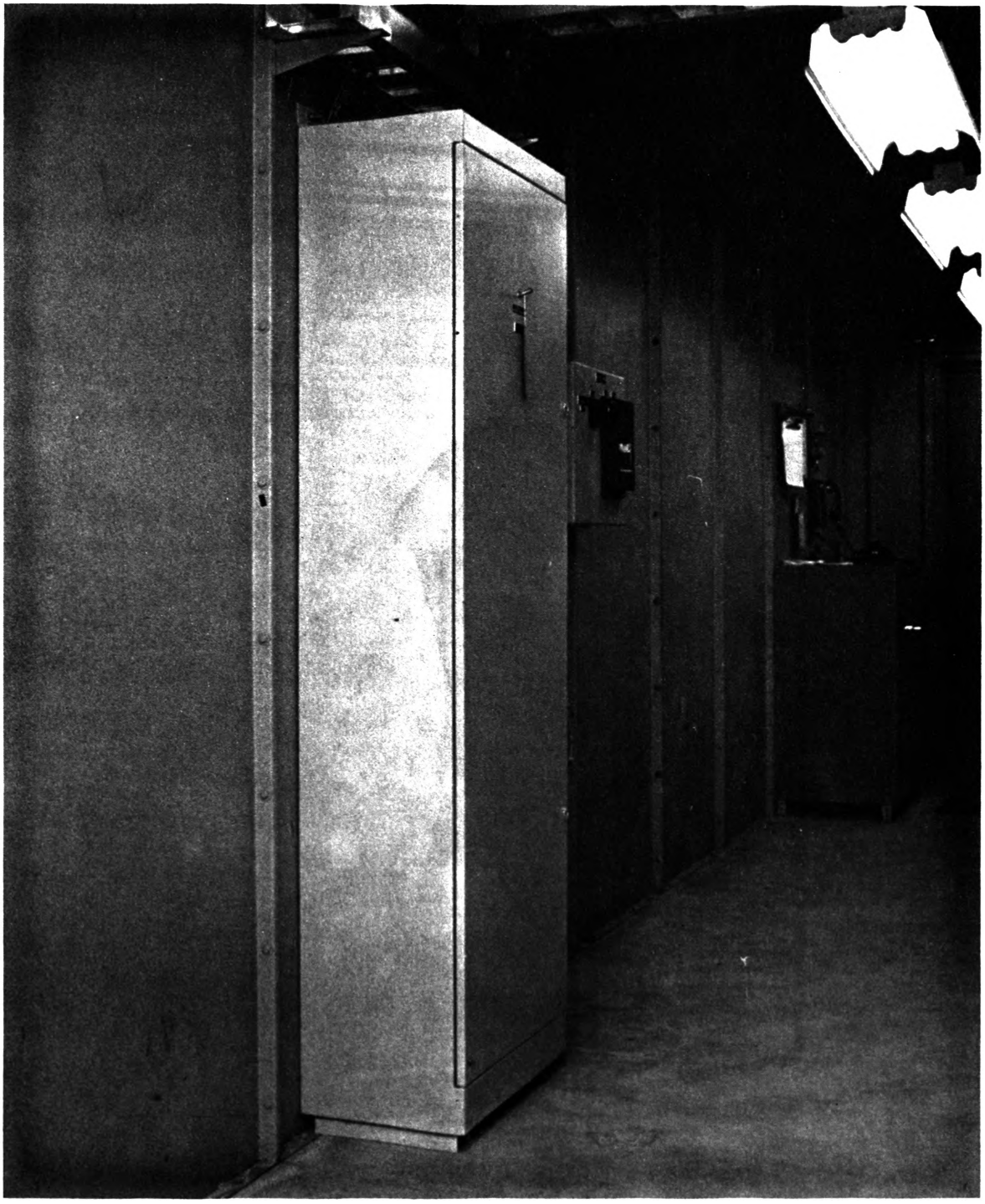
A number of remote terminal units have been installed by Union Electric field personnel. A considerable number of remotes as well as the CPU's and all its peripherals have been retained in Minneapolis by Control Data Corporation where the equipment is presently undergoing rigorous testing of both hardware and software.

Delivery of the system is anticipated for mid-summer 1974. After on-site debugging and installation, operation of the first phase of the system; i.e., master station equipment with presently installed remote terminals, will begin. As remote terminals are installed at the various substations, they will be added to the system. Initial on-line operation will begin early fall 1974.

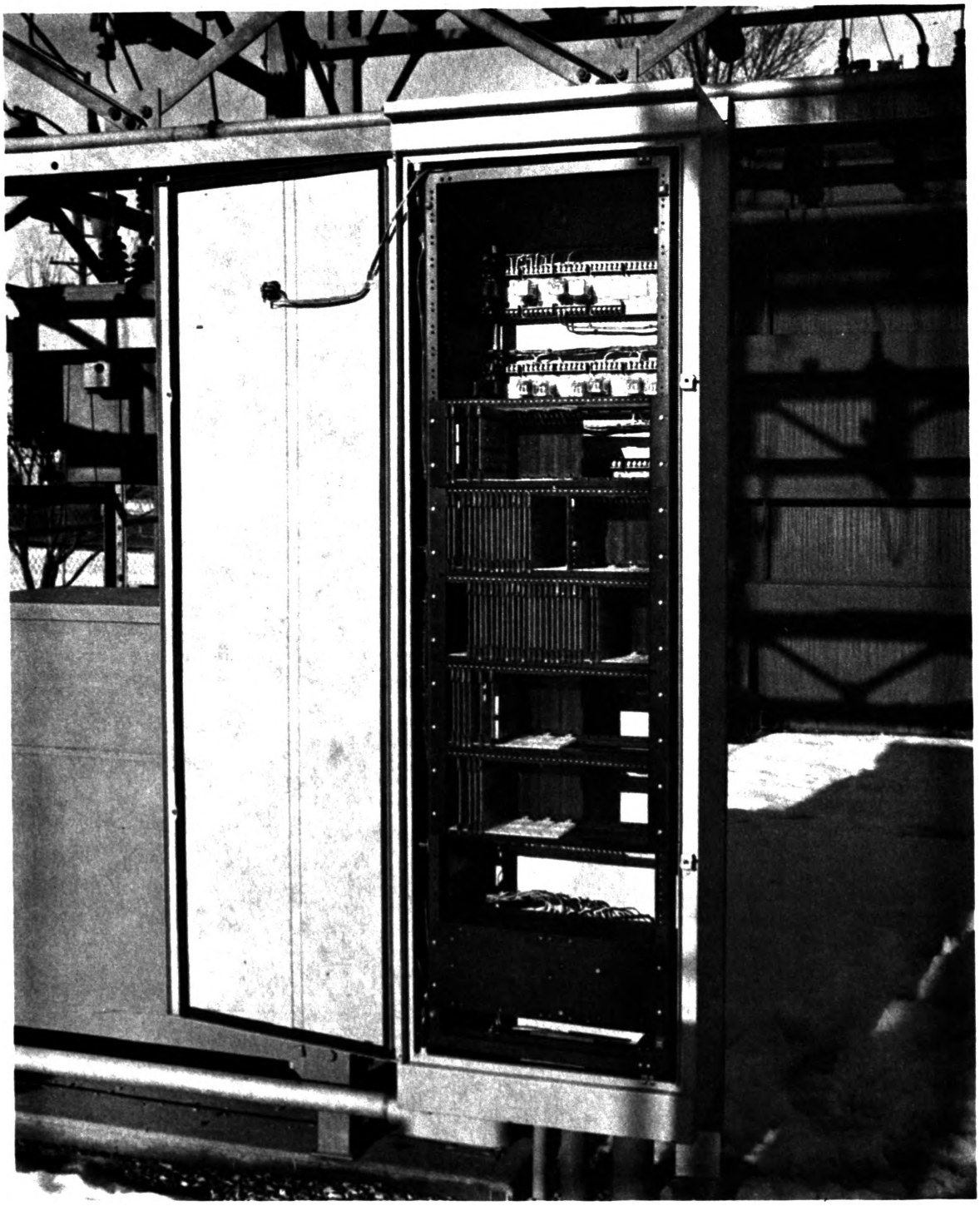


DISTRIBUTION SUBSTATION LOCATIONS - INITIAL PHASE

REMOTE TERMINAL INSTALLATION - OUTDOOR



REMOTE TERMINAL INSTALLATION - INDOOR

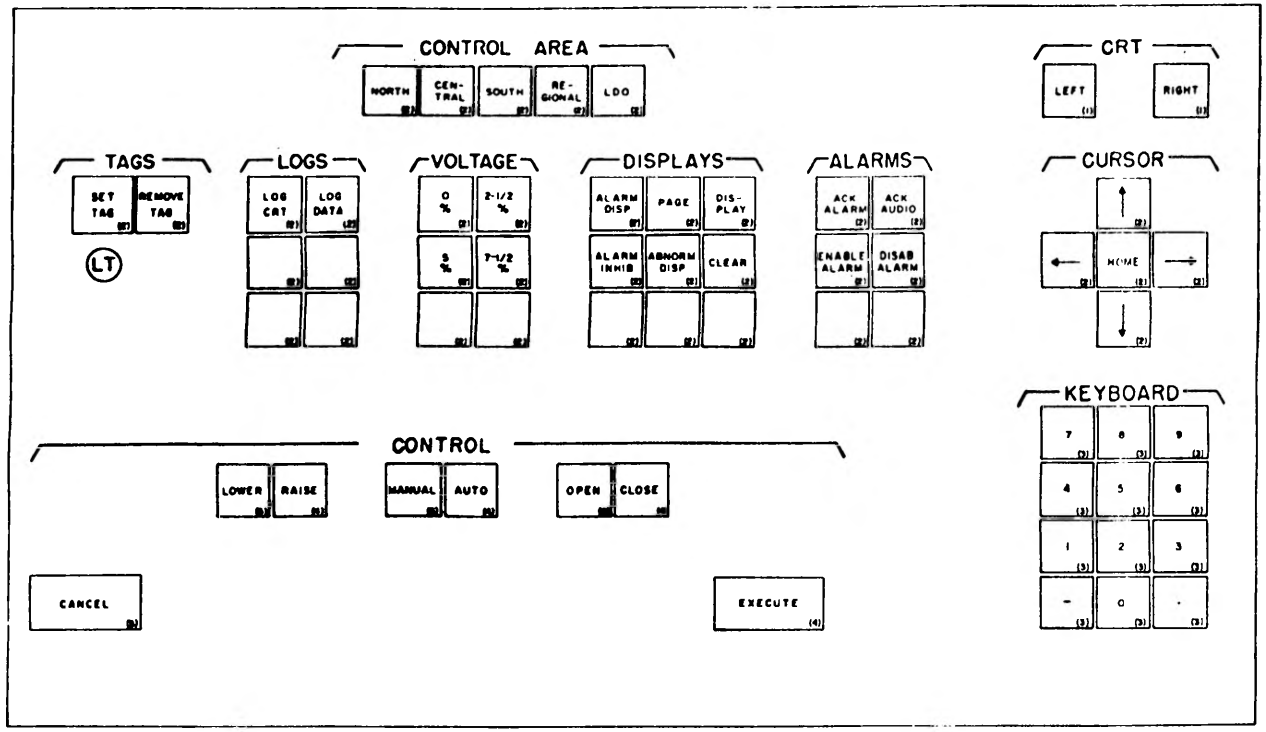


REMOTE TERMINAL - FRONT VIEW
(NOTE ROOM FOR FUTURE EXPANSION)

REMOTE TERMINAL UNIT - INSIDE VIEW
(NOTE ROOM FOR FUTURE EXPANSION)

8324-Z-72699

923

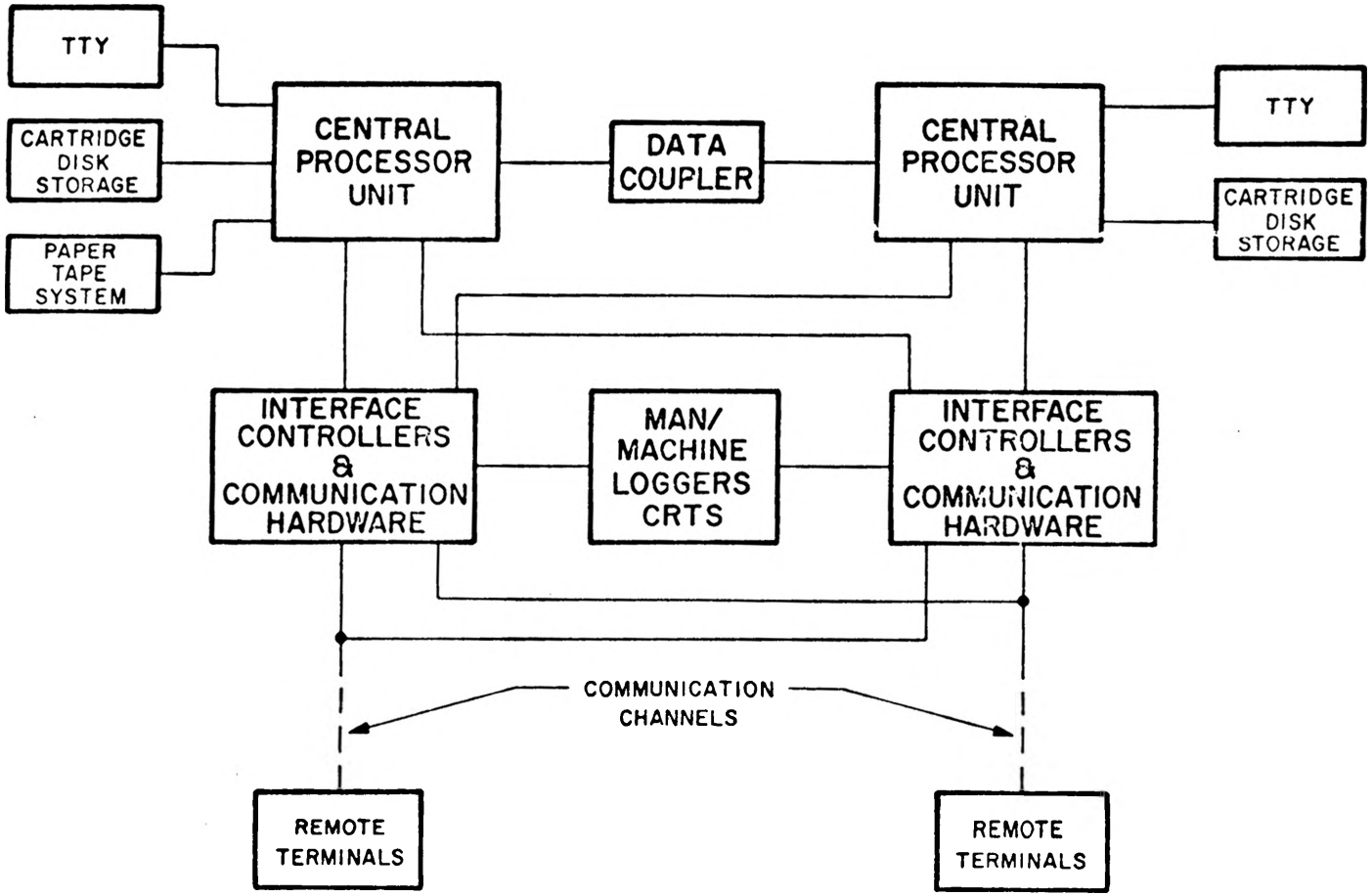


NOTES:
(1) ORANGE ILLUMINATED
(2) DARK GRAY
(3) LIGHT GRAY
(4) RED
(5) GREEN

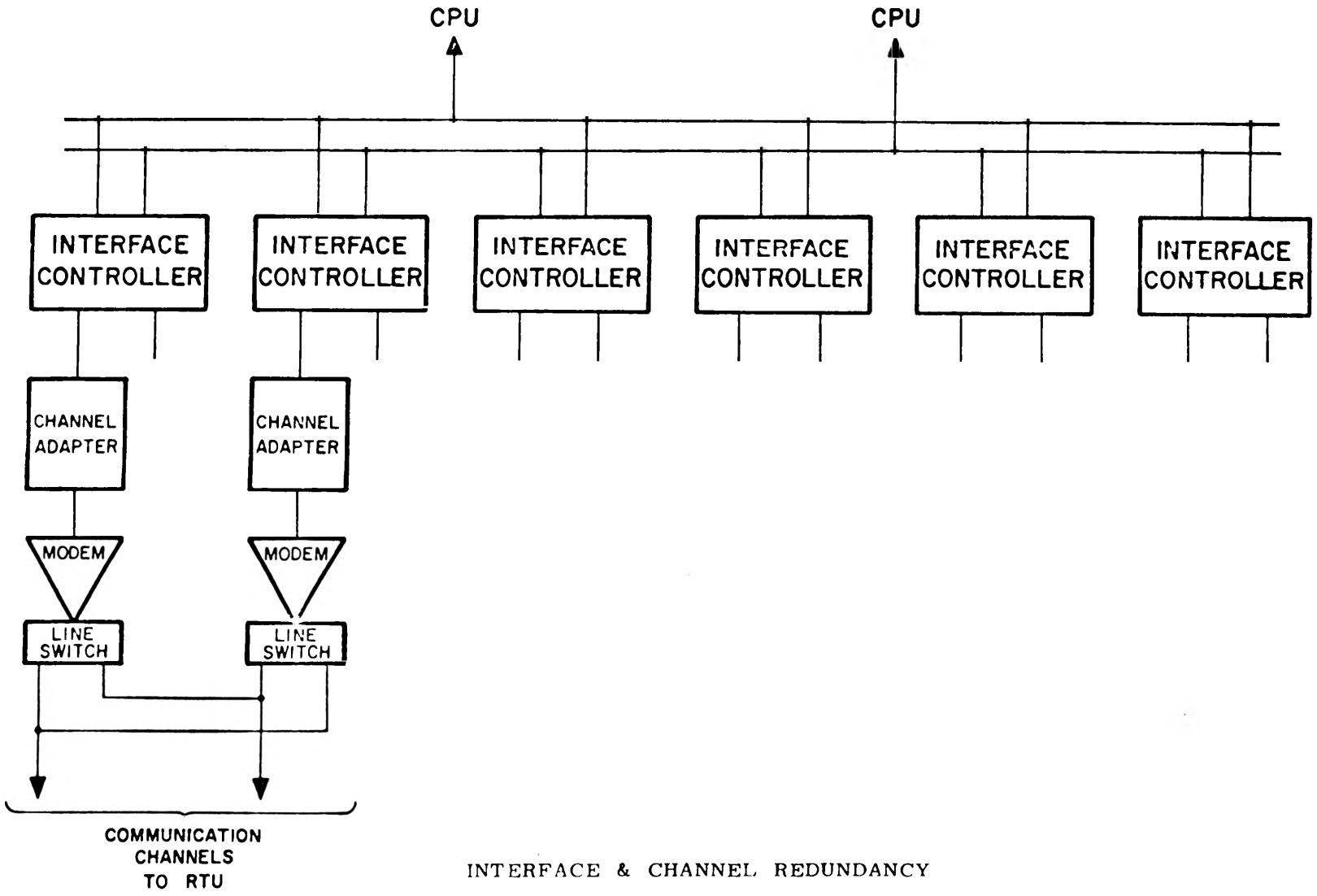
SUPERVISOR'S CONSOLE
KEYBOARD ARRANGEMENT
DDO OFFICE

UNION ELECTRIC SYSTEM ST. LOUIS, MO.
LOCATION GRATIOT ST. DDO

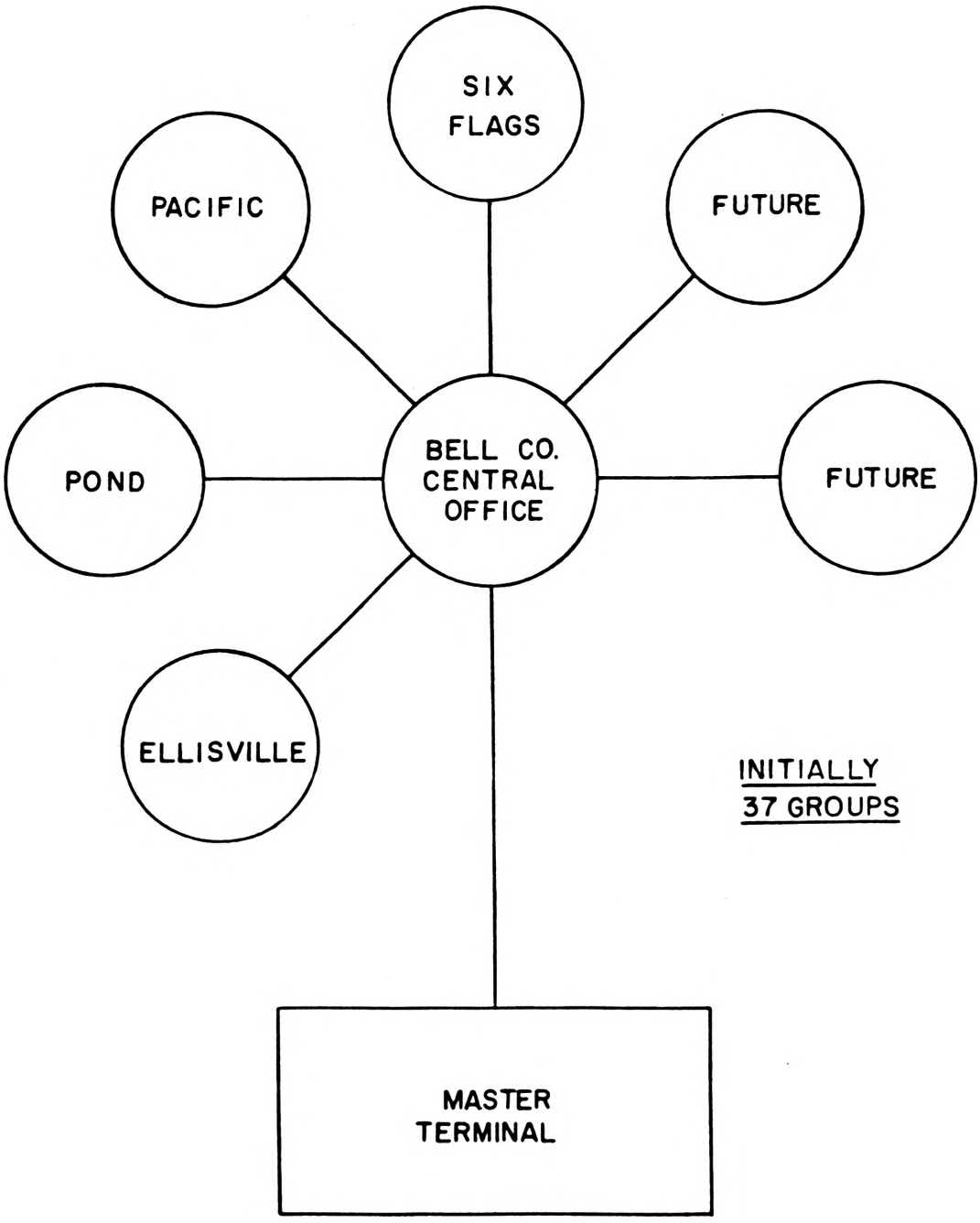
8146-Z-72699

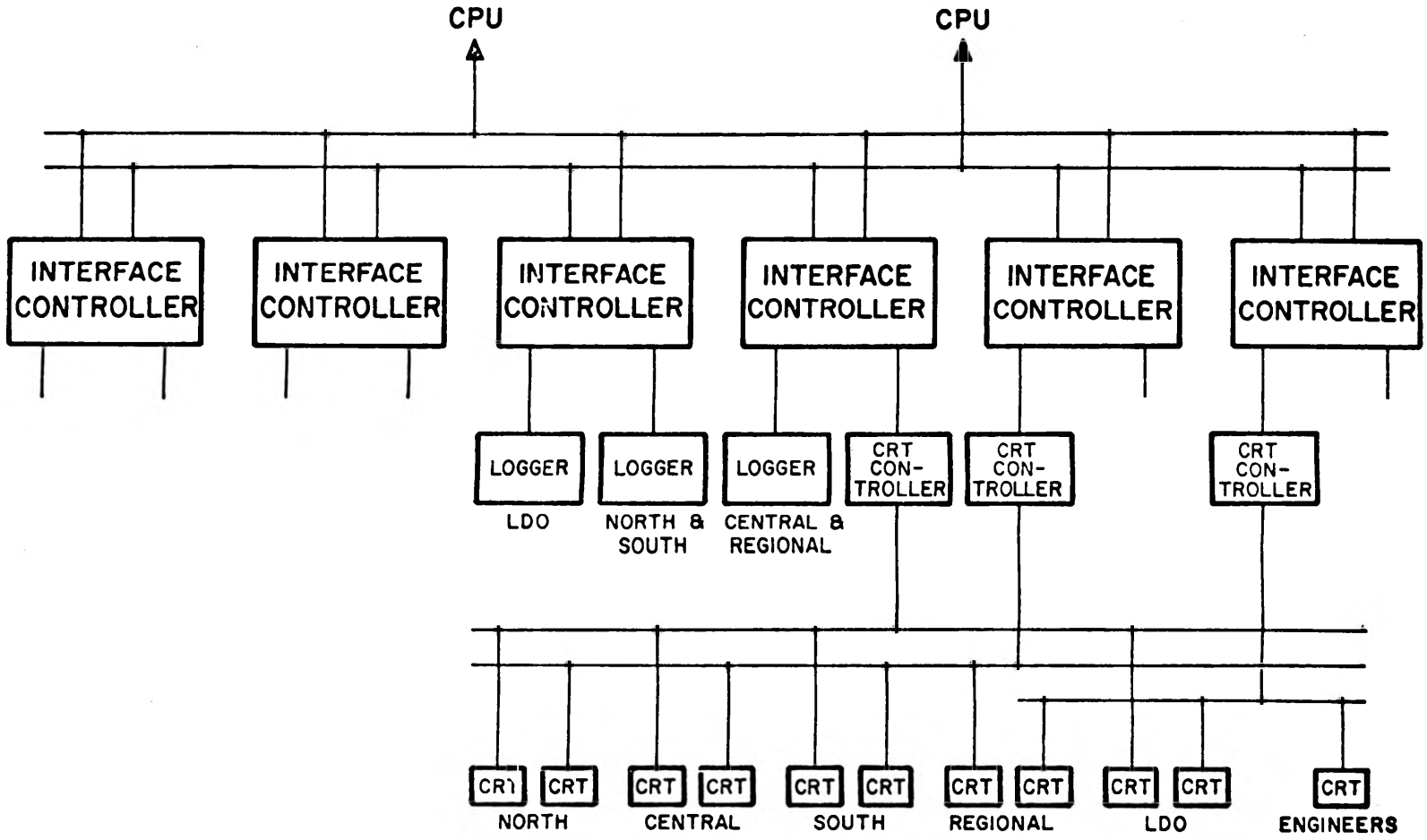


SYSTEM OVERVIEW



INTERFACE & CHANNEL REDUNDANCY


SIX FLAGS
PACIFIC
FUTURE
POND
BELL CO. CENTRAL OFFICE
FUTURE
ELLISVILLE
INITIALLY 37 GROUPS
MASTER TERMINAL



MAN/MACHINE INTERFACE HARDWARE