Operational Extensions to a Power Distribution Design Workstation for Enhanced Emergency Restoration

by

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(ABSTRACT)

A power distribution design engineering workstation is used as the basis for a restoration management system. The complete system contains three separate programs. The three programs are the Telephone Operator program, the additions to the design workstation, and the statistical collection program. The use of graphical interaction as a method of improving the restoration process will be presented. A method of contextual based editing is presented as an aid to the workstation based program. Records of the outages are kept by the system. The outage records are used to create statistical tables for the representation of each set of stored data.

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1.0 Introduction

1.1 The Restoration Problem

The economic and social effects of loss of electric service have significant impact on both the utility supplying electric energy and the end users of electric service. The effects of sustained loss of electric service to commercial and industrial customers can be measured in direct economic loss of production time and, for some industries, loss of material in process. For residential customers it is much more difficult to measure quantitative economic loss, however, adverse public opinion due to extensive outage duration can have a direct impact on the relation a utility has with it's residential customers.

Restoration of power is considered by regulating agencies when evaluating the utility as a supplier of electric service. The combination of regulatory review, loss of energy sales, and customer perception, provides the impetus for utilities to improve their restoration efforts. The ability for a utility to analyze and improve restoration is based on the current restoration methodology, available information, cost of improvements and ease of use of the new methods.

The availability of autonomous workstations with powerful computational, graphical and data storage capabilities provides a new method for enhancement of restoration of electric service. The design of the subject restoration program is based on the operational characteristics of a host workstation system, universal restoration requirements, availability of data, and improvement goals.

1.2 Major Requirements

Restoration is complicated by a number of factors. One of these is the size of distribution systems. Large metropolitan areas may contain over one hundred substations with one to ten separate circuits supplied by each substation. Location of outages based on customer calls and their relation to the supplying circuits is an extensive logistical problem. Fundamental to improved restoration is the access to, and manipulation of, large amounts of interrelated data. This data includes distribution system configuration, system fault protection, geographic information and customer location. Computerization of the restoration process provides for the effective manipulation of these types of data. The methods with which this data is stored, displayed and modeled determine the effectiveness of any computerized method.

A computer aid to restoration needs to provide the dispatcher with a variety of services. Location and extent of the power out is fundamental to the restoration process. Graphical depiction allows all of this data to be displayed in a manner that permits the dispatcher to assess the situation in a minimal amount of time. Information on outage location can be provided from a number of sources including crew scouting and Supervisory Control and Data Acquisition (SCADA) input. The use of SCADA among distribution systems is likely to increase, however in many current systems, outage data is derived primarily from customer calls. Full use of customer calls requires integration of customer information with circuit configuration and a method for making the customer information available in the proper format.

After location of an outage area has been made, the need exists to dispatch a crew to the location. A computer aid must have the ability to handle crew information in an effective manner. Proper management of crew services has an impact on factors such as operational safety as well.

Retention of outage information is currently required by regulating bodies. These records provide an indicator of a utility's ability to provide adequate and reliable service to customers. Significant effort is extended to maintain and analyze this information. The use of a computer based restoration system provides the opportunity to improve the accuracy of the records as well as reduce the labor involved in their retention.

1.3 The Workstation Environment

Current research at Virginia Polytechnic Institute and State University has produced an engineering workstation environment that has been primarily focused on the design and analysis of electric distribution systems. Much of the research effort has concentrated on the graphical display of the system and analysis of design parameters. Graphical interaction, including numerical entry, occurs with the use of a mouse pointing device. Operations such as status indication by use of color, zoom, pan, de-clutter, graphing and data base access are supported directly. Analytical functions such as fault current calculation, voltage constraint calculation and equipment capacity are available.

Information about the distribution system under study is permanently stored in data base tables. Initialization of the environment requires all system information to be loaded into the workstation active memory. This has significant bearing on the use of the environment as a restoration tool. The method of all data being placed in active RAM memory in the workstation eliminates disk access and permits graphical display and engineering analysis to occur within the time constraints of a real time system.

This requirement dictates that the models chosen be compact as possible and consistent with data structures within the workstation system.

2.0 Review of Literature

2.1 Areas of Interest

A major amount of the design effort in this type of system is in the area of information management. Much of the published material pertains to this aspect of the design. Several papers have also been published concerning the design of entire functional systems of similar purpose to the one being presented[1][2].

Other relevant research pertains to analysis of recommended switching and the determination of criteria on which the recommendations are made. The subject research will not deal with the methods used to make switching recommendations for restoration of power. This program is currently part of the design part of the workstation.

2.2 Connectivity of Data

Several recent trends in the utility industry have motivated research in the area of data connectivity. These authors view the utility data bases, on similar or dissimilar platforms, to be data objects which can be manipulated with the proper techniques. Three papers, briefly described, present the major focus of this viewpoint.

The first paper deals with the design factors integrating an existing AM/FM (Automated Mapping / Facilities Management) with an existing SCADA system[3]. The paper takes a close look at the hardware and software configurations necessary to complete the link with an adequate response time. The adopted methodology is based on the conversion and local storage of AM/FM data, and is not a direct connection method. The SCADA system consists of an extensive hardware network, including a VAX 3200 host computer. The results of this paper, although related, do not have direct bearing on the subject system, but do serve to demonstrate the complexity that intersystem interface can bring about.

The second paper deals with the connection of "Islands of Data" as a method of managing the increasing amount of information within the utility industry[4]. This philosophy does seem to have important application within the area of information management. The concept as applied to the restoration extension does not seem to provide any significant advantage and could cause performance degradation during peak access times to the mainframe computer.

The third paper culminates this process with a description of a complete distribution information management system[1]. The system as presented does meet a certain number of the goals of the restoration extension, in that system information is available graphically. Information access, response time, access peaking, hardware costs and configuration are not directly addressed in this paper. The main thrust of the paper deals with the application of the object oriented methodology of program development and maintenance. Object oriented methods are used, and will be presented, in the subject research.

2.3 A Restoration System.

One article of particular interest deals with the design of a computer based restoration system[2]. This paper presents a system that allows customer calls to be used in determining the location and extent of power outages. The system contains a telephone operator system and distribution dispatcher terminal. The system does not use a graphical interface and retention of outage records is not provided. The paper presents some of the problems associated with multiple outages within a single circuit. Hardware requirements are more extensive than for the system to be presented.

3.0 Materials and Methods

3.1 Hardware

The host workstation is an IBM 9371 that consists of two functionally separate units. The first is a unit that is capable of running the IBM VM mainframe operating system. Second, is a unit which is equivalent to an IBM PS/2 model 80 and has been configured to run the OS/2 operating system version 1.2, extended edition. The OS/2 unit has eight megabytes of RAM memory and 320 megabytes of fixed disk storage. Graphic display is on a color PS/2 monitor compatible with the VGA graphic standard. An IBM mouse pointing device is installed through the unit serial port. All development took place on the OS/2 unit.

The workstation program, including the restoration module, can be run on any system that supports OS/2. The hardware costs compared to other published systems are minimal.

3.2 Operating System and Software Development

3.2.1 OS/2 and Related Services

The OS/2 operating system is inherently multitasking and capable of concurrently executing independent programs on a priority based system[5]. Application programs can be designed to take advantage of a number of interprogram communication methods. Sixteen megabytes of RAM memory can be utilized by the operating system and virtual memory management is supported, allowing larger programs to be executed. The current version is 1.2 with an extended edition which includes a data base server and a communications manager. Presence of these features presents the system designer with a variety of application development tools.

OS/2 contains an internal Graphical User Interface (GUI) known as Presentation Manager. Application programs can be developed to run using the Presentation Manager Interface. OS/2 and Presentation Manager functions are available to program developers through calls to a system library. This library can be linked before execution of the program or the linking can be dynamic and occur when the program is run.

The data base manager supports calls through Structured Query Language (SQL) queries that are embedded in the source code of the application. SQL is an ANSI standard data base language. Queries are prefixed in the source code by the EXEC SQL statement. All code from the prefix statement until the line delimiter is treated as a single SQL statement. The source code is then precompiled to convert the SQL statements into library calls of the host language. Included in precompilation is a process known as binding that makes the final executable file compatible with the current version of the data base tables. The resulting source code is then compiled and linked like any program in the specific host language.

Access to the data base is also provided through a Presentation Manager Application known as Query Manager. The Query Manager system provides data base interface services that include table design, report functions, menu support, a variable configuration environment, and a procedure language. The procedure language is designed to provide a method of producing applications entirely within the Query Manager Program.

3.2.2 CGI Graphics

The host engineering workstation does not use the Presentation Manager interface. Graphics for the system are generated with the Computer Graphics Interface system (CGI). CGI is an ANSI standard system that includes a variety of graphical constructs based on a virtual screen system. The graphical objects supported by CGI are basic geometric shapes (such as lines and arcs), text, and color control. The workstation graphics represents significant effort in creation of the routines needed to display distribution circuits. Within the restoration system graphical routines are handled by calls to functions that were developed under the design aspect of the workstation.

3.2.3 Programming Language

All source code for the workstation design program and the restoration extension is written in the C Programming language. The IBM SQL precompiler, IBM C/2 compiler, IBM Linker and associated utilities are used to create the executable file. Many of the routine functions needed for both the normal workstation operation and the restoration extension are available as C function calls.

3.3 The Workstation Memory Models

3.3.1 The Circuit Model

The workstation is based on the concept of having the entire model of the subject system stored in system memory for all design functions. With this amount of data in active memory, data structure manipulation is a primary concern. A feature of the C language which has significant impact on this problem is the pointer. The pointer is a variable that holds the address of a data element. Pointers permit the construction of linked lists of data elements in the computer memory[6]. In the workstation, the pointers are links to data objects. This provides the inheritance feature of object oriented programming methods and allows all routines to share circuit information.

Due to the large number of devices used in power distribution, modeling methods have direct impact on the ability to perform engineering analysis. Use of the linked list allows the system interconnections and the equipment parameters to be directly available for analysis without any type of search algorithm. Intrinsic in the graphical creation of the circuits is the creation of the linked lists. The memory model of the workstation links together the circuit sources and the components of each circuit. In this way it is possible to trace from circuit to circuit, through an individual circuit, or through a particular branch of a circuit. An example of a search through a branch of a circuit that has direct impact on the subject program, would be a forward trace of all components down line from a protective device. The links provided that pertain to component traces involved in restoration are forward pointers, backward pointers, feeder path pointers, and brother pointers. For this reason, each component data object is known as a "trace" structure.

The brother pointer is used in tracing out of a branch in a circuit. Figure 3.3.1 shows the use of the brother pointer in a branch trace. Starting at a branch, the forward trace has covered all components in a branch when the trace reaches the component pointed to by the brother pointer.

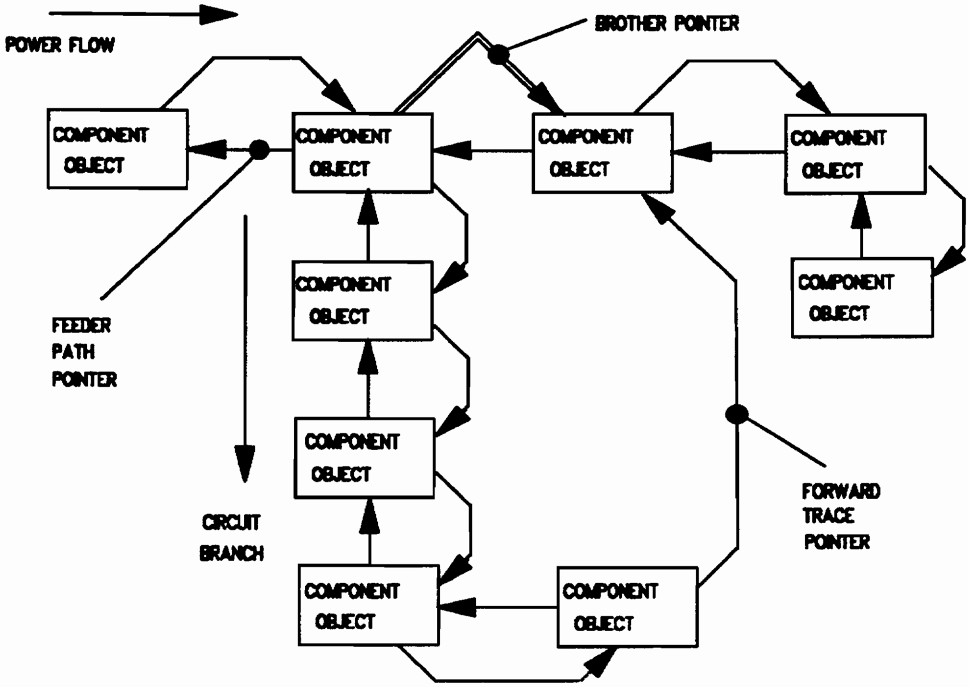

Figure 3.3.1 - Pointer Linked List for Component Objects

The restoration extension makes use of trace algorithms created for the specific functions as needed. These trace functions are needed to set attributes related to the groups, crew assignment and component color. Table 3.3.1 lists the elements in the trace structure that are related to the restoration extension. Each trace structure allocates 2048 bytes of memory and contains 198 data elements, including pointers to other structures. Due to the size of the trace structure, only the elements which affect the restoration extension are listed.

Table 3.3.1 - Trace Structure Elements Which Pertain to the Restoration Extension.

Element Name	Data Type
(Workstation Intrinsic Elements)	
Component Number	Short Integer
Circuit Number	Short Integer
Type Number	Short Integer
Forward Pointer	Pointer
Backward Pointer	Pointer
Brother Pointer	Pointer
Feeder Path Pointer	Pointer
Repair Time	Floating Point
.	
.	
.	
(Elements Added for Restoration Extension)	
Group Pointer	Pointer
Crew Pointer	Pointer
Number of Failures	Short Array by Weather Type
Component Color	Short
Number of Customers	Short Array by Customer Type
Failed Component Flag	Short Integer
Lost Power Flag	Short Integer
Highlight Flag	Short Integer
Number of Calls	Short Integer
Absolute Component Index	Long Integer
Preswitching Component Number	Short Integer
Preswtiching Circuit Number	Short Integer

3.3.2 The Group Model

The Restoration Extension has added several new models to the workstation. Group modeling is the most basic to the restoration process. The group model captures data on the group location, group size, number of customers affected, and logistic information needed to analyze the restoration process. In addition to analysis, the group model provides for the retention of outage records to meet the requirements of regulating agencies. The memory image of the group model is presented in Table 3.3.2.

A primary concern in evaluating the effect of outages is the number of customers who have lost power. Beyond the simple concept of number of customers is the economic impact of outage based on the type of customer. Industrial and commercial customers can measure the loss of revenue or product directly in dollar amounts. The economic value of loss of power to residential customers is more difficult to measure. Subjective criteria are used in many cases to measure this impact[7]. Based on the need to model this type of data, the group model includes the number of customers outaged by type. This type is either residential, commercial, or industrial. To provide a measure for the effectiveness of restoration switching, a maximum number of customers outaged for the group is also recorded. This is used to determine how many times partial restoration of power is accomplished by switching for outage groups.

In order to retain records needed for reliability analysis the group contains data for cause, failed component type, weather condition, location and circuit number. Type of component is saved to determine the reliability indices of individual types of equipment. Location information will aid in the isolation of area specific problems such as tree conditions. This information is transferred to a table in the data base as each group is released in memory. The Outage Statistics program as described in section 3.3.6 makes use of this data. In addition, the failed component flag and repair time are stored in the trace structure for use by the workstation intrinsic functions.

A part of the model also includes the number of callers for each group. This type of data will allow the study of resource allocation for Telephone Operators. This could include the number of Operator terminals and the number of Operators on duty during outages.

All of the previously mentioned group data is linked with the duration of the outage and the time of day the outage occurs. The time off and time on are stored in seconds as long integers[8]. This permits simple integer arithmetic to determine the length of outages. Because the times can be converted to absolute year, month, day, hour, minute and second, the time of day factors are also modeled.

A unique identification number is assigned to each group to allow the linking of the group with any crew or crews assigned during repair. The link with the crew model, the group linked list, and the location pointers are all compatible with the workstations other models.

Table 3.3.2 - Group Structure Active Memory Image

Element Name	Data Type
Group Identification	Long Integer
Time Power Restored	Long Integer
Group Release Status	Short Integer
Group Order	Short Integer
Group Confirmed Flag	Short Integer
Group Assigned Flag	Short Integer
Number of Calls	Short Integer
Call Back Flag	Short Integer
Call Back Result Flag	Short Integer
Number of Customers	Short Array by Customer Type
Maximum Number of Customers	Short Array by Customer Type
Number of Components	Short Integer
Maximum Number of Components	Short Integer
Protective Device Location	Pointer
Crew Location	Pointer
Next Group in Memory	Pointer
Previous Group in Memory	Pointer

3.3.3 The Crew Model

The ability to make effective use of the crew resource is the major factor in successful restoration. A crew model has been designed to record crew times, associated group, and status. Table 3.3.3 is the memory image of the crew model.

As with the group model, crew times are recorded as integers indicating the number of seconds elapsed since an absolute time reference. This permits the same type of integer math calculations as used in the group model.

Four times are recorded for each crew. The descriptions of these data fields are provided in the following paragraphs.

Time Available - When calls are received indicating the start of a restoration cycle, the dispatcher can show crews as being available for restoration work. When the selection of a crew is made from the menu provided, the time is recorded. This is the time available data field for this crew. Once a crew has completed all activities concerning a particular outage, the time available is reset to the current time.

Time Assigned - When the decision has been made as to where the crew will be working, the dispatcher will place the crew at a certain group. In combination with the time available, the amount of time a crew is idle waiting assignment can be modeled. Assignment time will give a measure of how well the workstation interface supplies the Dispatcher with the information necessary to assign crews.

In addition, this data can be used as part of the overall restoration crew model.

Power On Time - This time is associated with the time radio contact is made with the crew stating that the power has been restored to a certain group. Taken with the assigned time, the repair time is recorded. This repair information is also stored as input to the reliability analysis algorithm.

Release time - By providing a method for release time the crew model takes into account any time a crew may stay at a site after the power has been restored. The term crew latency is used to describe this factor. Latency can be a significant amount of the total crew time under certain circumstances. In most cases this is due to a situation that is unsafe without a crew at the site and involves additional repair time.

Table 3.3.3 - Crew Model Data Image

Element Name	Data Type
Crew Name	Character String
Crew Description	Character String
Crew Release Status	Short Integer
Crew Order	Short Integer
Crew Type	Short Integer
Crew Assigned Flag	Short Integer
On Duty Flag	Short Integer
Time Available	Long Integer
Time Assigned	Long Integer
Time Power Restored	Long Integer
Time Crew Released	Long Integer
Crew Location	Pointer
Group Location	Pointer
Next Crew in Memory	Pointer
Previous Crew in Memory	Pointer

3.3.4 Customer Information Model

The Customer Information System (CIS) is a table down loaded from the mainframe records of the host utility. These records provide the data necessary to identify and locate a customer. The information is taken from the billing information image in the utilities records. The data image is shown in Table 3.3.4. In the local utility's main frame system, all character data is down loaded as fixed length strings. Each string has a length the same as the maximum number of characters for that particular field. A large number of spaces would have to be stored in the workstation CIS table if fixed length strings were used. To reduce table storage requirements, the data base allows the use of variable length strings. When a variable length string is stored, a four byte length field is included at the start of each string location to record the number of characters in the string[9].

The use of variable length strings in the workstation CIS tables saves significant hard disk space as calculated in equations 3.3.1 and 3.3.2. The mean length of the variable length strings is based on a random sample of customer records from a local utility [10]. These total storage figures are for a local utility division office with about 65,000 meter locations.

Equation 3.3.1

$$\text{Number of Customers} * (\Sigma \text{ Maximum Field Lengths} + \Sigma \text{ Integer Field Bytes}) = \text{Total Storage in Bytes} = 8.98 \times 10^6 \text{Bytes}$$

Equation 3.3.2

$$\text{Number of Customers} * (\Sigma \text{ Fixed Length Fields} + \Sigma(\text{Variable Length Field} + 4) + \Sigma \text{ Integer Field Bytes}) = \text{Total Storage in Bytes} = 6.56 \times 10^6 \text{Bytes}$$

Table 3.3.4 - Customer Information System Data Image

Field Name	Field Length in Host	Mean Length in Host	Type in Workstation
Name	30	15.99	30 VLS
House Number	6	1.68	6 VLS
Street Name	30	10.43	30 VLS
City and State	20	11.21	20 VLS
Zip code	5	5.00	5 FLS
Telephone Num.	10	3.02	10 VLS
Account Num.	9	9.00	9 FLS
Rural Route	10	6.94	10 VLS
Additional Data	10	1.93	10 VLS
Component Number	N/A	N/A	1 INT
Circuit Number	N/A	N/A	1 INT
Component Index	N/A	N/A	1 INT

Note: FLS = Fixed Length String
INT = Short Integer
N/A = Not Applicable
VLS= Variable Length String

3.3.5 Customer Caller Model

A list is maintained of all customers who call to report power lost conditions. The data image of these records is the Customer Caller Model. The model allows for the entry of all CIS information; time variables directly effecting the customer and restoration process; links to the crew and group models; and flags used in determining the customer status.

The copying of all of the CIS information makes available the name and address of customers for access by the dispatcher. Address information is frequently needed during the restoration, particularly in emergency situations such as fire. The account number provides a convenient unique index for the customer in order to test for repeat callers. The data image is shown in Table 3.3.5.

The time variables retained provide a method for estimating the power out time of the group with which they become associated. When a group is created the caller list for that group is searched for the minimum first call time. This figure is used to estimate the time the group lost power. Last call time and number of calls are two variables added to help provide feedback to frequent repeat callers. This is important during outages of long duration.

In addition to the last call time and the number of calls, the links with the crew and group models provide further feedback to repeat callers. The Operators will be able to tell a repeat caller that their outage has a crew assigned and what time the crew was assigned to their outage.

Determination of the status of the customer occurs through the use of two flags. A single customer flag is provided to help reduce the possibility of an entire line section being considered as having lost power when a problem exists for only one customer.

Table 3.3.5 - Caller List File Date Base Image

Field Name	Field Type in Workstation
Name	30 VLS
House Number	6 VLS
Street Name	30 VLS
City and State	20 VLS
Zip Code	5 FLS
Telephone Number	10 VLS
Account Number	9 FLS
Rural Route	10 VLS
Additional Data	10 VLS
Component Number	1 INT
Circuit Number	1 INT
Problem Type	1 FLS
First Call Time	1 DTS
Last Call Time	1 DTS
Call Back Flag	1 FLS
Call Back Result	1 FLS
Group Number	1 INT
Crew Number	1 INT
Manually Entered Record	1 FLS
Scan Flag	1 FLS
Number of Calls by Customer	1 FLS

Note: DTS = Database Time Stamp

3.3.6 Outage Statistics Modeling

A primary objective of this project is to provide for the collection of outage statistics for use in analysis of the restoration process. This effort is broken into three areas.

First, the workstation itself was designed to use four outage indices; CAIFI, SAIFI, CAIDI and SAIDI [11]. These are industry standard methods for measuring system reliability. The data on which these indices are based are updated automatically by the restoration extension. An intrinsic program is in place as part of the original workstation programming to take the component and circuit failures and covert them into the CAIFI, SAIFI, CAIDI and SAIDI indices. The workstation was originally intended to down load this information from utility outage records. However, with the addition of the restoration extension, the workstation itself is generating this information.

Second, all crew and group activity records are archived by the program. These records form the basis for the retention of outage information as required by the regulating agencies. The group and crew records are linked by a unique group identification number and the crew name. The location, type of failure, cause, outage time, repair time and all other information on the outage is recorded. This data is stored in the archive file until the up load to the mainframe computer or storage on a backup system, such as a tape drive.

Third, records are kept for each outage cycle. This includes overall records based on the global parameters such as number of groups, number of crew assignments and cycle length. Records are also collected based on the models for the crews and groups. Records of this type are archived as with the outage group records. In addition, a data base table is maintained to provide a condensed version of the data used for analysis inside the workstation. Due to the number of records, it would be physically impossible to store all of the data concerning the outages over long periods of time. A system was developed that updates these cycle records during the archive process. The data stored in a statistics table has three types of data fields. First, is a single field which is the total count of samples added to the tables. Second, is a histogram of the data broken into 24 single hour fields. And third is the first six moments of the data about the origin.

The condensed data tables serve several purposes. The data is in a form for which many types of analysis can be performed. Table size for this condensed format is not a prohibiting factor as far as the workstation environment is concerned. Histograms of data such as overall repair times, repair time for particular types of equipment, switch operation times and any other type of data the system designer may need can be easily presented. An advantage of this type of system over the standard outage indices is, the CAIFI, SAIFI, CAIDI and SAIDI indices are all based on averages, where as with this type of storage the distribution of the data is represented.

The histogram of the data was included to provide the ability to make graphical displays of the information to the designer. Other methods were considered for storage of the distribution data. A method based on cumulents was investigated due to the success of the method in storing power plant availability data [12]. In this method, the cumulative probability functions are approximated by the Gram-Charlier expansion of the stored cumulents. This method has the advantage that once the normalized cumulents are calculated, the CDFs can be convolved by addition of the cumulents. This is a simple and fast method, and can be applied to density functions.

The method was tested on restoration times, which listed lightning as the cause over a five year period, as supplied by a local utility [13]. The hand calculations showed very poor results. The method was abandoned due to the nature of the data which is being represented. The Gram-Charlier expansion, as well as other type A expansions, show poor behavior for densities which have skewness (β_1) and kurtosis (β_2) coefficients which are not close to zero [14]. As an example of this behavior, the expansion becomes non-unimodal for values of β_1 greater than 0.25. For other relatively small values of β_1 and β_2 the expansion can become either negative, non-unimodal or both. Convergence of the expansion by the addition of higher order cumulants is not assured. For this reason, it is not possible to calculate a closed form error term for poorly behaved distributions, in the sense of Gram-Charlier. The conclusion is the type A expansions are valid for only a very limited number of distributions[15]. As an alternative, the histogram method was chosen.

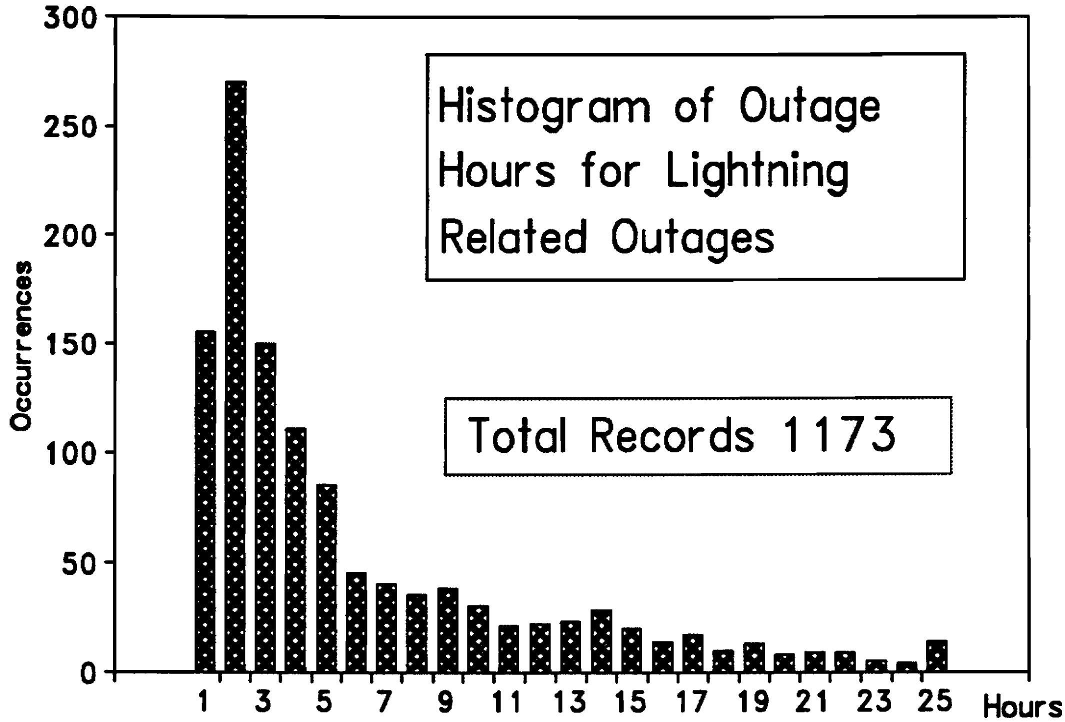

Figure 3.3.6.1 Typical Stored Histogram

3.4 The Workstation Environment

The workstation environment uses a pull down menu system to select all functions. The pull down menus are activated by picking "buttons" with the mouse which represent each functional division. The restoration extension functions all reside within one main menu button and are activated by the user by picking the Operations button and then picking on the submenu function. Figure 3.4.1 is a depiction of the workstation screen with the Operations menu pulled down. In cases where the restoration extension required modification to other menu selections, the new actions were made transparent to the user. The operations menu and changes to intrinsic workstation functions are discussed below.

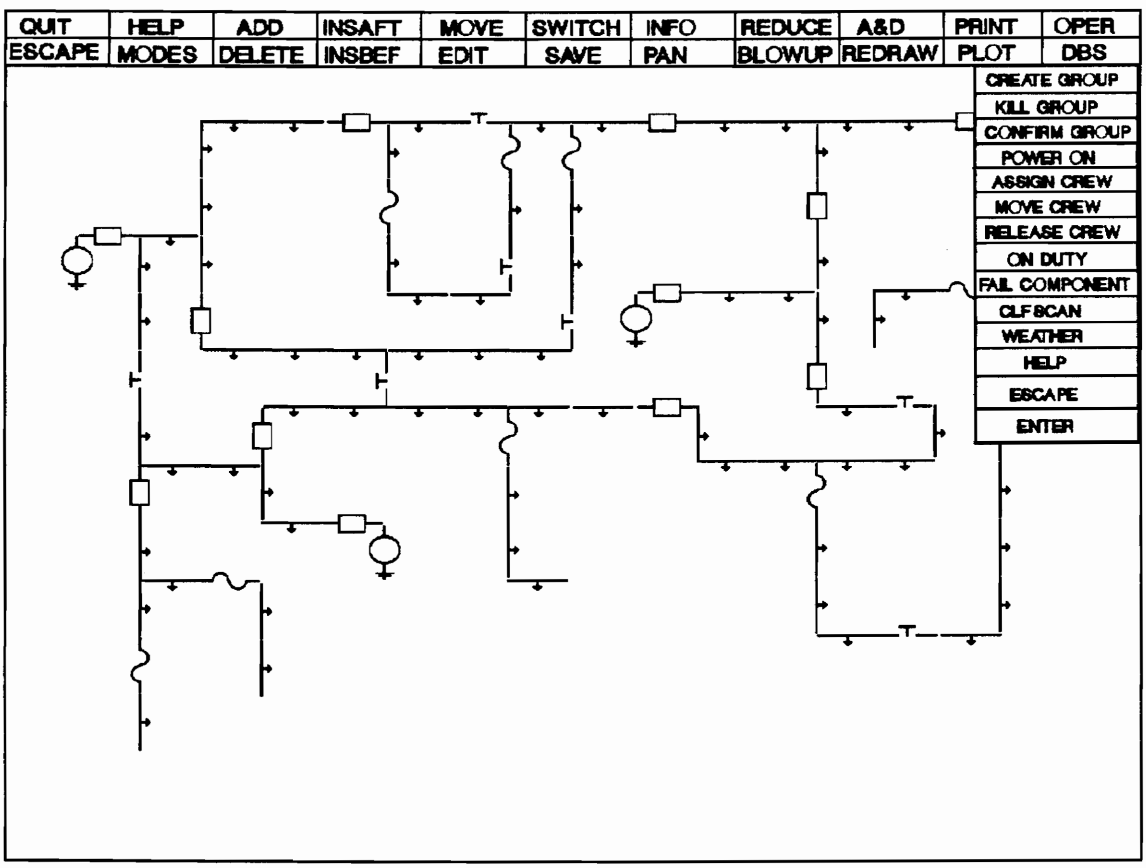

Figure 3.4.1 - Workstation Screen with Operations Menu

3.5 Program Operation

The entire restoration system actually consists of three separate programs. First, is the Telephone Operator Program, which will be referred to as the Operator Program, for the entry of caller information. Second, is the workstation program which includes the Operations Menu and the additions to the intrinsic workstation functions. And third, an Outage Statistics program that calculates data on the statistical models and archives the outage data.

3.5.1 Telephone Operator Program

In order to provide an interface for input of the customer calls, an Operator Program was provided. The Operator Program functions independently of the workstation environment and is an independent contribution of the restoration extension. This program was implemented with the procedure language of the data base interface, Query Manager. Query Manager provides for the construction and sequencing of panels used for the searching and input of data.

Development within Query Manager does not depend solely on language statements available within the procedure language. Control of the interface is provided through the configurability of panel menus, return values from callable queries and data transfer through global variables. The complete Operator Program took advantage of these features.

The main menu of the Operator Program provides three functions. First, is the searching of the Customer Information System (CIS) data, display of matching records, and entry of caller information. Second is the provision for the entry of manual customer records. Manual entry is required for callers who cannot be matched with CIS records. And third, call back verification of power restored. Call back verification is a procedure that contributes to improved outage statistics. Call back also provides feedback on possible equipment problems down line from the main isolating device, such as a failed distribution transformer.

Figure 3.4.1 and 3.4.2 shows the input screen used to search the CIS data base and the caller input screen used once a record is selected. All screens of the Operator Program provide a similar interface.

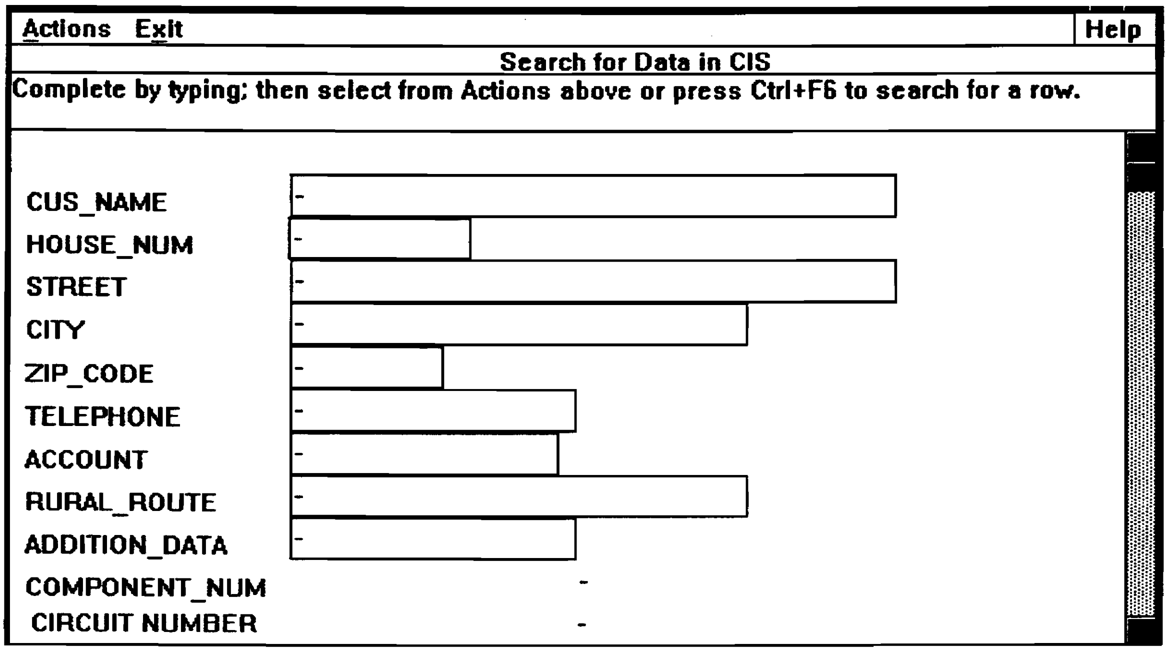

Figure 3.4.1 - Search Screen for CIS Information

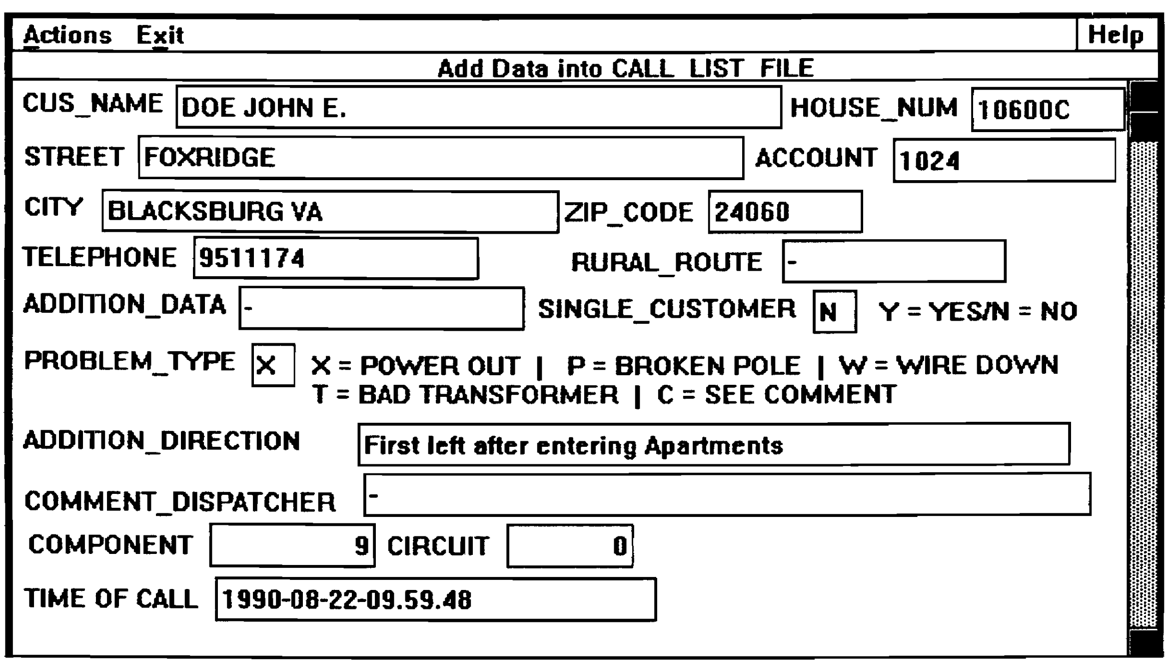

Figure 3.4.2 - Caller Information Input Screen

3.5.1 The Workstation Operations Menu

The following sections form a list of the Operations Menu functions and a description of the purpose and action of each. The primary thrust of the research effort is contained within the design of these functions and the data base actions that support them. The design of the Operations Menu included analyzing the number of functions needed, the layout of the functions, and the testing of the functions to assure they met specified criteria.

The first selection of the Operations Menu prompts two actions. First, the select weather function as described below is called. This assures the system has a valid weather variable to use during the writing of the outage information to the statistics tables. Second, the system sets an Operations Mode flag. This flag prevents data base update of CIS and CLF information during use of the workstation for system design. The operations mode flag suppresses these actions until the first access of the Operations Menu.

The primary extension design factor was to allow as much versatility to the system dispatcher as possible, without creating too large of a list of functions to choose from. This was accomplished by incorporating a system of implicit editing, which will be described during the explanation of the individual functions. Implicit editing is an unique concept to the restoration extension.

3.5.2.1 Create Group

The create group function is the start of the restoration process as far as the data structures in the memory model are concerned. After selecting this function the dispatcher will make a graphical pick of a protective device by "clicking" the location with the mouse. Error checking is incorporated to exclude picks of components that are not protective devices, and devices which currently hold a group. The dispatcher makes his selection based on the location of components that have been marked as having lost power by a link with a customer call. The CLF Scan function completes this task and is described below.

Several actions take place internal to the Create Group function. A down line trace is performed to mark all down line components as lost power and to accumulate in the group structure the number of components, number of customers, and number of callers. Concurrent to this process, all customer caller records are updated with the group order number in order to establish the link for the call back verification and to provide feedback to return callers about the progress of their restoration.

During the down line trace, if any open switch is encountered, the Dispatcher will be prompted if to include the components down line from the open switch into the group that is being created. This allows the Dispatcher to either increase the scope of a group, or have one group interior to another. Figure 3.5.1 shows the application of this concept. Intuitive editing is the term that is applied to this type of interaction.

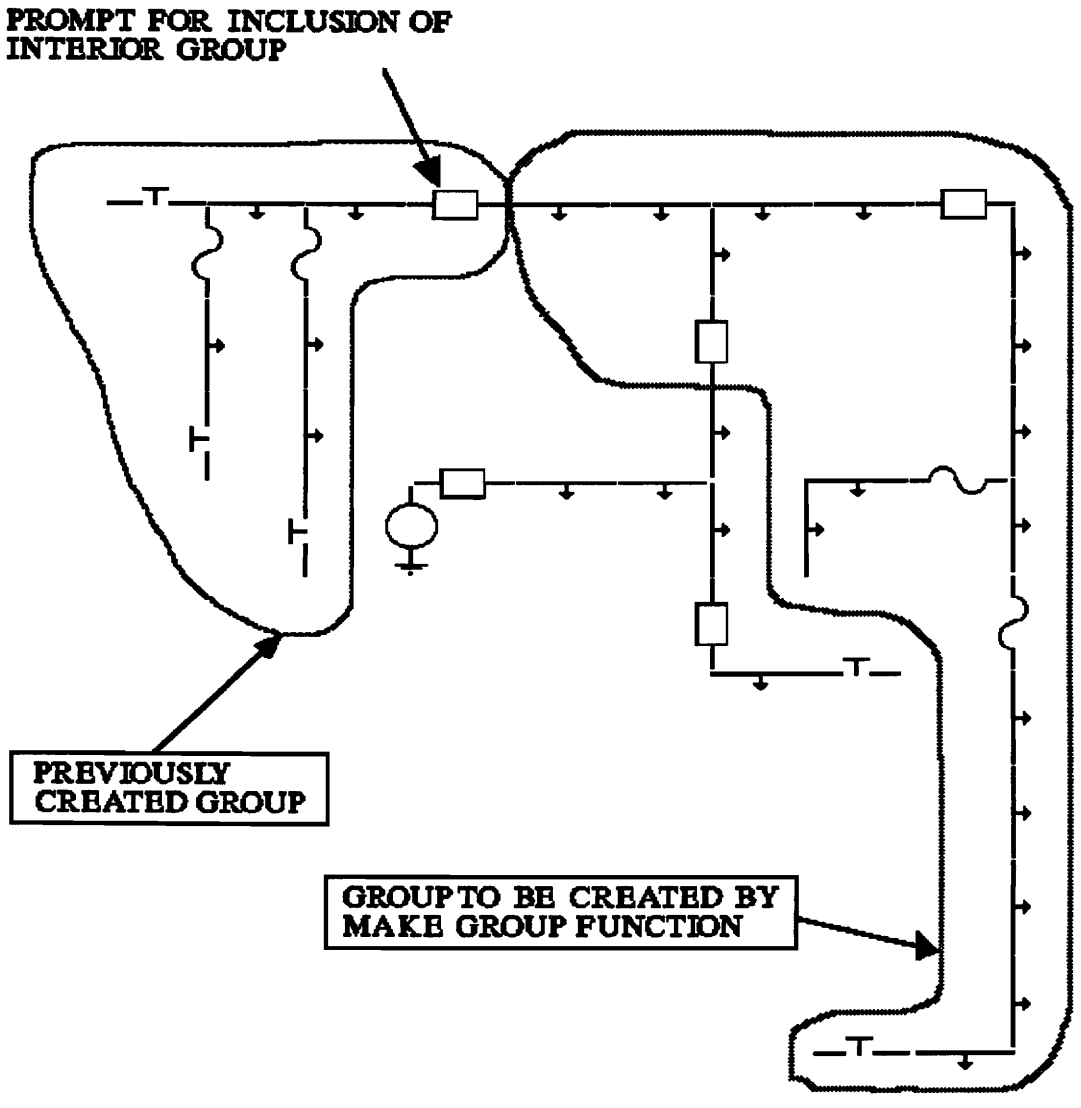

Figure - 3.5.1 Make Group Function and Editing

3.5.2.2 Kill Group Module

The first purpose of kill group is to correct graphical picks of protective devices that were made in error. Any time before the group is confirmed, the Dispatcher may kill the group.

Second, the kill group plays a part in the intuitive editing scheme. The group to be killed may be isolated, exterior to a group, or interior to a group. When an isolated group is selected, the group is shown power on and no statistics are accumulated. By killing an interior group, the components in the killed group are included in the exterior group. Killing of an interior group, in effect, concatenates the two groups.

Selection of an exterior group with the Kill Group function is similar in philosophy to the intrinsic editing used in the Create Group function. If an open switch is encountered in the forward trace, the Dispatcher is prompted if to create a new group with all components down line from the open switch. This permits the splitting of a group into two or more groups, and the reduction in the scope of a group as needed. Figure 3.5.2 demonstrates the kill group intuitive editing scheme.

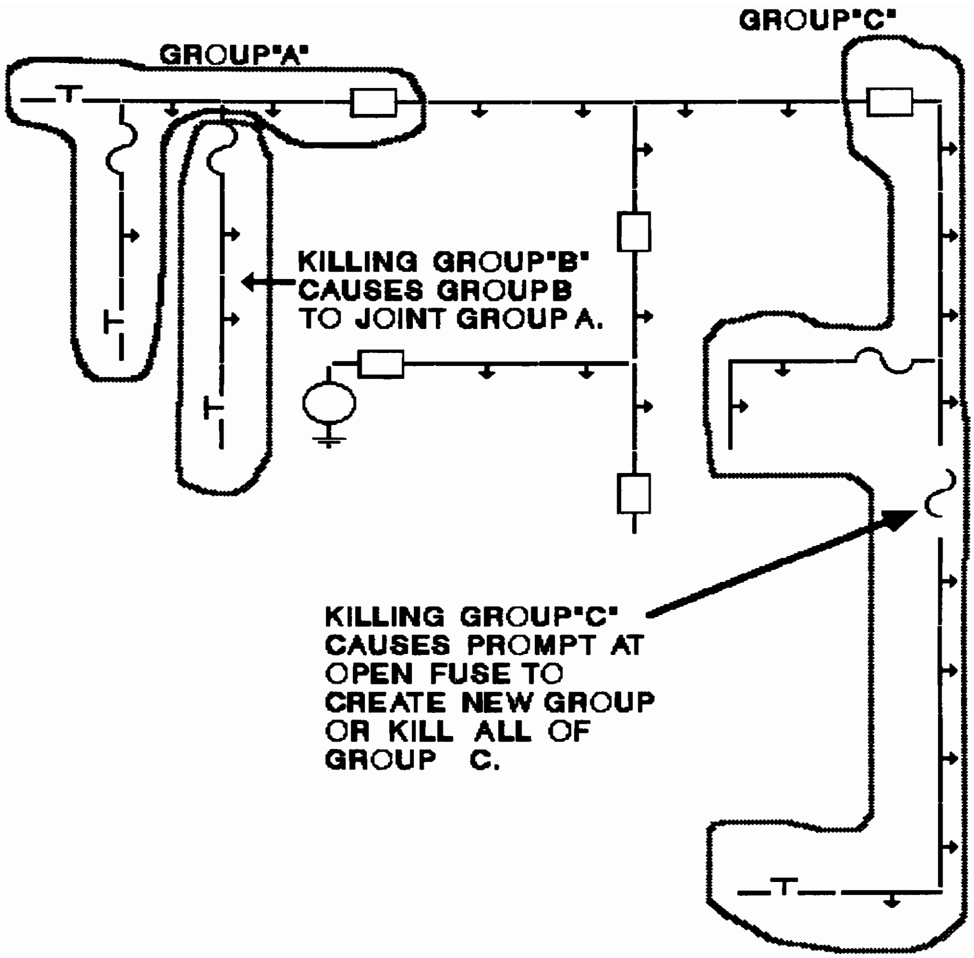

Figure 3.5.2 - Kill Group and Editing

3.5.2.3 Confirm Group

Collected data must be accurate for generation of the outage statistics and in order to provide necessary input to a restoration algorithm. In order to provide for the location of the failed component and assure accurate entry of the cause of the outage, the Dispatcher will pick the failed component within the group after receiving a radio report from the crew. Two tasks can be completed with one selection using this method. One, the location of the protective device that has operated is now confirmed by the repair crew. Two, the location of the failed component is confirmed as well. After choosing Confirm Group from the menu, the Dispatcher will graphically pick the component within the group that the crew has reported as failed. A highlighting icon will remain on the component to show the failure location. Confirmed and unconfirmed groups will be displayed in different colors.

After the selection of the CLF Scan function, the Dispatcher is asked to "guess" at the location of the operated protective devices. Without a crew at the location, it is impossible for the Dispatcher to be certain of which protective device has operated and which component has failed. For this reason, the intrinsic editing was added. The intrinsic editing allows the Dispatcher to edit the group to match the field conditions as determined by the crews. Once the group is correct the Dispatcher can confirm the group on the workstation.

3.5.2.4 Power On

Picking on a device that holds a group after this menu selection will show the group as having the power restored. The action will initiate the customer call back process and start the collection of the group outage statistics. This function will close all open switches interior to the group and show all components as power on. This function will not override interior groups. In other words, if two protective devices holding groups are in series, any down line devices that are holding groups will not be shown as Power On.

The selection also serves a part in the collection of the crew statistics. At the time power on is selected, the dispatcher is prompted if to release the crew. If the crew is released, the crew statistics are recorded at that time. If the crew is not released, the latency time of the crew is started for the time the group is shown power on.

3.5.2.5 Assign Crew

Crews will be picked from a list of available crews that are on duty. This provides a uniform interface method and incorporates functions such as recording the time the crew was assigned automatically. When initially assigned, the crew is located at the protective device that holds the group, no matter where in the group the Dispatcher may pick. The need to prompt for the location of the failed component during confirmation is the reason for this restriction. New crews may be added to the list of crews by use of the data base manager.

Crews are represented on the workstation screen by icons. The icons contain a character to show the type of crew. A station crew would have an icon with the letter "S" in the center for example. The color of the icon shows the crew to be a company crew or a contract crew.

3.5.2.6 Move Crew

The Move Crew function allows for the assigned crew to be located at any component within a group. When the Dispatcher picks a component after this menu selection, the crew assigned to that group will be relocated. This method has the advantage of not requiring the crew to be selected from a list before relocation.

3.5.2.7 Release Crew

Crews may have to remain at a location for some amount of time after the power has been restored. Crew latency is the term used to describe this factor. When a crew reports power on, but remains at the site for clean up or other purposes, this function allows them to be released into the pool of available crews. The function can be used to release a crew before restoration for reassignment to a more important task.

3.5.2.8 On Duty

The On Duty function allows for crews in the crew list to be toggled on and off duty. Only unassigned crews will be displayed. This function automatically records the time the crew is placed On Duty for use in the crew statistics.

3.5.2.9 Caller List File Scan

This selection initiates the SQL queries needed to pull up all caller records from the Caller List file. As the records are pulled up the appropriate components are marked as power out. The Dispatcher runs this procedure to update the workstation screen with the calls as taken by the operator.

3.5.2.10 Weather

When the operations menu is selected for the first time, the Dispatcher is prompted to pick a weather type based on the IEEE weather types. This selection provides a method of changing the weather type.

3.5.2.11 Component Failed

In order to provide a method of marking which component has failed, the Component Failed function is supplied. This information is needed for collecting outage statistics specific to a particular device and provides a required input to a restoration analysis program. The confirm group function will mark components as failed, however this selection will allow toggling of the components for relocation or can be used in the case of multiple component failures.

3.5.2.12 The Intrinsic Switch Function

One major intrinsic main menu selection had to be altered in order to provide consistency with the Operations extension. This was the SWITCH function. When a switch on the system is closed, the possibility exists for components to be switched from a group to power on; from power on to a group; from one group to another; or between power on segments not effected by groups. When the switching involves groups, the program must maintain the proper data models. This modification is part of the workstation extension. All functions as implemented under the Operations Menu are supported as needed in the switch function. This includes proper display of components and the setting of call back flags.

3.5.3 The Outage Statistics Program

This program is an independent C program with embedded SQL. Command line execution of the program causes all archive tables to be updated with the new information. The histogram tables are also updated concurrently. The outage tables are cleaned to prepare for the next outage cycle.

Unless an error is generated by the program, there is no screen output. The user can access the tables with Query Manager to view the new information. Once the program is run the new histograms are available to the workstation program.

3.6 Program Construction

3.6.1 Operator Program

The Operator Program is presented to detail the operational configuration as determined by the subject research. Due to the recent introduction of this product, and the significant impact of the OS/2 operating system, the program as presented also serves as a model for others developing applications with Query Manager.

3.6.1.1 Query Manager Programming Objects.

Query Manager provides a set of objects for the creation of user applications. Because the programming objects are unique to the Query Manager System, a brief description is provided.

The user interface tools consist of panels and menus. Control flow is provided with procedures, written in the Query Manager procedure language, and with the use of local and global variables. Global variables are used for the passing of values between procedures. Queries complete the list of application tools. Query construction provides the means to test existence; count; find the maximum or minimum; insert; or modify table values. Each programming object is contained in it's own development panel in the Query Manager interface to permit rapid creation and editing.

In the procedure diagrams used to describe the construction of the Operator program, a unique flow charting system is used. The need for this type of flow charting is required by the ability of any panel, procedure or menu to call any other panel, procedure or menu. In addition, the menu actions of the panels can be redefined. This produces an event dependent, object oriented, program control. A procedure diagram is used to depict this object oriented, event driven interdependency[16].

A description of the Query Manager Objects is presented as follows:

Panels - Panels are definable screen forms that allow the entry of typed data. This data can then be used to add to data tables or search existing records in a table for a match to the entered data. Panels are extensively used throughout the program. The main mechanism for the Operator entry of data is by the use of panels.

Menus - Menus consist of programmer defined "Buttons" that are actuated by use of the mouse pointing device or the keyboard. The Operator program is controlled by the use of a menu screen. Using menu selections to drive the Operator Program reduces the need for continual prompts to determine the next function the Operator needs to perform. This follows the event driven philosophy of the Query Manager system in general.

Procedures - Procedures are a group of program lines based on the Query Manager procedure language which has a top-down structured format. These structures encompass the IF-THEN-ELSE and DO-UNTIL program control functions of most high level structured languages. Procedures are used for panel initialization when data fields need to be sorted or default values need to be set. Variables are supported in three ways by Query Manager for use in procedures. Local Variables are created by procedures for use during the life of the current procedure. Global variables can be generated that have a life during the entire Query Manager session. System Global variables have values that are maintained by the Query Manager System. System variables consist of the current time, current date, system version and return codes.

Queries - Queries are SQL statements, or the equivalent, that can be called by panels, menus, or procedures. Queries have the option of generating reports or suppressing the report. This suppression feature is used in conjunction with the return code, which is a System Global Variable set after every query, to test the existence of rows matching a certain criteria. Queries are also used to update tables based on Operator entries.

Due to the nature of the procedure language, reentry into a procedure module is not allowed. This requires a separate module for each procedure function. This accounts for the relatively large number of procedures written for this application.

3.6.1.2 The Main Menu

The Main Menu of the Operator Program provides three selections for the Operator. The Main Menu is started by selecting the Operator Program from a list of available menus in the menu area of the Query Manager Interface. In a production system a method exists for a command line program to be created to allow direct access to the Operator Program Main Menu without access to any other Query Manager functions. In addition, users may be requested to provide a password during sign on to the Operator Program. Query Manager provides a multiuser security system for restriction of certain users to individual applications.

The three sections of the Main Menu operate as independent program modules.

3.6.1.3 Caller Entry Program Module

The most extensive of the program modules is the Caller Entry System. The developed system is intended to provide a flexible and usable system to the Operator for entry of search data to find the caller in the CIS records. Once the caller is found the program provides as much default information as possible in the Caller Entry panel to reduce the amount of data entry to a minimum.

Several additional features are incorporated into the Caller Entry System. First, the system checks to see if the current caller has called previously. The number of return calls are kept for each caller. Second, the time of the first call and the time of the most recent call is retained by the system. The primary purpose of keeping the number of calls and last call time is to aid in answering customer complaints about the restoration process.

Figure 3.6.1.1 is a procedural chart of the actions of several of the programming objects as described above. When the program model is started the first action is to run the panel for searching the CIS records. Search data is entered and the panel will display the first records matching the search. The Operator will then have the option of entering new search data, viewing the next matching record, or selecting the record as an outage caller.

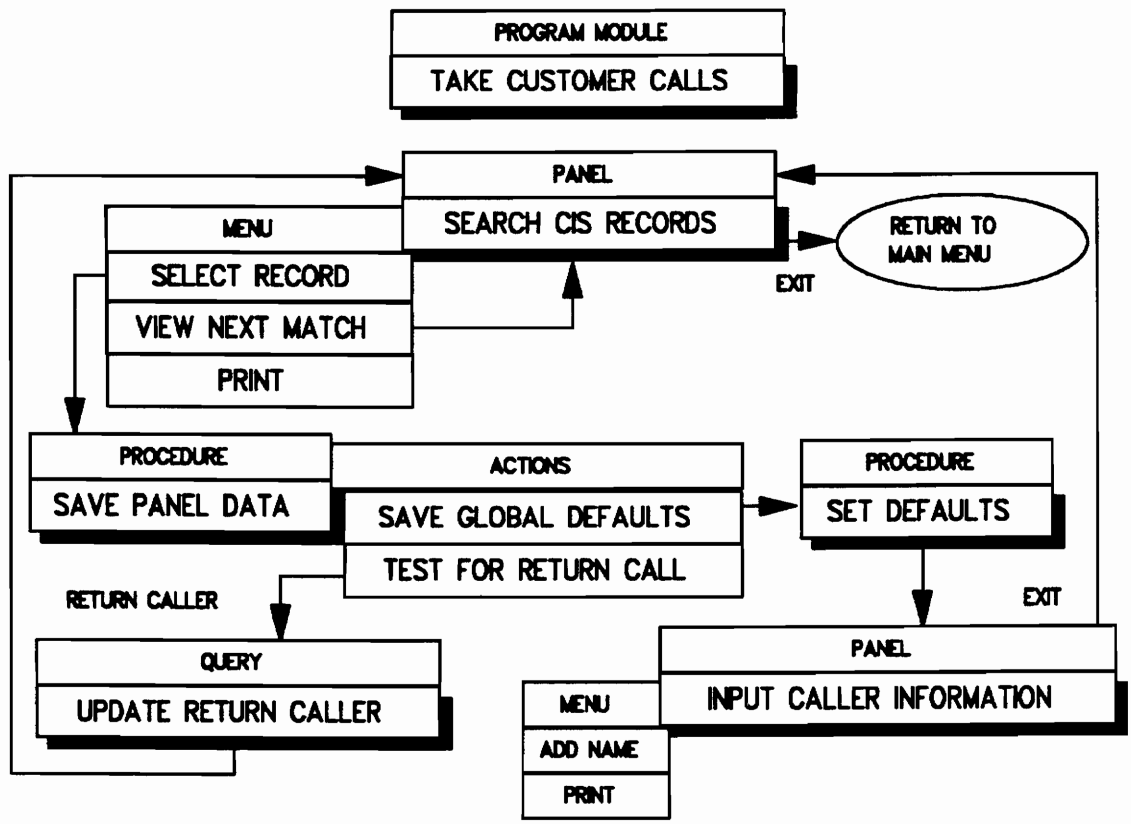

Figure 3.6.1.1 - Take Customer Calls Module

When a record is selected as an outaged customer, a procedure is run from the action menu of the panel. This procedure saves the caller information in global variables for initialization of the next panel. The procedure also runs a query of the current caller list to determine if the customer is a return caller. The procedure checks the return code from the query to determine if to treat the record as a new or return call. If the call is a repeat, then another query is run to update the caller record. If the record is a new caller, a procedure is run to initialize the panel for the input of the caller information and the panel is run. After the caller information is entered the Operator exits the input panel and returns to the search panel.

3.6.1.4 Enter Manual Record

The CIS records are maintained by periodic down loads from the utilities mainframe records. A possibility exists that a new customer's record may not be in the local CIS records. Another possibility is that the customer may not be able to convey to the Operator the information necessary to provide a match to the CIS record. In these cases, a manual entry panel is provided. This allows the entry of a caller for whom no match can be found in the CIS records. Figure 3.6.1.2 is the procedure diagram for this function.

The program module starts by calling a procedure that initializes the panel default values and runs the manual input panel. After the data is entered the procedure returns the Operator to the main menu. There will be no need to enter two manual records in a row, so the procedure returns to the main menu.

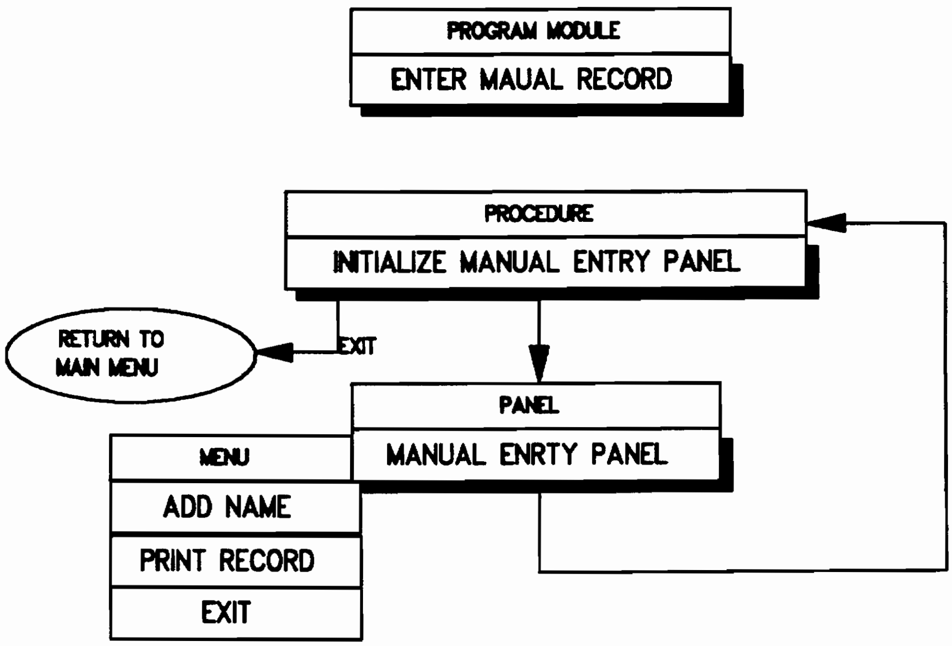

Figure 3.6.1.2 - Manual Record Input Procedure

3.6.1.5 Check for Call Backs

As shown in figure 3.6.1.3, the call back program module initially runs a query to determine if any call back records are in queue. These are records that have been graphically shown as power on from a graphical pick on the workstation by the Dispatcher. These records are updated in the CLF table by the restoration extension as power on picks are made. The initial query searches the CLF for customers pending a call back. If customer records are in the call back queue, the call back panel defaults are set and the panel is displayed.

If no call backs are in queue the program displays a message and returns to the main menu. The panel will continue to display call back records until the queue is empty or the operator exits the panel. Based on the response of the customers called back, flags used to determine the status of the callers are set. In the event that the call back report is negative, the customer record reenters the system as a power out condition.

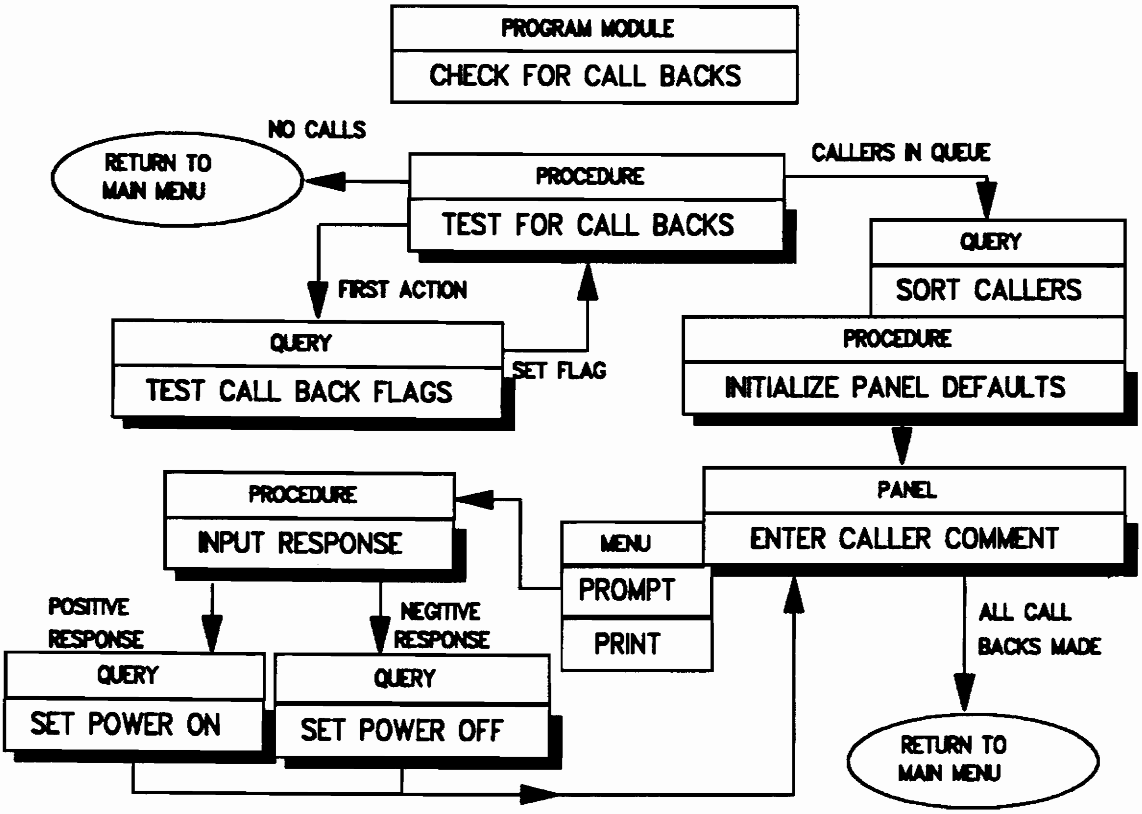

Figure 3.6.1.3 - Take Call Back Module

3.6.1.6 CIS Data Location

The CIS data is located within the workstation and is stored in a data base table. The calculation of table size in the CIS model section show this to be quite feasible. The "Island of Data" was avoided to reduce hardware costs, reduce program complexity, to prevent system shut down due to communications loss and to avoid poor response during peak mainframe access times[1][4].

3.6.2 The Workstation Program

The workstation program is constructed of program modules in a similar fashion to the Operator Program. Most of the program modules are called from menu selections under the Operations Menu. Several additions to the original workstation functions were necessary to maintain consistency with the Restoration Extension.

All major functions are described in the following sections. Flowcharts use standard flowchart notation and are intended to provide details of the logic of the program modules. The flowcharts are not intended to be an exact line for line representation of the code. The objects in the flow charts are linked to modules of code. The code is written in a style using long variable names, comments and formatting to allow anyone familiar with C to determine the intent of the functions. Some function calls are intrinsic to the workstation program and are commented as to their function. The source code for the intrinsic functions is not commented as to the operational links.

3.6.2.1 The Operations Menu

The basic function of the Operations Menu is to decode menu picks by the use of a case statement. Once the decoding is accomplished, the corresponding program module is called. Several compact functions are coded in the operations menu and are described below. In addition, all calls to the workstation graphical pick component routines are contained in the Operations Menu to provide for easy escape from an incorrectly selected function. Figure 3.6.2.1 is the flowchart of the operator program.

As an example of the use of the intrinsic routines, the On Duty selection of crews is coded entirely in the operations menu. The majority of the logic for this function is provided by the "modes" workstation function. This intrinsic function permits the toggling of menu selections with graphical picks. After all selections are toggled as desired, the Dispatcher picks the enter selection to start the menu actions. "Modes" returns a pointer to an array of the responses. This array is used to determine the crew status and the time the crew is placed on duty.

Weather condition selection is the only other program module contained in the operations menu coding. Again, the primary logic is provided by the intrinsic menu function "modes". A flag is passed to the modes function to configure the function to return the first picked menu selection, rather than the toggling type of menu as used for the On Duty selection.

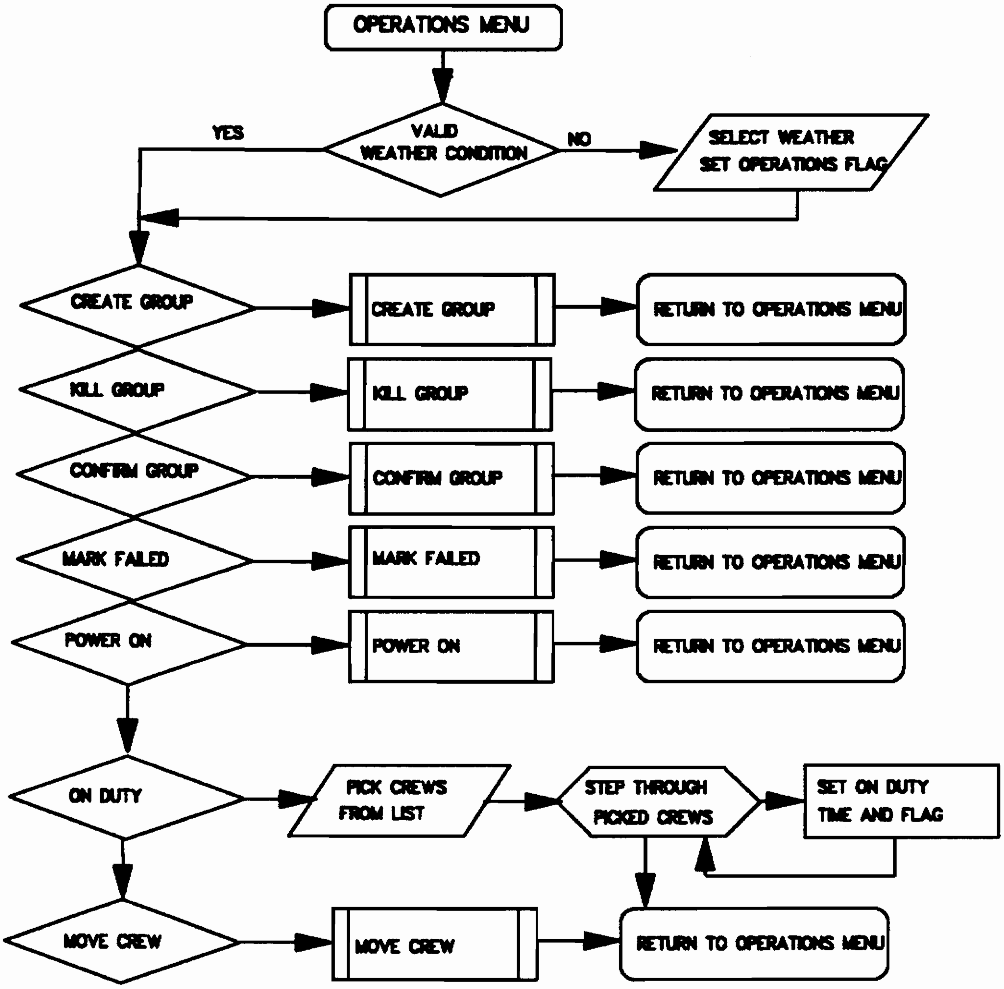

Figure 3.6.2.1 - Operation Menu Flowchart

The Confirm Group and the Fail Component selections are program modules, however both require the selection of a cause code for the component to be marked as failed. The "modes" function is again coded into the operations menu for selection of the cause code from a menu list.

3.6.2.2 Initialization

Initialization of the restoration is accomplished in three basic parts. First, the memory needed to store the group model is allocated. Second, the memory for the crew model is allocated. Third, the default crew information is loaded from the data base tables.

A temporary part of the initialization process is the assignment of an absolute index to each component. It was the addition of this variable that greatly simplified the update of the customer lists (CIS and CLF) under switching operations. The absolute index has been adopted by other researchers working on the design aspect of the workstation and is slated to become part of the intrinsic function of the workstation.

3.6.2.3 Creation of Groups

The Create Group function is the start of the collection of components into groups after power out has been marked by the CLF scan. Create Group is the first program module presented which demonstrates the forward trace methodology. After error checking, the module traces through the down line components. The circuit memory model, which was inherited from the workstation, permits these searches to be coded in a relatively small number of lines.

The module does check for open switches during the trace. When an open switch is encountered, the dispatcher is prompted if to include the interior group in the currently forming group. This is the intrinsic editing feature as described in the section on the operation of the workstation program. Figure 3.6.2.1 is the flowchart for the create group function.

3.6.2.4 Kill Group Module Construction

The Kill Group module has the most complex logic structure of all the program modules in terms of the use of the tracing of components. Three separate scenarios are possible with the Kill Group function. These are described in detail in the Kill Group section of the program operation section. See figure 3.6.2.3 for the flowchart of the kill group function.

The main complicating factor in the Kill Group Module is that the presence of open switches means the module must have the ability to create groups. Creation of the new groups is handled by the use of a "stack" of switch locations. The stack is internal to the Kill Group function, so that the memory is only allocated during the life of the Kill Group function. At the end of the routine the stack is checked for valid pointers to protective devices. If any are found, new groups are created at these locations. Customer records in the CLF table are updated by this routine.

3.6.2.5 Confirm Group Module

After initial error checking, the Confirm Group module steps through the group components to set the display color of the components. Interior groups are simply skipped over during this process. In addition, the circuit and group models are updated with the location of the failed component.

The test for an interior group, as shown in figure 3.6.2.4, is if the group pointer in the forward trace matches the group pointer at the start of the trace. If the group pointers do not match, the group is an interior group and is skipped.

3.6.2.6 Mark Failed Component

The selection of the Mark Failed component permits the toggling of a component as failed or not failed. The menu choice is included for two reasons. One is to allow the relocation of a failed component in a group. Two is for use of the workstation as a design tool. The flowchart for the mark failed component is shown in Figure 3.6.2.4.

During a design phase, the failed component function is used to fail components under several different system configurations. A reliability algorithm needs this information as input. The reliability program is run to determine the best system configuration among alternatives for certain failure locations. Because the same action is needed during restoration, the function is included here.

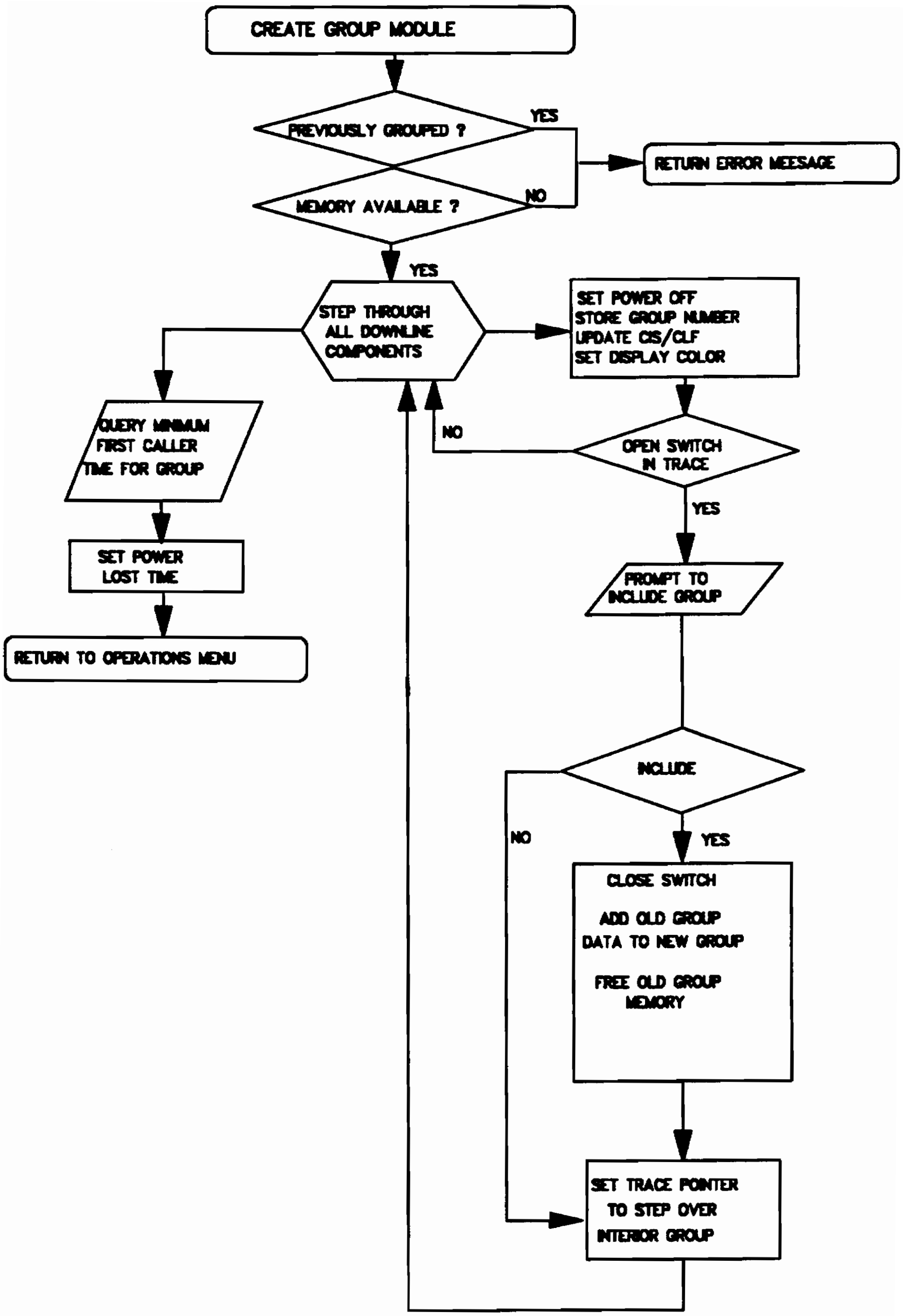

Figure 3.6.2.2 - Create Group Flowchart

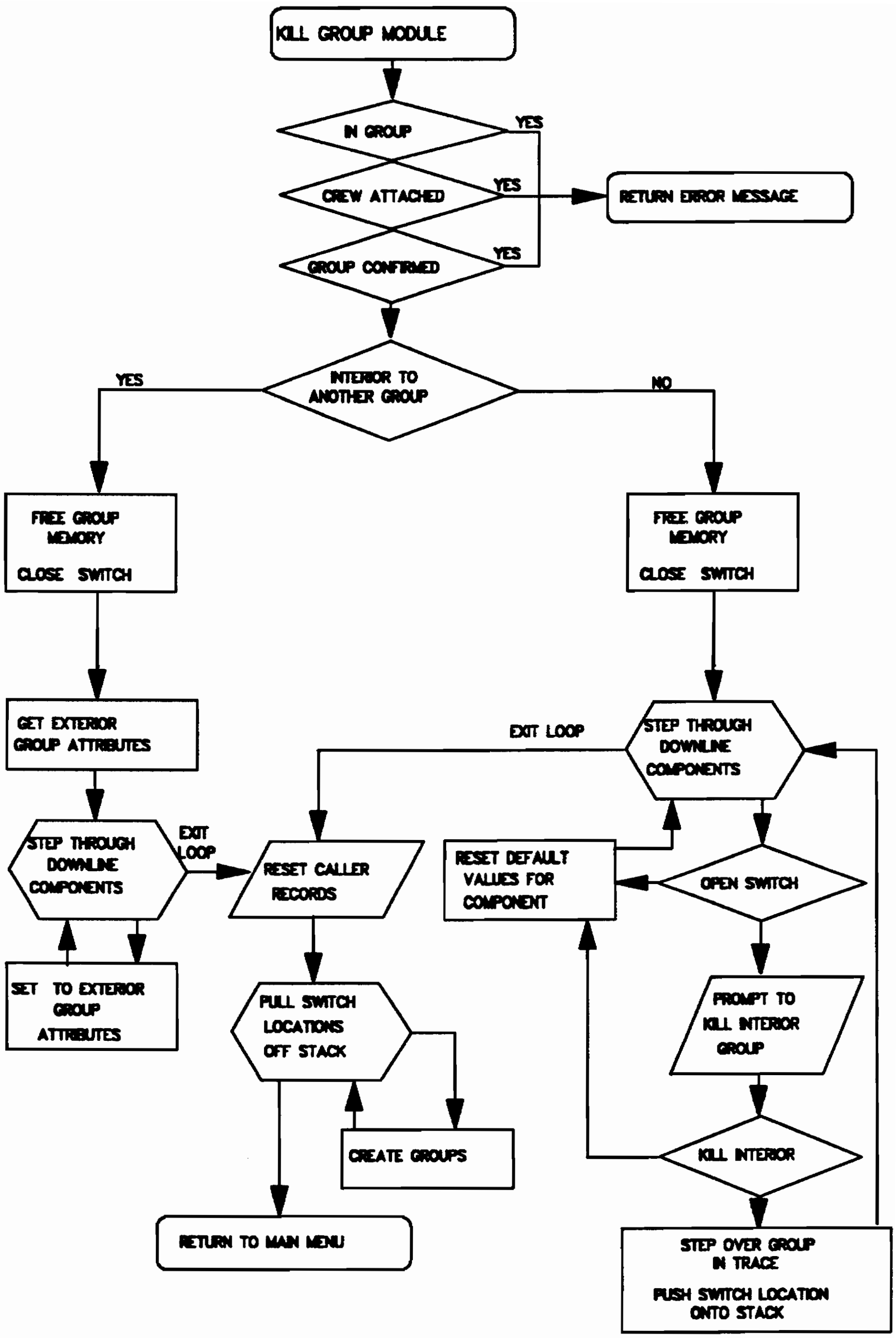

Figure 3.6.2.3 - Kill Group Flowchart

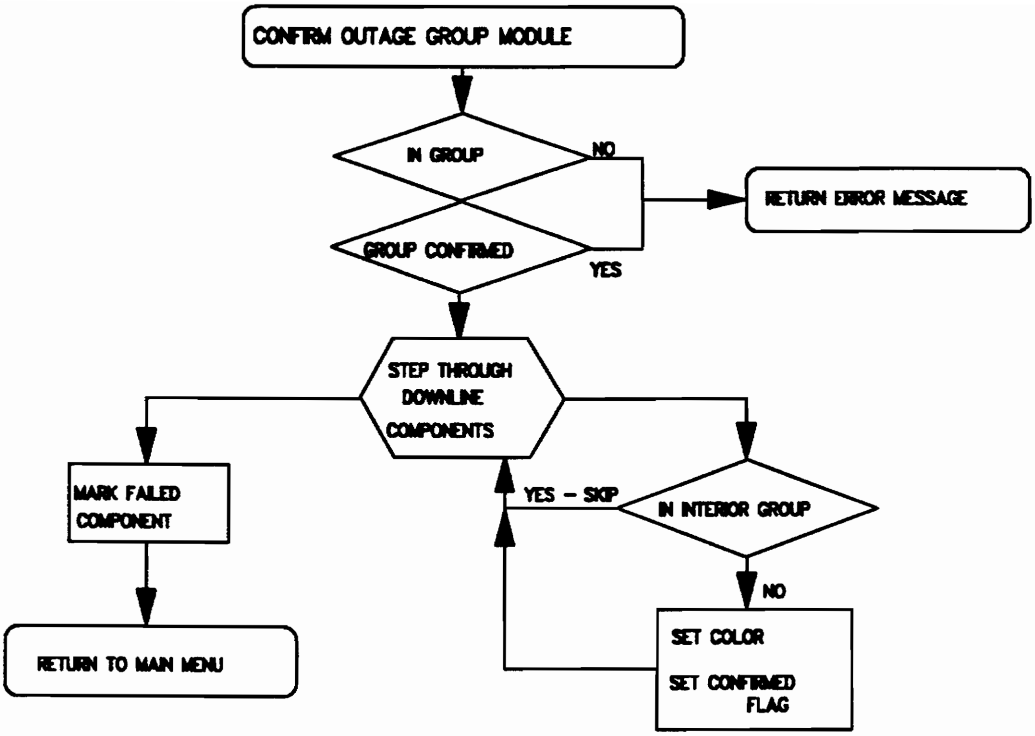

Figure 3.6.2.4 - Confirm Group Flowchart

3.6.2.7 Power On Module

The Operations Menu program passes the Power On Module the location of a component from a graphical pick. A check is made, as seen in Figure 3.6.2.5, to see if the component is part of a group. If not, an error is returned. After the choice to release the crew is made, the forward trace begins.

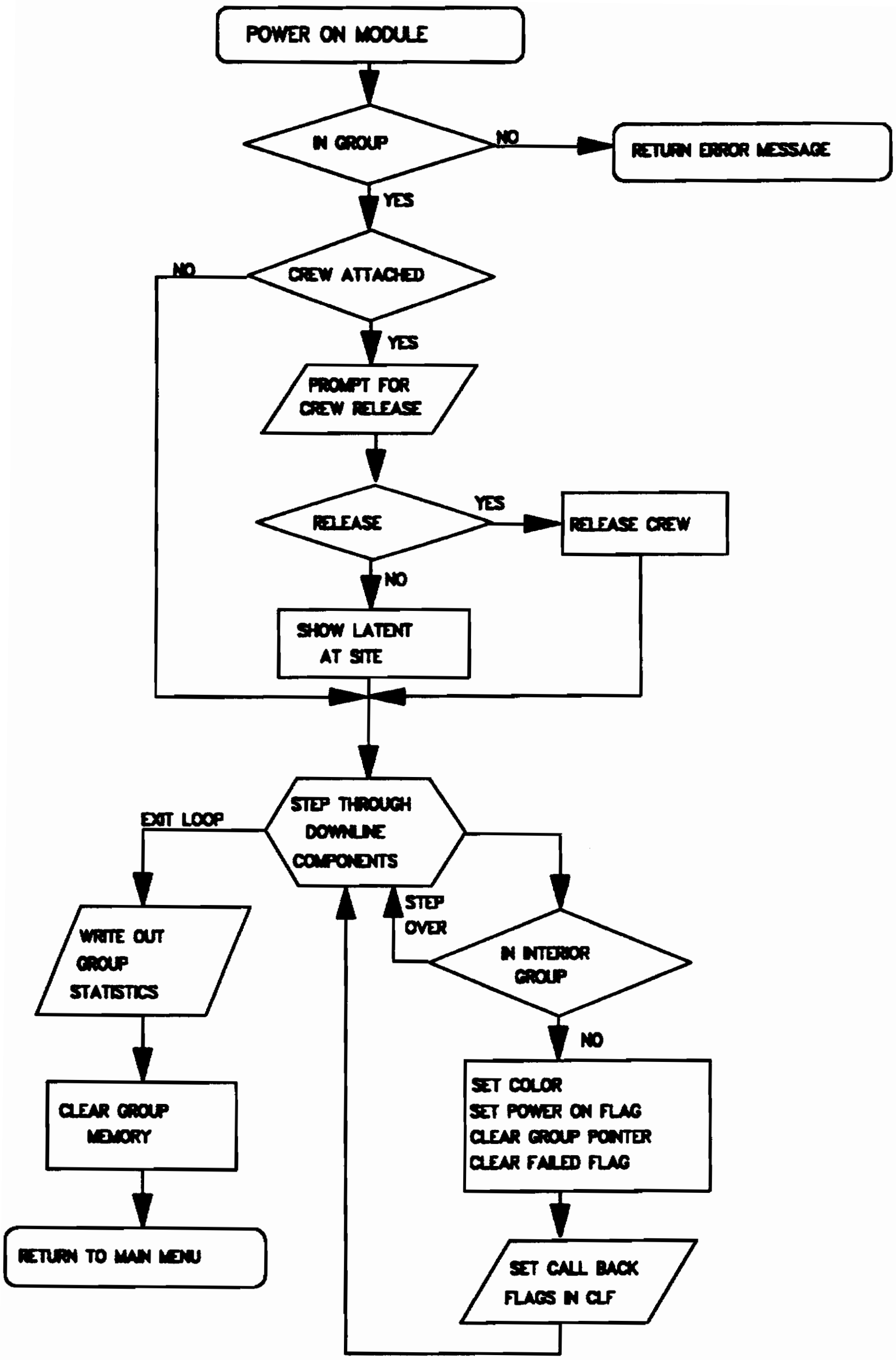

Figure 3.6.2.5 - Power On Module Flowchart

All components down line from the protective device are stepped through, with the components in interior groups not effected. The attributes in the circuit model for each component are set as the trace progresses. Callers attached to each component are updated as each component is traced. At the end of the trace, the group statistics are written to a table and the group memory is freed.

3.6.2.8 Toggle Crew On and Off Duty

This function's code is contained in the operations menu. A menu list is generated with the intrinsic menu function. After the Dispatcher has toggled the crews On or Off duty, a trace of the linked list of crews is made to set the on duty time as needed.

3.6.2.9 Assign Crew to Outage Group

During the creation of the group, all components in the circuit model have the pointer to the holding group set in an internal variable. The group has the pointer to the protective device set at the same time. With this information, the program module has the ability to place the crew at the protective device, no matter which component in the group is chosen.

3.6.2.10 Move Crew to New Location

Construction of the Move Crew function requires only the pointer to the new location within the group. This requires the new location to be in a group, and a crew to be assigned to the group. Because of this requirement, the program module is short and error checking is straight forward.

3.6.2.11 Release Crew

In order to record the crew statistics for each assignment, the Release Crew function prompts the Dispatcher for the release status of the crew. This input sets the flag passed to the function with writes the crew statistics. The module allows the crew to be released either before or after the power is restored.

3.6.2.12 Caller List File Scan

The CLF Scan selection is the function that ties the Operator Program and the Workstation Program together. Each time the function is called, all new callers in the table are pulled into the workstation memory individually. This is accomplished with the cursor function of SQL. As each record is brought in, the component to which the customer is attached is tested to see if power is presently marked off. If not, the component is marked for display as power off.

If the component is already marked as power off, then the number of callers for the component is incremented.

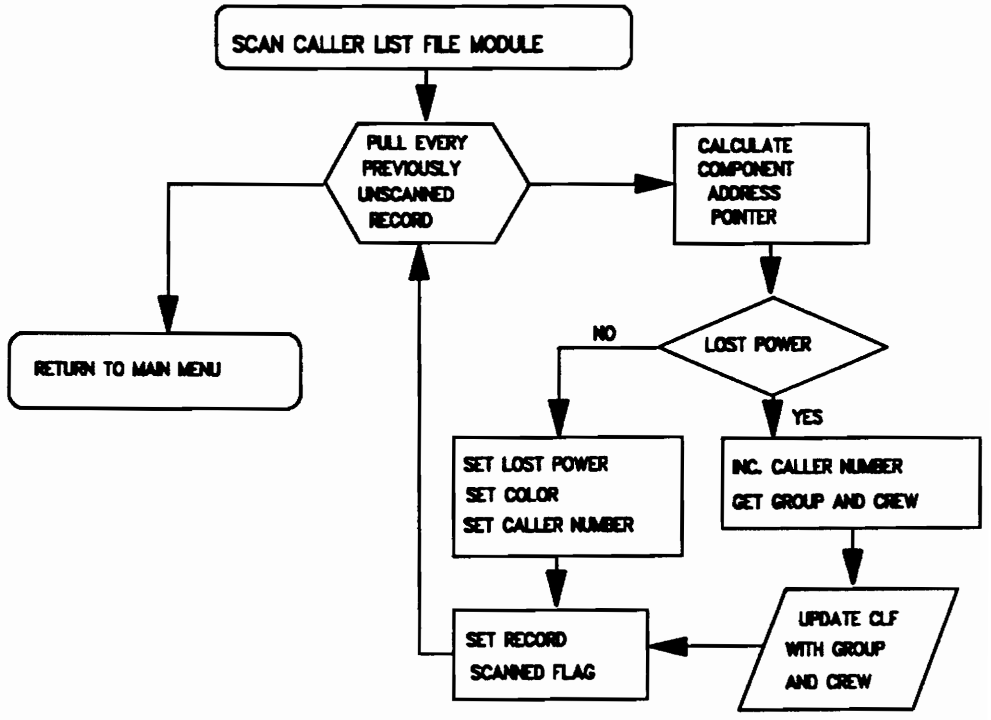

Figure 3.6.2.6 - Caller List File Scan Flowchart

3.6.2.13 Weather Condition

The function of Weather Condition is identical to the action that occurs when the function is called at the first selection of the Operations Menu, with the exception that the operations mode flag is not set.

3.6.2.14 Additions to Intrinsic Workstation Functions

The restoration extension is designed to minimize the amount of modification to the workstation's source code. One function that, by necessity, required a major addition, is the main menu switch function. In order to maintain consistency under switching actions, the group attributes of the components must be adjusted.

The flow chart, Figure 3.6.2.7, for the new switch function demonstrates the fact that only under the closing action of a switch is it necessary to adjust the groups. When no groups are involved, the action is still the same as the intrinsic function. For the other cases the groups are updated as needed.

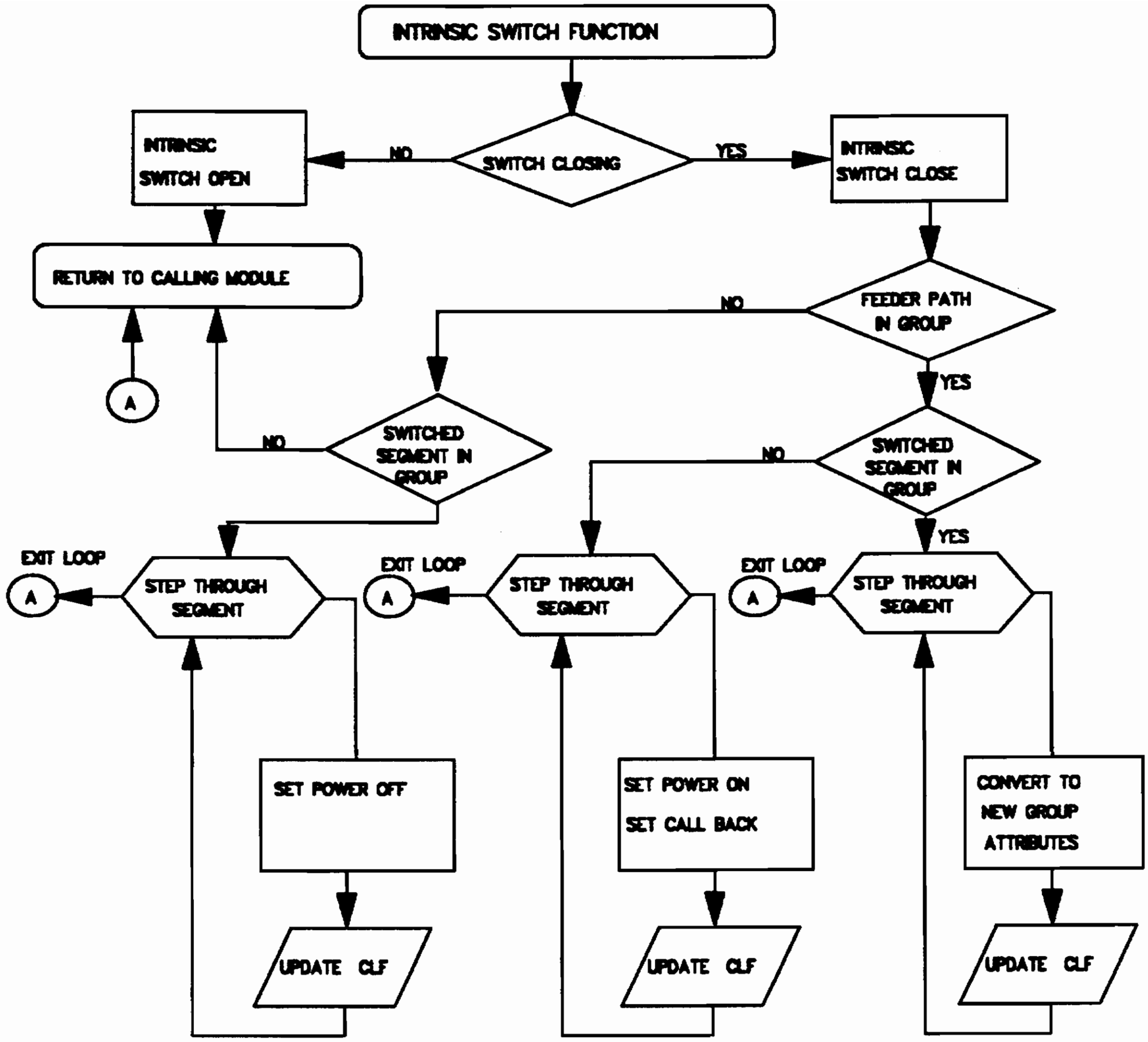

Figure 3.6.2.7 - Intrinsic Switch Function Flowchart

3.6.3 The Outage Statistics Program

The flowchart shows the sequence of actions in the Outage Statistics program. This first action is to archive the existing crew, group, and caller records. This is accomplished with a SQL insert using a subquery. The subquery saves considerable programming effort in the archive activity. The construction of the insert statement allows all rows from a table to be appended to a second table.

After the archive functions have been completed, the cycle table is updated. The counts are made and written to the cycle table.

A SQL cursor is used to step through the group and crew tables. As each record is fetched the histogram, total table count and moment data is updated. When a designer needs a new model for study, a new histogram base table can be generated from the archive tables and new code to provide updates for the table can easily be added to the statistics program. In the program code in the appendix, the repair time based on outage cause in presented as an example.

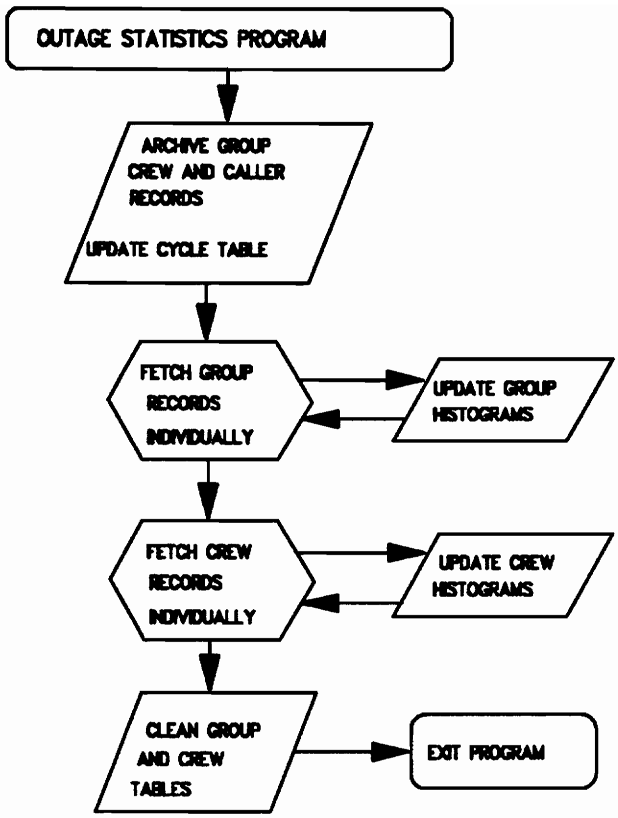

Figure 3.6.3.1 - Outages Statistics Program Flowchart

4.0 Results

All programs and modules were tested with a sample circuit and CIS data to assure consistent and correct results. The program has met all major requirements of the original design specifications.

The Operator Program has confirmed the use of the Query Manager as a development tool for a complete application. It also provides an example of a remote program which can communicate with the workstation environment over a computer network. Multitasking support in OS/2 allows the Operator Program to be run concurrently with the workstation program as well. The demonstration of network and multitasking interface with the workstation confirms the feasibility of adding real time data acquisition, such as SCADA.

Many new types of data are being collected by the system. Crew information accounts for most of these new data types. For this reason, an extended test at a field office would help confirm the adequacy of the crew model. All table updates were confirmed by hand calculation to verify that the Outage Statistics program provides consistent and expected results.

5.0 Conclusions and Remarks

5.1 Conclusions

The workstation extension and the related programs provide the basis for considerable improvement in the restoration of electric service during emergency outages. Hardware requirements are much smaller than similar published systems. Other published systems have not taken into account the combination of localized data storage; intrinsic engineering analysis; graphical display and interface; and outage statistics collection.

New Statistical Models for crew actions during restoration are presented. The inclusion of crew assignment time and crew latency time extends the ability of the program to model crew activities.

Other models are presented that provide improved information for the entire restoration process. The collection of outage statistics is accomplished through a stand alone program. The program is designed to allow addition models to be easily added. Models that are retained by the system are based on the reconstruction of the distribution of the data, and not just the average or some other single valued measure. The additional data will permit a more robust analysis of distribution reliability. The histogram method of distribution storage is compact and efficient.

CIS information is used to provide the connection between customer calls and the circuit model in the workstation memory. The interface of the data does not interfere with the design function of the workstation.

Finally, the program provides input to a variety of intrinsic workstation functions. One of these is a restoration algorithm that recommends switching to the Dispatcher to restore load. Design programs, such as a reliability algorithm, use the outage data generated by the program.

5.2 Remarks

Several future research topics are possible based on the subject research. Inclusion of the statistical moments in the histogram tables could provide for a future method of reconstructing the data by an expansion series on other method. Weather related outage prediction and crew scheduling could be linked to data from the new crew and group models. As further research the CIS information could include load information for use by design functions or restoration algorithms.

6.0 REFERENCES

1. K.I. Geisler, S.A. Neumann, T.D. Nielsen, P.K. Bower, B.A. Hughs, "A Generalized Information Management System Applied to Electrical Distribution," ***IEEE Computer Applications in Power***, July 1990, pp. 9-13.

2. W.G. Scott, "Automating the Restoration of Distribution Services in Major Emergencies," IEEE/PES 1989 Transmission and Distribution Conference.

3. D. Trudeau, R. Hoffman, M.A. Seymour, "Integrating AM/FM Maps with Distribution SCADA", IEEE Transactions on Power Delivery, Vol 5., No. 2, April 1990, pp 1216 - 1221.

4. W.E. Delcomyn, "Management Report - Connecting Islands in a Sea of Data," ***Electric World***, April 1990, pp. 37-42.

5. ***IBM Operating System/2 Extended Edition Version 1.2, User's Guide Volume 1: Base Operating System***, IBM Corporation, Armonk, New York, 1989, p 8-5.

6. R.P. Broadwater, J.C. Thompson, T.E. McDermott, "Pointers and Linked Lists in Electric Power Distribution Circuit Analysis", submitted to the 1991 Power Industry Computer Applications Conference, Baltimore Maryland.

7. G. Wacker, R. Billington, "Customer Cost of Electric Service Interruptions", Proceedings of the IEEE, Vol. 77, No. 6, June 1989, pp 919 - 930.

8. ***IBM C/2 Version 1.10 Language Reference***, IBM Corporation, Armonk, New York, 1988, p 5-443.

9. ***IBM Operating System/2 Extended Edition Version 1.1 Database Manager SQL Reference***, IBM Corporation, Armonk, New York, 1988, p 54.

10. Customer record statistics were based on a random sample of 413 customer records as provided by Appalachian Power Company, General Office, Roanoke, Virginia, August 1990.

11. ***Development of Distribution System Reliability and Risk Analysis Models Volume 2***, Electric Power Research Institute, Project 1356-1, Final Report, Palo Alto, California, August 1981, p 3-3.

12. J.P. Strmel, R.T. Jenkins, R.A. Babb, W.D. Bayless, "Production Costing Using the Cumulent Method of Representing the Equivalent Load Curve", IEEE Transactions on Power Apparatus and Systems, Vol. PAS-99, No. 5, Sept/Oct 1980, pp 1947 - 1956.

13. Outage records were provided for all outages that listed lighting as the cause within the Lynchburg, Virginia division office of Appalachian Power Company from January 1985 until May of 1990. Records provided by Appalachian Power Company, General Office, Roanoke, Virginia, August 1990.

14. M. Kendall, A. Stuart, J.K. Ord, ***Kendall's Advanced Theory of Statistics***, Oxford University Press, New York 1987, pp 222 - 229.

15. H. Cramer, ***Mathematical Methods of Statistics***, Princeton University Press 1946, pp 222 - 229.

16. ***IBM Operating System/2 Extended Edition Version 1.2, User's Guide Volume 3: Database Manager***, IBM Corporation, Armonk, New York, 1989, p 8-5.

7.0 VITA

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