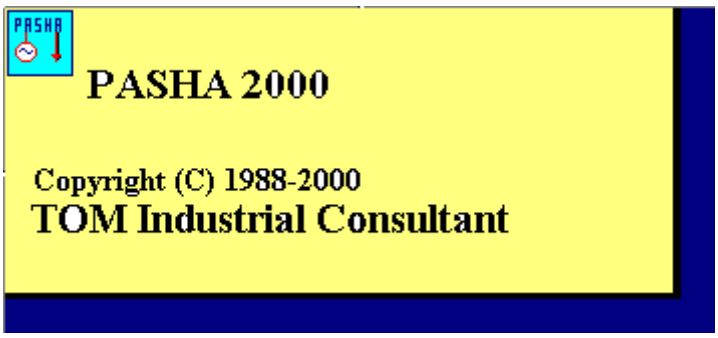


CHAPTER 12
CALCULATE THE RELIABILITY INDICES

12.1 Introduction

This part of manual describes the reliability analysis of PASHA package. The reliability analysis evaluates the three main reliability indices (expected failure rate, average outage duration and annual outage time) of each busbar of power system networks. It can not only be used to evaluate the reliability of electrical systems but also it has successfully been used in other industrial system like piping, since the basic concept remains the same.

There are many reliability indices that can be calculated and used. The most appropriate being dependent on the system and its requirements. Typical examples of these indices are:

- the expected number of failures that will occur in a specified period of time
- the average time between failures
- the average outage duration or down-time of a device
- the expected loss in revenue due to failure
- the loss of load expectation

The appropriate reliability index or indices are all determined using probability theory. All the reliability indices, however, are dependent to each other and can be related by using simple formulas. The expected failure rate and average outage duration are two reliability main indices that the other indices can be calculated from by using simple formulas. Therefore, PASHA provides you with the best indices that will be required in finding the criterion of adequate reliability level. They can be used in both an engineering and managerial problems where the requirement will vary with the system and the associated consequence of failure.

12.2 Method of analysis

PAHSA uses failure mode analysis that is based on the minimal path/minimal cut set theory. It considers a realistic three-state model for each component: the operating state, the state immediately following a failure and the state following subsequent switching and isolation

operations. The technique permits failure modes and restoration procedures to be modeled and gives a realistic representation of the system behavior.

The criteria for a busbar failure are total loss of continuity; these being identified from the minimal cut sets and include events up to third order, i.e. up to three overlapping failures events are considered.

12.3 Definitions and terminology

Input node - Any busbars or junctions a generator is connected

Output node - Any busbars or junctions which the failure events or the reliability indices are to be evaluated

Path - A set of components that connect any input to the output node being considered

Minimal Path - A path in which no node or branch is traversed more than once

Cut set - A set of components which, when failed, causes failure of the output node

Minimal cut set - A cut set which causes failure of the output node but when any one of the set has not failed, does not cause failure of the output node

Outage state - The State in which a component is isolated from the system

Overlapping state - An outage created when two or more components are in the outage state ate the same time. The starting and ending time need not be the same.

Forced outage - An outage state caused by the failure of a component

Maintenance outage - An outage state caused by the isolation of a component for the purpose of scheduled or preventive maintenance

Passive failure - A component failure which is due to three phase open circuit (outage of component will be assumed)

Active failure - A component failure which causes the opening of the entire protected zone around the failed component, e.g. short circuits

Total failure - Sum of the active and passive failure of a component causes the component gets out of service for repair

Failure rate - The average number of component failures per year

Average repair time - The average time taken to repair all kinds of component failure modes

Switching time - The average time between the occurrence of an active failure and the instant when failed component is isolated and all possible healthy components are restored to service following a repair or replacement action

Maintenance outage rate - The average number of occasions per year that a component is taken out of service for preventive maintenance

Average maintenance time - The average time taken to maintain (service) a component

Stuck probability - The probability of a breaker or a switch failing to open or close when called upon to operate

12.4 Overview of data organization in PASHA

To find out about the place of reliability in PASHA, an overview of what described in this manual is represented in this section.

A particular system is entered to PASHA by drawing the network on the terminal screen. For all the components the corresponding data arrays are generated automatically. To input the system parameters the user selects the edit option from the main PASHA and this enables him to access the appropriate data tables for all the groups of components in the network diagram. The reliability data can be accessed the same (see section 4.2). It requires to press <R> to access to the reliability pages.

Once the required data table is displayed the user selects with the graphic cursor the data item to be entered or modified, and inputs the corresponding value using the keyboard (chapter 4).

By selecting the save option from the main menu the user can store the network entered and the associated data on disc storage so that it may be retrieved later at any further PASHA session (ch.5).

The data base facility in PASHA allows data of standard types of equipment to be stored centrally for access at any time. Network data can therefore, be entered either explicitly or by referring to the standard data base types. All the data base entries are stored automatically at the end of each PASHA session (chapter 9). A reliability database page is also provided and it is unique for all kinds of elements. This is because the basic data required for reliability analysis is not dependent to the component. However, if any data is not required for a component, it may leave blank.

12.5 Database

This section has been configured to provide input, editing and storage facilities for all the reliability device data required for the calculations. Figure 9.1 in chapter 9 also reproduced here in figure 12.1 shows the data base menu, which displays additional options to enable, access to the reliability data base pages.


USE THE CURSOR TO SELECT ONE OF THE OPTIONS, OR TYPE 'H' FOR HELP
PRESENT DIRECTORY :
C:\PASHA\FORCABUW
SELECT TO CHANGE DATA BASE DIRECTORY
DATA BASE OPTIONS:
LINE DATA BASE
TRANSFORMER DATA BASE 1,2
GENERATOR DATA BASE 1,2
AVR DATA BASE 1,2
GOVERNOR AND TURBINE DATA BASE
INDUCTION MOTOR DATA BASE 1,2
PROTECTION DATA BASE -RELAYS 1,2,3,4,5
PROTECTION DATA BASE -FUSES 1,2,3,4
PROTECTION DATA BASE -DISTANCE RELAYS
CIRCUIT BREAKER DATA BASE
RELIBILITY DATA BASE
RETURN TO MAIN OPTIONS
COPYRIGHT (C) TOM InC 1988 TIME : 17:30:20 03/09/2001

Figure 12.1

12.5.1 Reliability database

The reliability database page is shown in figure 12.2 and 12.3.

TYPE : An integer number identifying each data base entry.
TFR : Total failure rate in (fail/yr)
AFR : Active failure rate in (fail/yr)
RT : Average repair time in (hr)
ST : Average switching time in (hr)
RMR : Maintenance rate in (maintenance/yr)
AMT : Average maintenance time in (hr)

PASSWORD : Enter the correct password, but only when required.
COMMENT : Spare column for entry of an alphanumeric identifier.

NOTES:

1 The values are used in reliability evaluation studies

2 Can be called from LOAD, LINE, GENERATOR, AC/DC CONVERTERS EDIT PAGES

3. Figure 12.3 shows an extra option can be accesses by pressing key <E>. This option allows you to write memo for any field of reliability database. Please refer to chapter 9 section 9.4 for more information about memo.

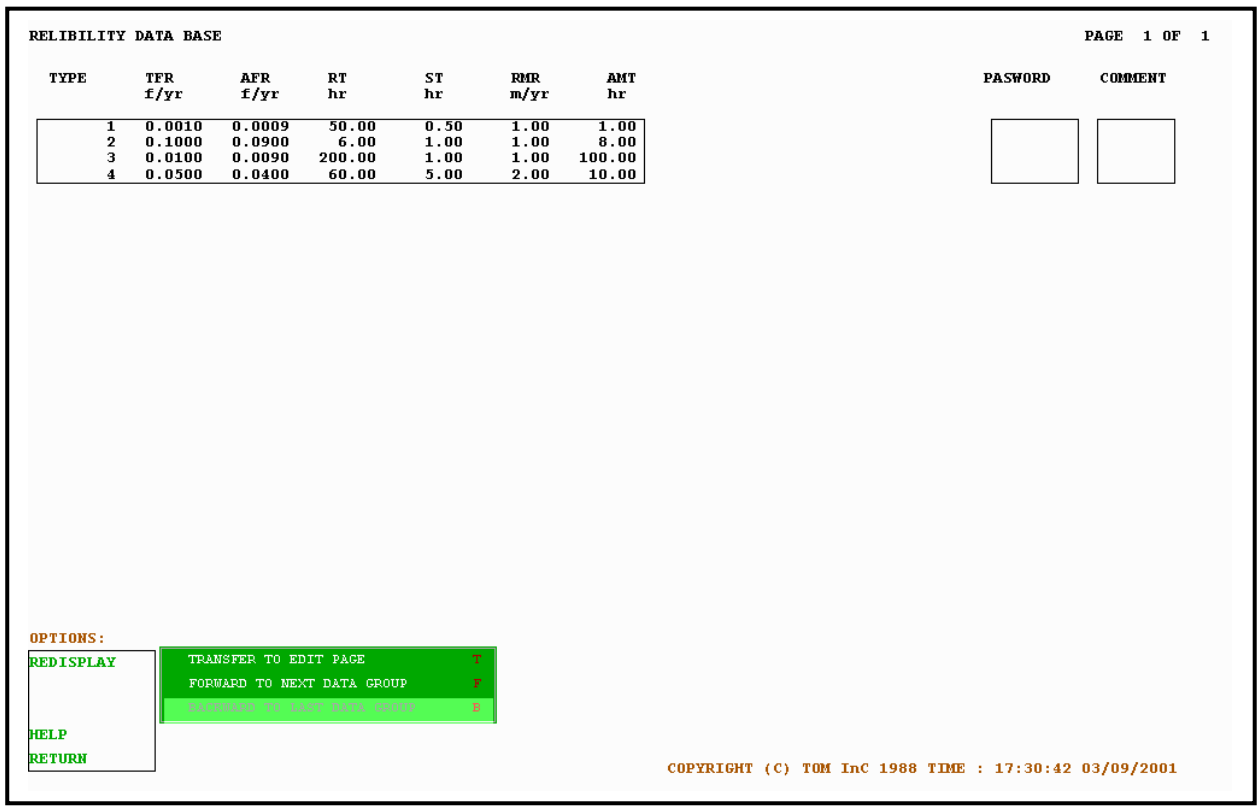


Figure 12.2

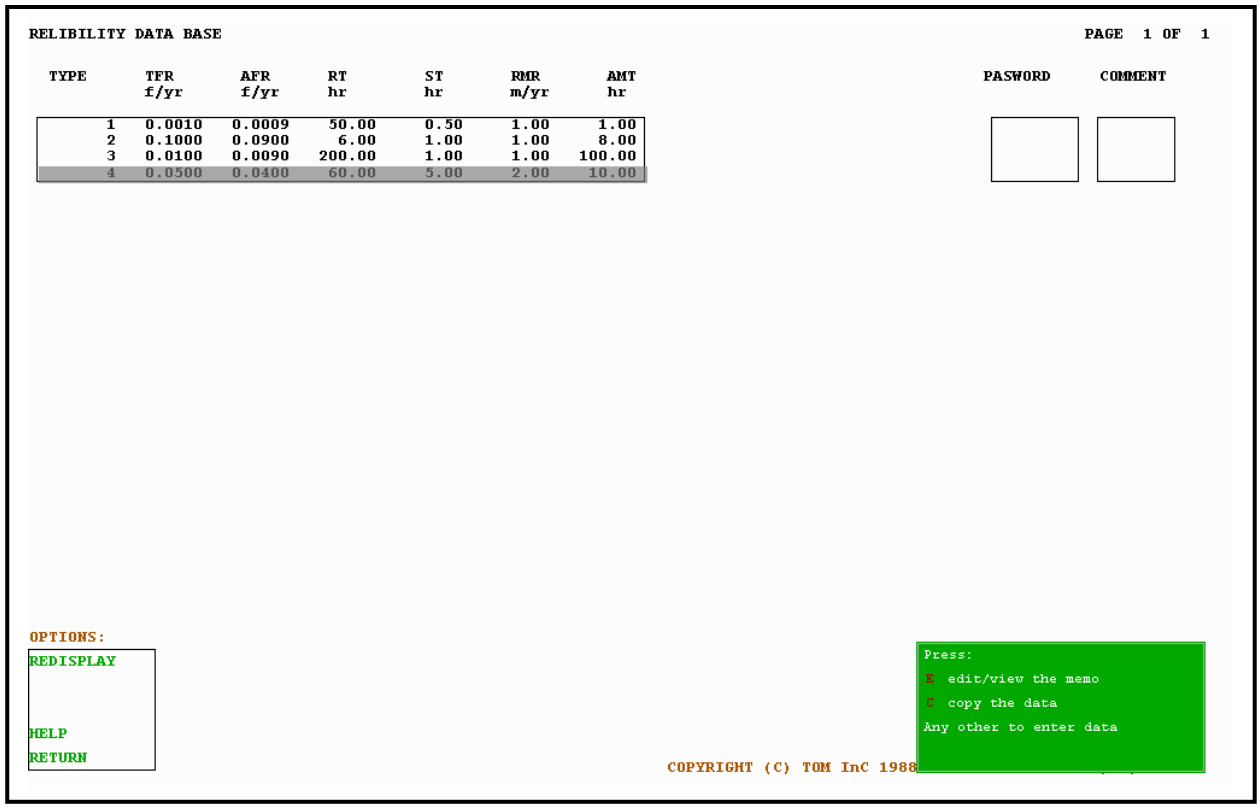


Figure 12.3

12.6 Edit : network reliability data

Figure 12.4 shows the layout for the edit menu as shown in chapter 4, showing the pages for power system elements while those accept the reliability data are indicated by R. The pages can be accessed from this menu are reliability data for busbars, reliability data for lines, reliability data for generators, reliability data for AC/DC converters. To choose a particular data page, the user must now select the component using the cursor and press the key <R>.

The reliability data page can also be accessed from single-line diagram. If you are in the reliability analysis section and a single-line diagram is on the screen, typing the edit key <F1>, while the cursor is positioned on an element will reroute you to the reliability data page for that particular element. The selected element will be red highlighted. In return you will be back to the reliability analysis section where you start. In this regard you may change the analysis parameters and see their effects on the reliability evaluation results instantly.

All the standard 'REDISPLAY', 'NEXT PAGE', 'PREVIOUS PAGE', 'HELP', and 'RETURN', facilities in PASHA as described in chapter 4 are included in these pages too. Transfer to (and from) database operations are also available in this page. The additional operation can be accessed via green menu boxes too.

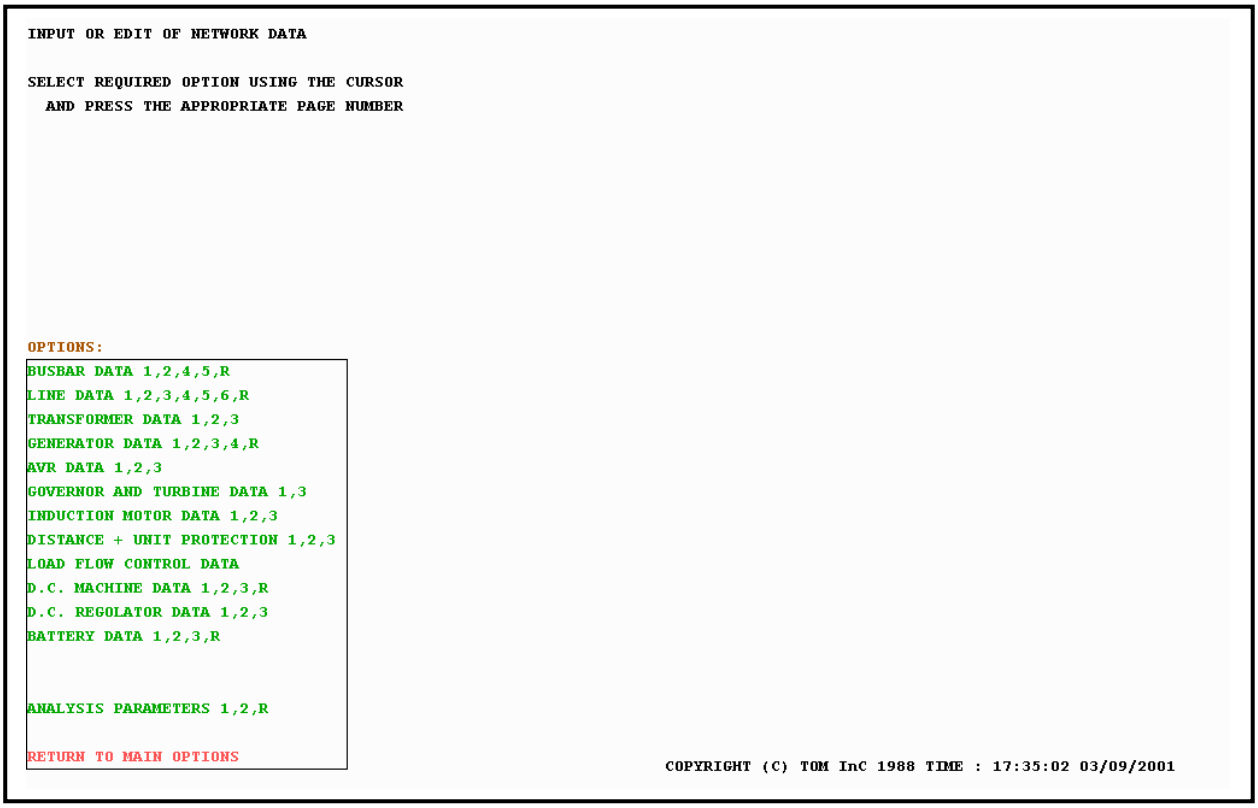

INPUT OR EDIT OF NETWORK DATA
SELECT REQUIRED OPTION USING THE CURSOR
AND PRESS THE APPROPRIATE PAGE NUMBER
OPTIONS:
BUSBAR DATA 1,2,4,5,R
LINE DATA 1,2,3,4,5,6,R
TRANSFORMER DATA 1,2,3
GENERATOR DATA 1,2,3,4,R
AVR DATA 1,2,3
GOVERNOR AND TURBINE DATA 1,3
INDUCTION MOTOR DATA 1,2,3
DISTANCE + UNIT PROTECTION 1,2,3
LOAD FLOW CONTROL DATA
D.C. MACHINE DATA 1,2,3,R
D.C. REGOLATOR DATA 1,2,3
BATTERY DATA 1,2,3,R
ANALYSIS PARAMETERS 1,2,R
RETURN TO MAIN OPTIONS
COPYRIGHT (C) TOM InC 1988 TIME : 17:35:02 03/09/2001

Figure 12.4

12.6.1 BUSBAR RELIABILITY DATA, LINE/TRANSFORMER RELIABILITY DATA, GENERATOR RELIABILITY DATA, AC/DC CONVERTORS RELIABILITY DATA

The reliability data page enables the user to specify the reliability data of each element. Although, there are separate data pages for each of the above elements, but the basics of all are the same. Therefore for the sake of simplicity they are all described in this section using busbar reliability data as example. Figure 12.5 shows the layout of this page. It can be seen here that the reliability data can use the reliability data base too.

TYPE : The data base type number user to identify a particular reliability data.

TFR : Total failure rate in (fail/yr)

AFR : Active failure rate in (fail/yr)

RT : Average repair time in (hr)

ST : Average switching time in (hr)

RMR : Maintenance rate in (maintenance/yr)

AMT : Average maintenance time in (hr)

These quantities can be entered or modified by the user whenever the data page is displayed, using the input/edit facilities of PASHA. The current values will be stored together with the rest of the system data if the network is 'saved', therefore the information will be available for further work after the PASHA session is finished.

After entering reliability data, if you are in line data page, the "ID" column will contain either "C" or "T" to indicate circuit or transformer.

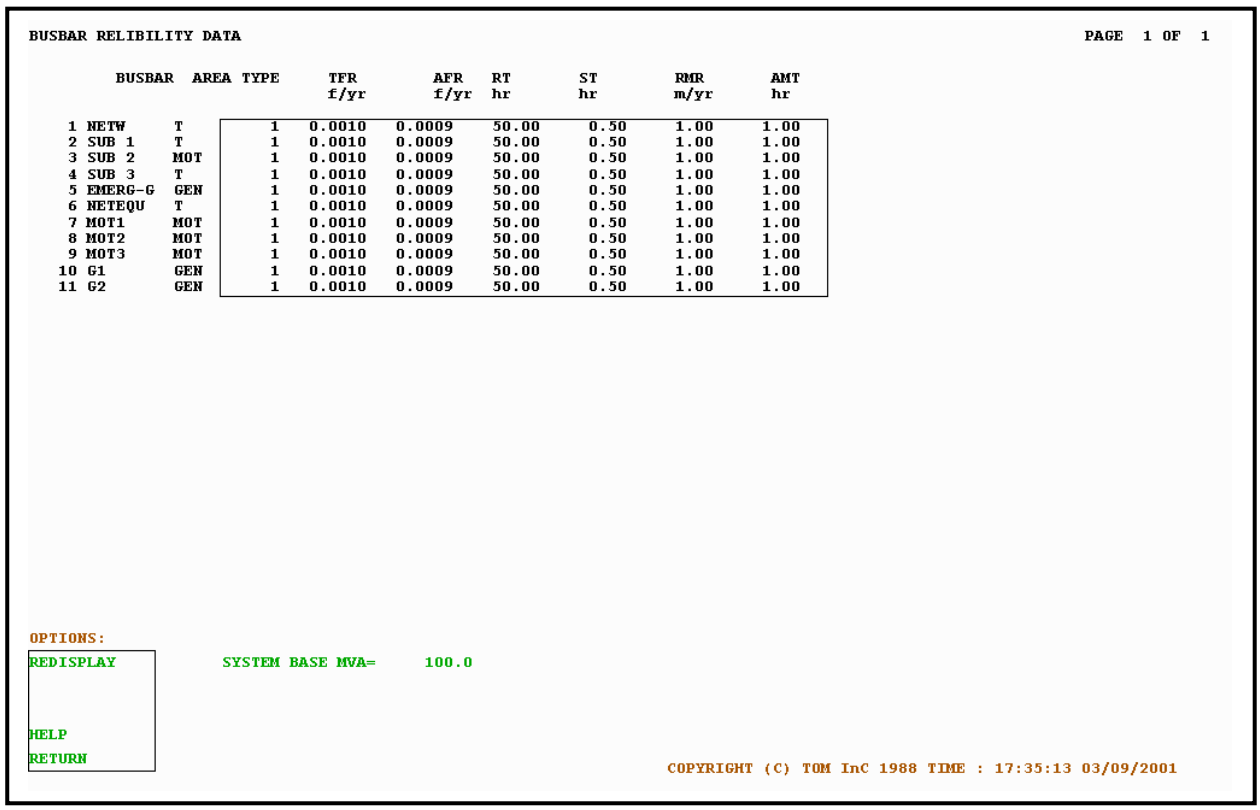

BUSBAR RELIBILITY DATA
PAGE 1 OF 1
BUSBAR AREA TYPE TFR f/yr AFR f/yr RT hr ST hr RMR m/yr AMT hr
1 NETW T 1 0.0010 0.0009 50.00 0.50 1.00 1.00
2 SUB 1 T 1 0.0010 0.0009 50.00 0.50 1.00 1.00
3 SUB 2 MOT 1 0.0010 0.0009 50.00 0.50 1.00 1.00
4 SUB 3 T 1 0.0010 0.0009 50.00 0.50 1.00 1.00
5 EMERG-G GEN 1 0.0010 0.0009 50.00 0.50 1.00 1.00
6 NETEQU T 1 0.0010 0.0009 50.00 0.50 1.00 1.00
7 MOT1 MOT 1 0.0010 0.0009 50.00 0.50 1.00 1.00
8 MOT2 MOT 1 0.0010 0.0009 50.00 0.50 1.00 1.00
9 MOT3 MOT 1 0.0010 0.0009 50.00 0.50 1.00 1.00
10 G1 GEN 1 0.0010 0.0009 50.00 0.50 1.00 1.00
11 G2 GEN 1 0.0010 0.0009 50.00 0.50 1.00 1.00
OPTIONS:
REDISPLAY
SYSTEM BASE MVA= 100.0
HELP
RETURN
COPYRIGHT (C) TOM InC 1988 TIME : 17:35:13 03/09/2001

Figure 12.5

12.7 Reliability calculation facilities

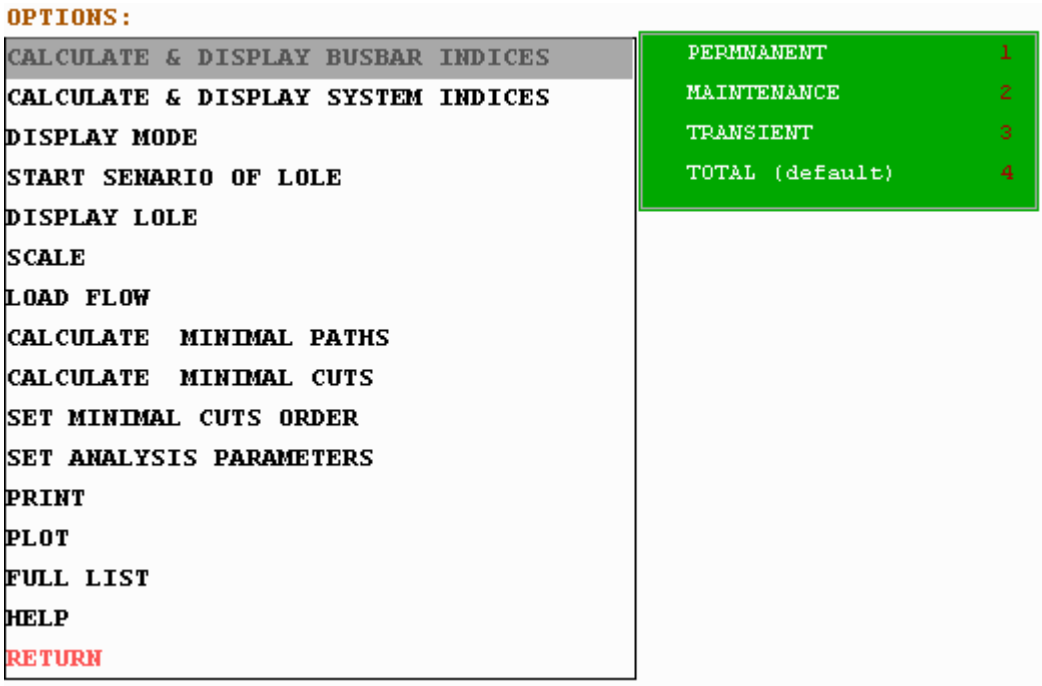
Access to these facilities is gained by selecting the [CALCULTATE THE RELIABILITY INDICES] option from the main menu of PASHA. Entry to the reliability section initially performs some basic checks on the data entered for the components of the network. If any essential data is found to be missing, an appropriate error message is displayed. Depending the data is missed or is passed the user may either be provided with a partial or full menu options. The full menu option is shown in figure 12.6 and the partial one is shown in figure 12.7. If all the checks are passed as stated before full reliability menu option will be displayed on the screen and the user is invited to select an option.

Among the options available, the [LOAD FLOW] option provides a means for doing load flow and also to do outages. The outages facility in the load flow section enables the user to simulate the temporary removal of network components to obtain the most onerous conditions for the network under study. All the removed components are restored by selecting outages again, or by returning to PASHA main options.

The organization of the program allows the user to 'move' freely from reliability calculation section to edit or load flow outages facilities, perform any change and return to reliability to continue the calculation without any unwanted disturbance.

12.7.1 Reliability main menu

The layout of the reliability main menu is shown in figure 12.6 as well as in the following figure. The first two options refer to the calculation of reliability indices and they are options mostly needed in reliability evaluations. The other options either provide a means of looking at the reports or to help the user to go deep inside the process of reliability calculations.



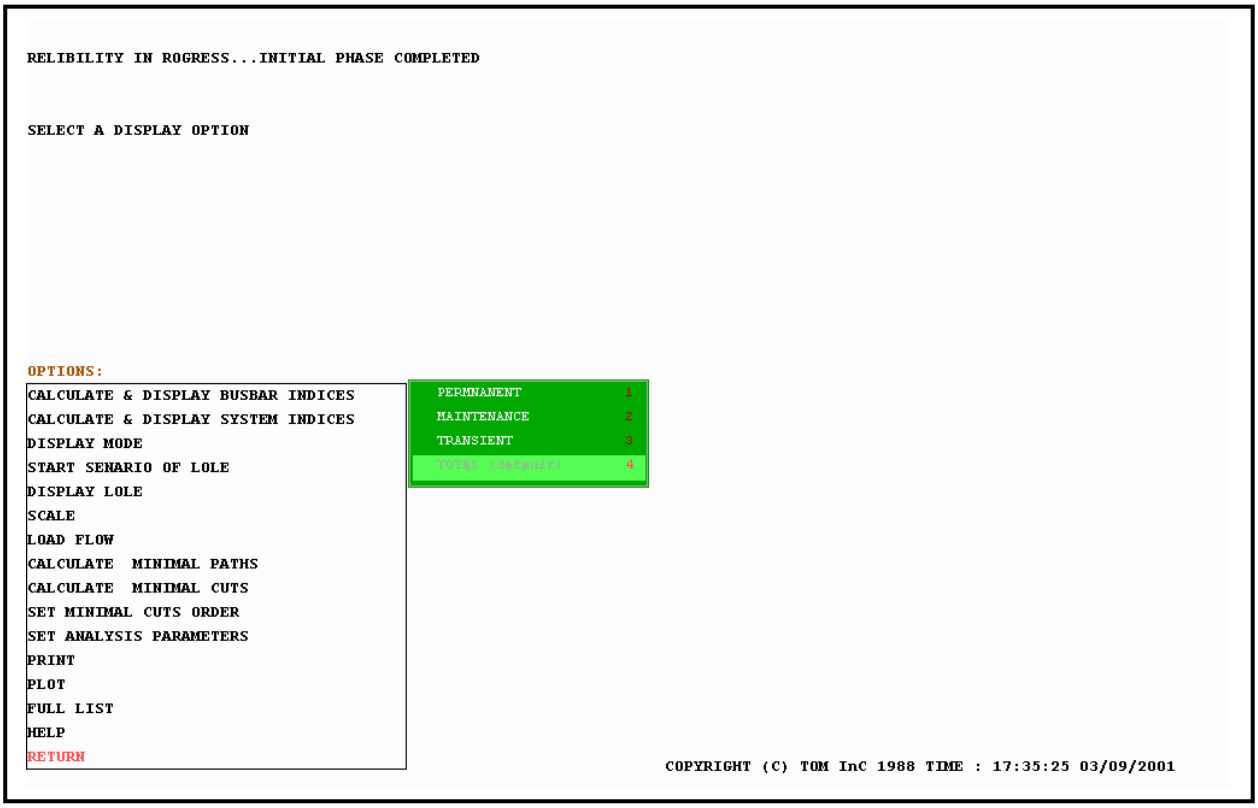


Figure 12.6

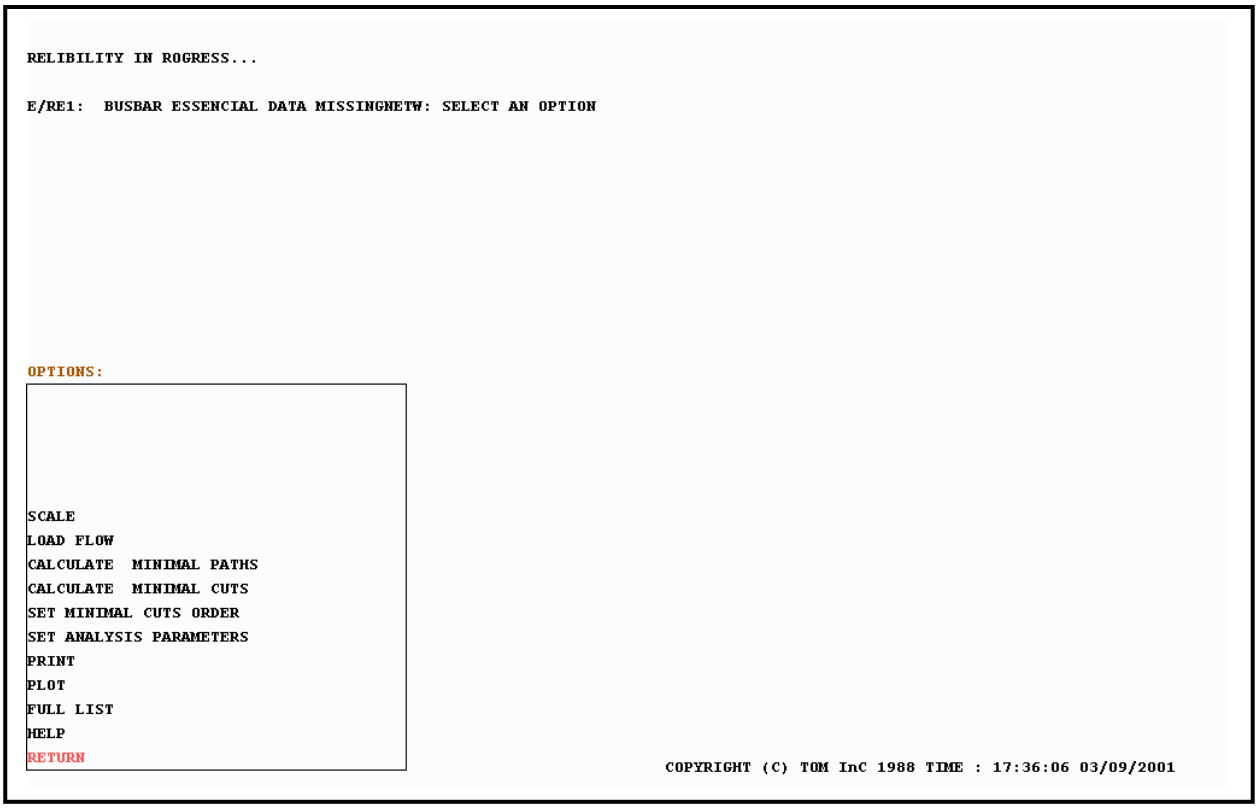


Figure 12.7

12.7.1.1 [CALCULATE & DISPLAY BUSBAR INDICES]

The [CALCULATE & DISPLAY BUSBAR INDICES] option is used to calculate and display expected failure rate, average outage duration and annual outage time of a single busbar of power system networks being studied.

Once the [CALCULATE & DISPLAY BUSBAR INDICES] option has been selected, the user is invited to specify the busbar to be desired, as shown in figure 12.8. To select a busbar the cursor is positioned over the required busbar and the <SP> key or a click is pressed. The diagram is then re-drawn with the indices displayed under the name of busbar. The indices displayed beneath the busbar names. Figure 12.9 shows the reliability indices shown when busbar 'SUB 1' is selected. If the click is not over a busbar, the name of the busbar will be asked for.

Four different results can be calculated and displayed on the diagram by using the special keys <1>, <2>, <3>, or <4>:

Press key <1> to display permanent reliability indices

Press key <2> to display maintenance reliability indices

Press key <3> to display transient (active) reliability indices

Press key <4> or any other key to display total reliability indices (default)

These special keys may also be selected by a click on the options provided inside the green box.

The loads MW is also will be displayed. Multiplying the MW loads to annual outage time will provide the LOLE, what will be displayed on request in the [DISP LOLE] option described in section 12.7.1.5. The order in which each component of the system is contributed to the cut set events will also be displayed in front of each component. For example, in figure 12.9 the branch between 'SUB 1' and 'SUB 3' is contributed as a second order event in the reliability calculations.

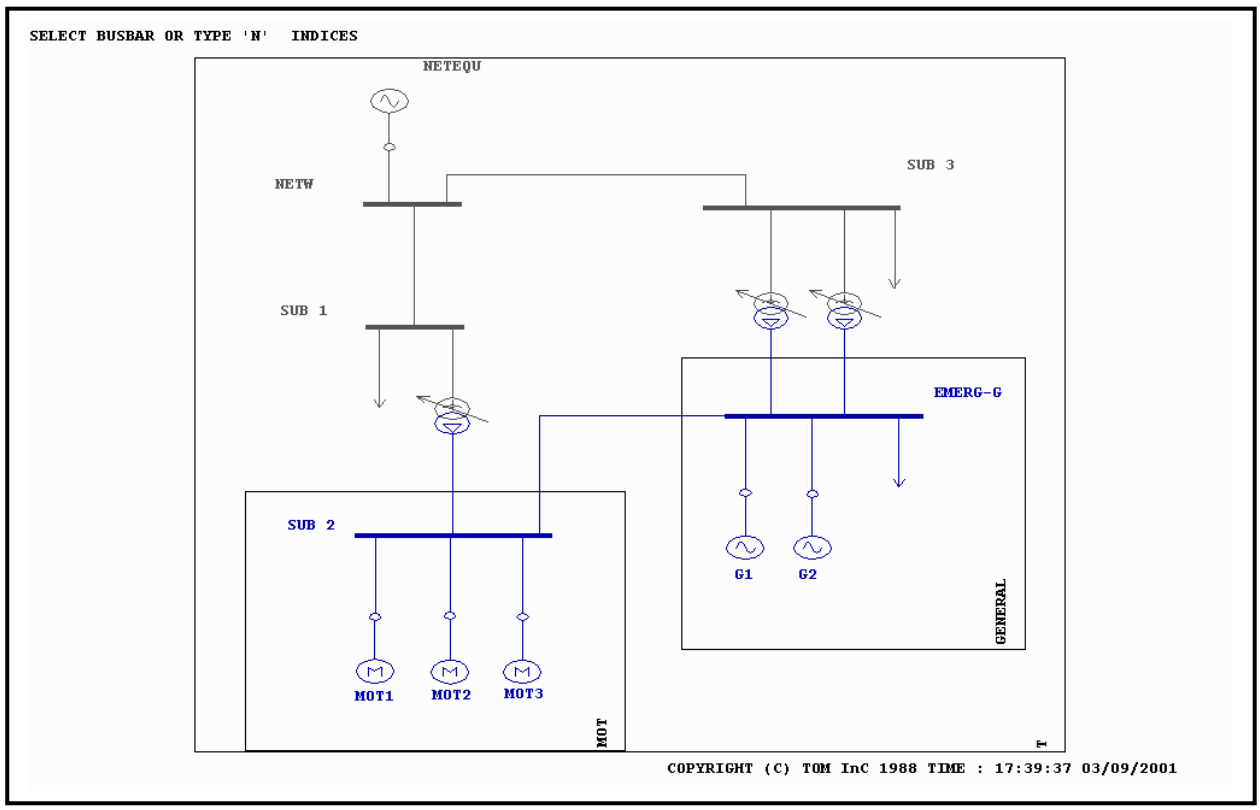


Figure 12.8

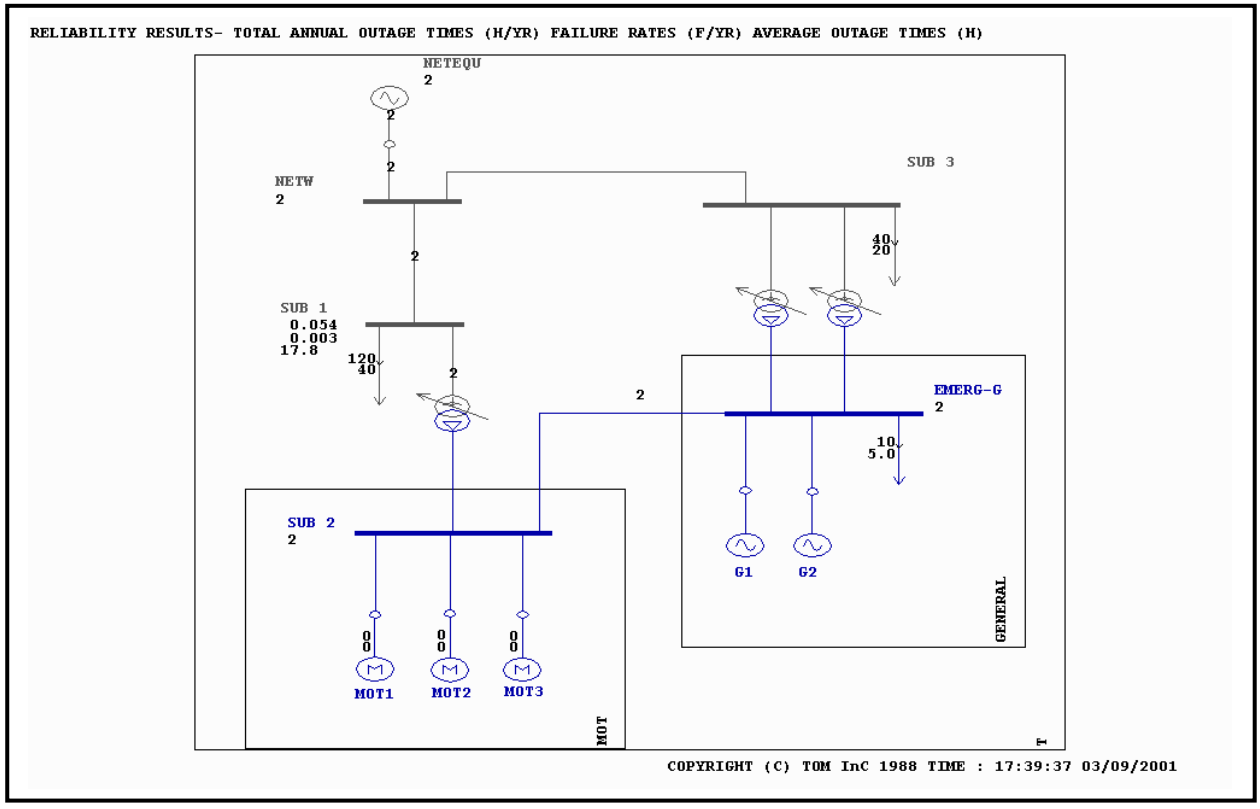


Figure 12.9

12.7.1.2 [CALCULATE & DISPLAY SYSTEM INDICES]

Selection of this option calculates the reliability indices on each busbar in turn, draws the system diagram and displays the busbar indices on the diagram. This is shown in figure 12.10.

Four different results can be calculated and displayed on the diagram by using the special keys <1>, <2>, <3>, or <4>:

Press key <1> to display permanent reliability indices

Press key <2> to display maintenance reliability indices

Press key <3> to display transient (active) reliability indices

Press key <4> or any other key to display total reliability indices (default)

These special keys may also be selected by a click on the options provided inside the green box.

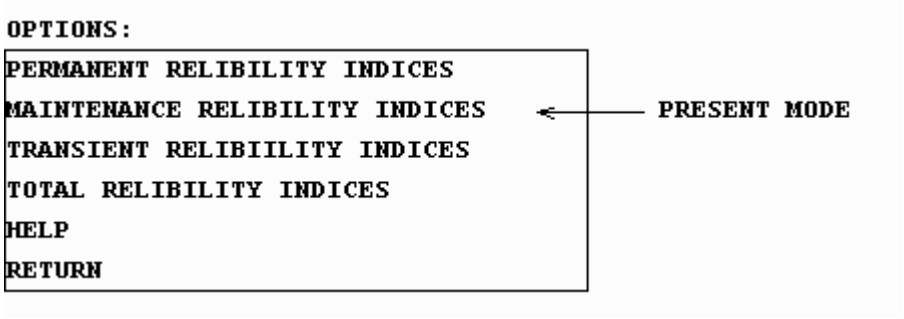
12.7.1.3 [DISPLAY MODE]

The display mode option enables various reliability quantities to be displayed on the system diagram. In the new version of PASHA you may select most of the options associated with display mode from the in-line green box menu.

However, If the [DISP MODE] option is selected another display subsection is entered. Figure 12.11 shows the display menu, after initial entry.

To select a particular mode position the cursor over the required option title and:

Press the <SP> key or a click to change the display mode or Press <X> to select the mode and produce the new diagram display.



For example, if the cursor is positioned over the [**MAINTENANCE RELIABILITY INDICES**] option and the <SP> key or a click is pressed, then display mode is changed, and this is indicated by an arrow, shown in above figure. When the [RETURN] option is selected,

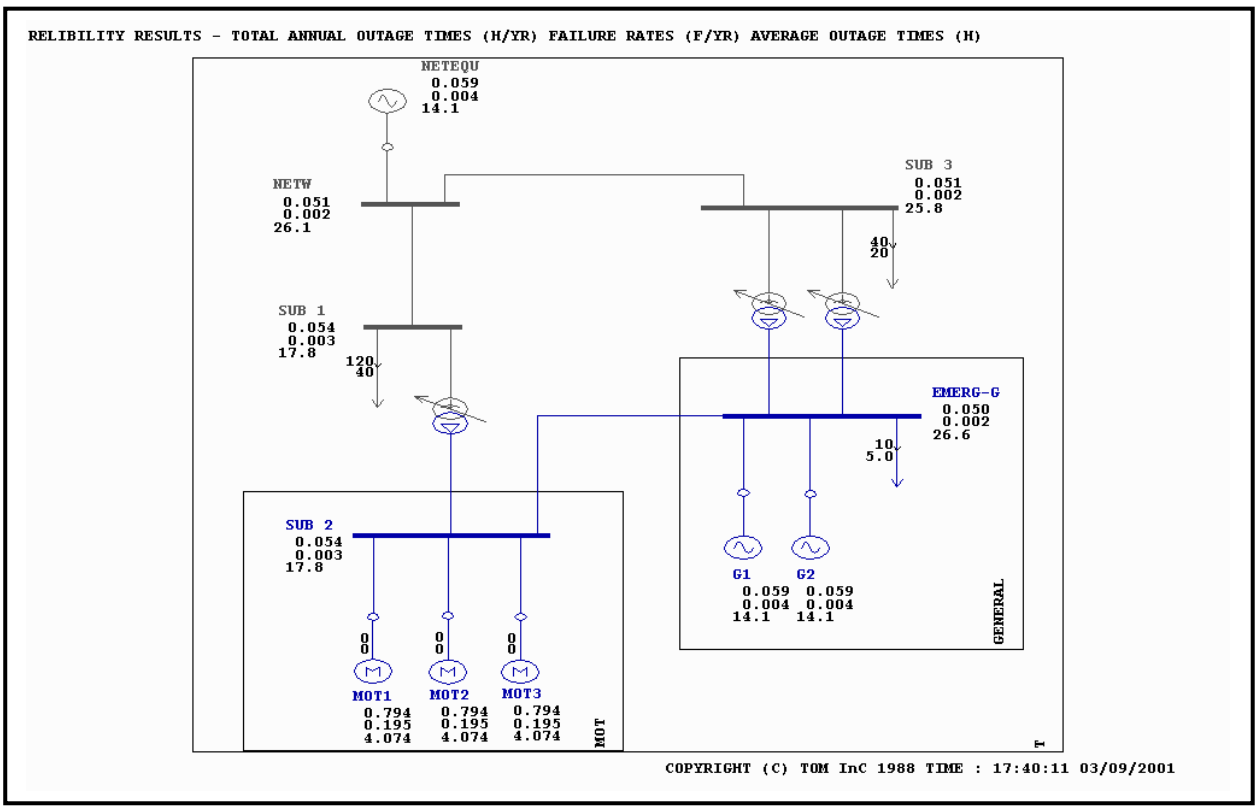


Figure 12.10

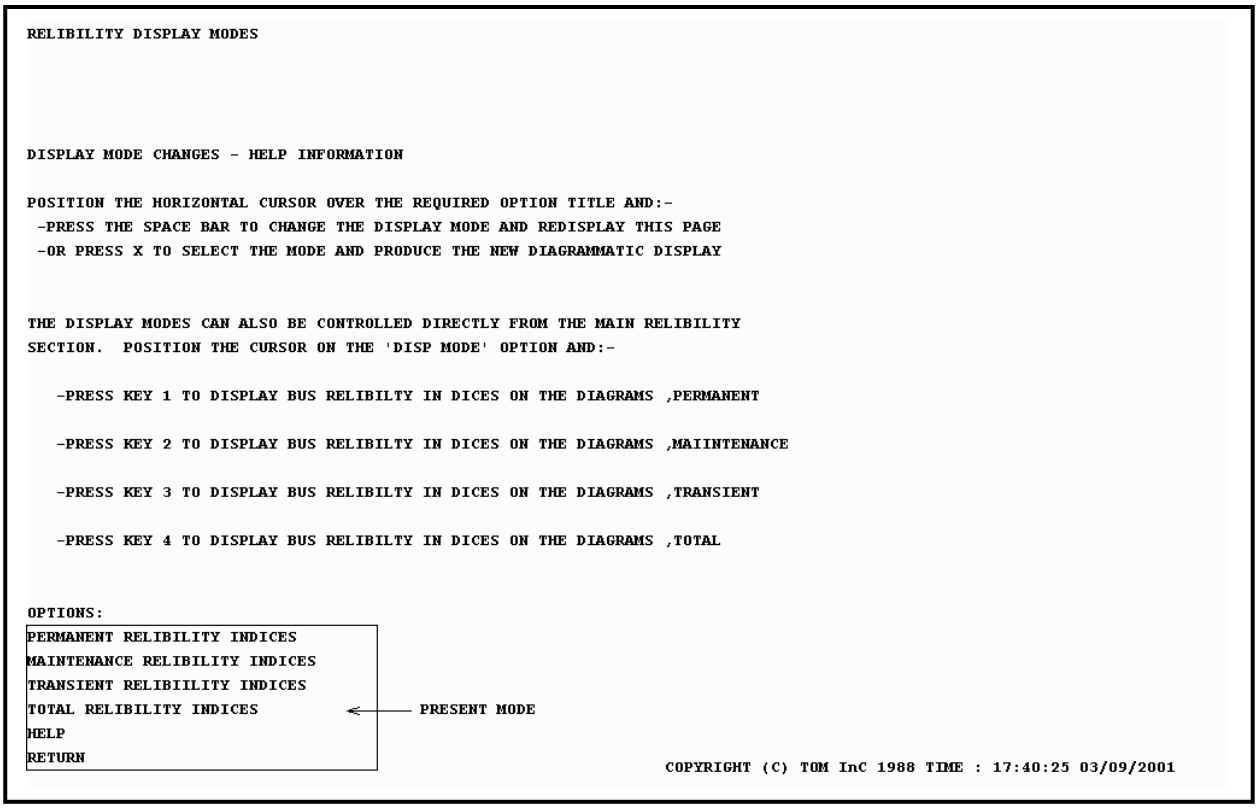


Figure 12.11

the diagram is immediately re-displayed with the selected information on it.

The display modes can also be controlled directly from the main reliability section which produces a diagram with the selected calculation displayed on it (it overrides the display mode menu page). To do this position the cursor on the desired calculation option and:

Press key <1> to display permanent reliability indices

Press key <2> to display maintenance reliability indices

Press key <3> to display transient (active) reliability indices

Press key <4> or any other key to display total reliability indices (default)

These special keys may also be selected by a click on the options provided inside the green box.

12.7.1.4 [START SCENARIO OF LOLE]

This option is under reconsideration at time of releasing this manual. Please refer to on line help of PASHA program for more information.

12.7.1.5 [DISP LOLE]

Selection of this option calculates the reliability Loss Of Load Expectation (LOLE) on each busbar in turn, draws the system diagram and displays LOLE on the diagram. This is shown in figure 12.12. The LOLE expectations is either the results obtained from SENARIO OF LOLE described in previous section or if such a result is not available it calculates the total LOLE with multiplying total outages time by MW loads consume at the busbar.

12.7.1.6 [SCALE]

Allows the system diagram to be re-scaled and recentered. Different sections of a large system can thus be displayed on the screen, with the appropriate loadflow results. For further details on scaling see section 3.4.

By introducing zoom facility like those described in chapters 2 and 3, using mouse right click or using the key <Z>, an easier facility has been provided for scaling. However, there are certain use of this facility, e.g. bringing a substation in center of the screen by using its name.

12.7.1.7 [LOAD FLOW]

Selection of this option provides the user with direct entry, or return, from the faults section to the loadflow section.

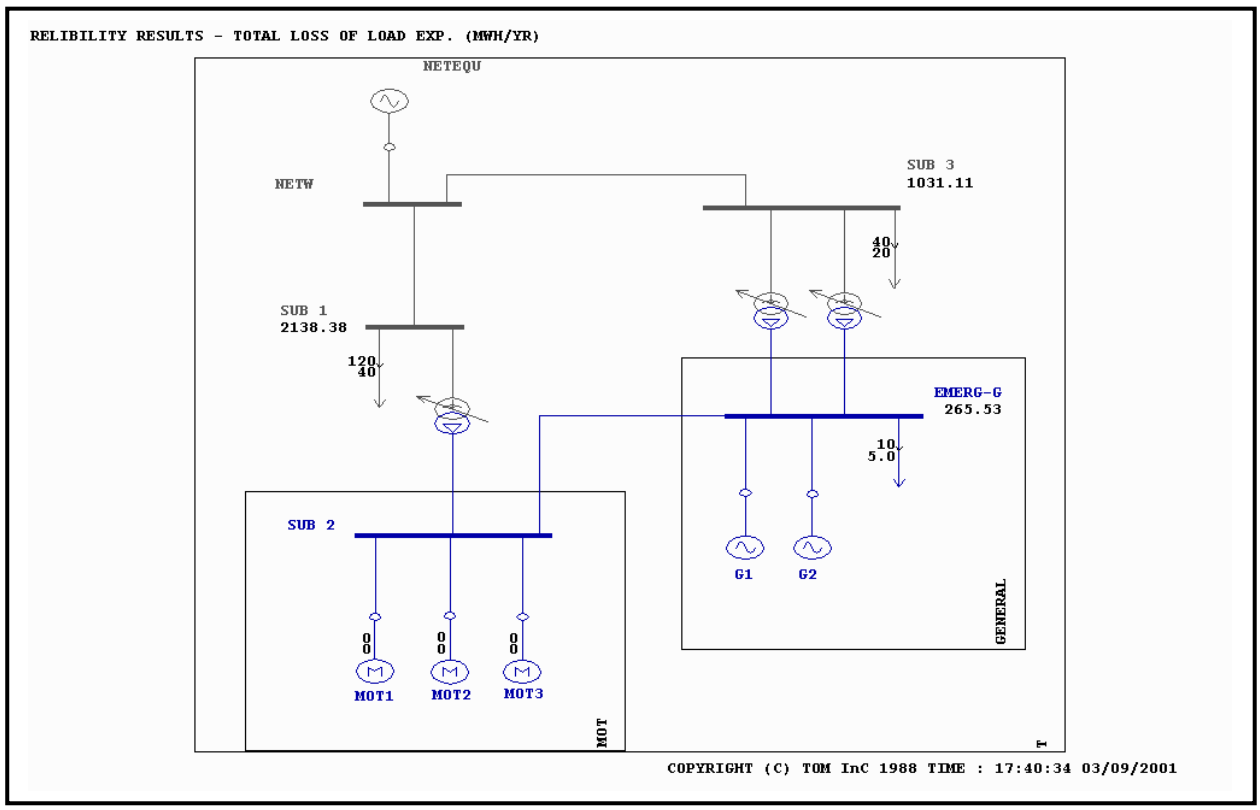


Figure 12.12

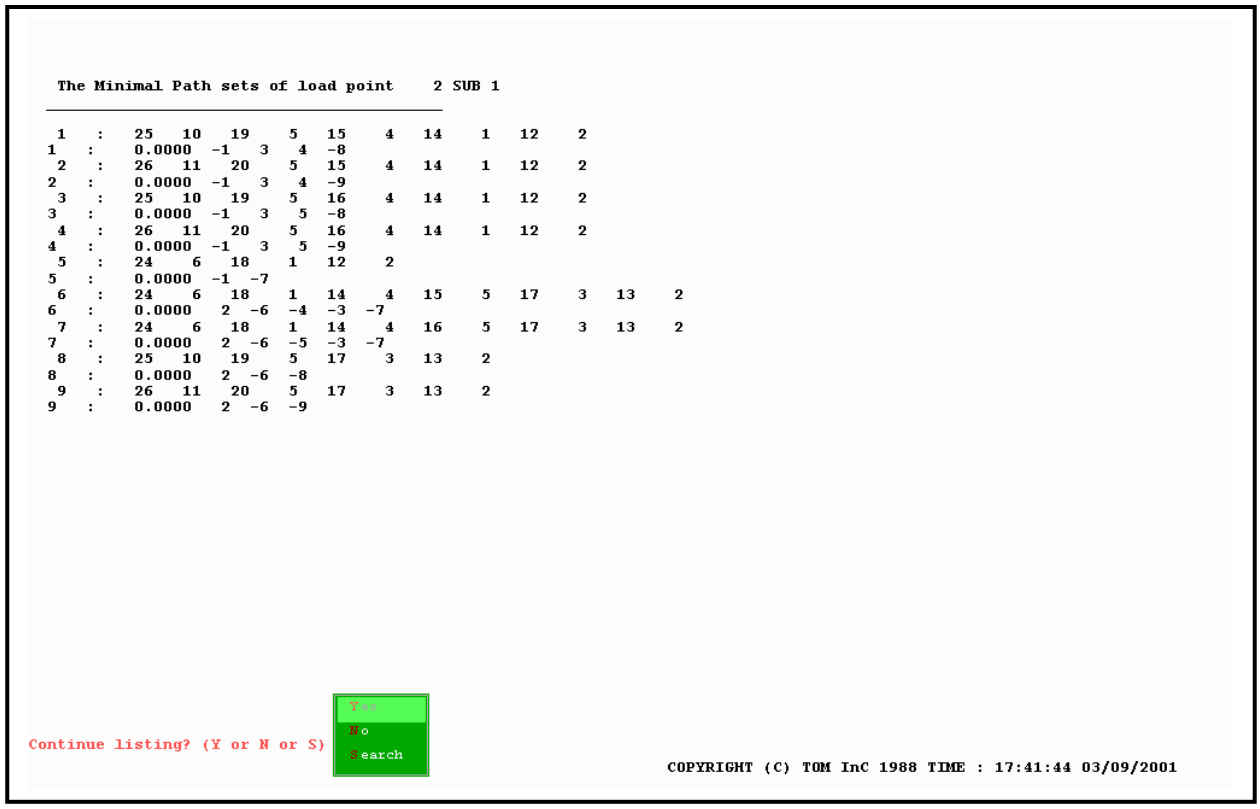


Figure 12.13

12.7.1.8 [CALCULATE MINIMAL PATHS]

Once the [CALCULATE MINIMAL PATHS] option has been selected, the user is invited to specify the busbar to be desired, as shown in figure 12.8. To select a busbar the cursor is positioned over the required busbar and the <SP> key or a click is pressed. The calculation will be performed and the results will be available in the result files. You can view the result files by using [FULL LIST] option described in section 12.7.1.13.

The results contain the busbar and the paths indicated by their numbers and the elements of the paths. An example is shown in figure 12.13.

12.7.1.9 [CALCULATE MINIMAL CUTS]

Once the [CALCULATE MINIMAL CUTS] option has been selected, the user is invited to specify the busbar to be desired, as shown in figure 12.8. To select a busbar the cursor is positioned over the required busbar and the <SP> key or a click is pressed. The calculation will be performed and the results will be available in the result files. You can view the result files by using [FULL LIST] option described in section 12.7.1.13.

The results contain the minimal cut sets events for the busbar selected. An example is shown in figure 12.14.

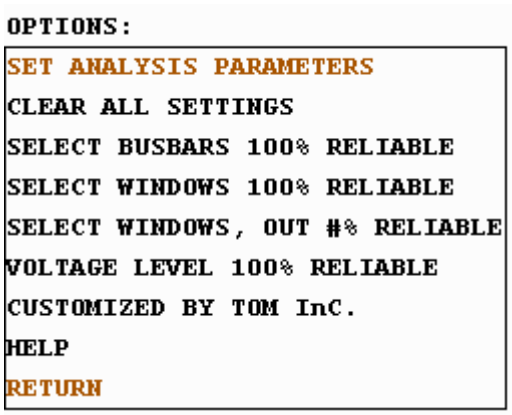
12.7.1.10 [SET MINIMAL CUTS ORDER]

Selection of this option enables the user to change the cut sets order. The user is prompted to enter the new order. Up to third order minimal cut sets can be considered in PASHA reliability evaluations.

When entered the program responds by displaying the new cut sets order. The new value is then used for all the calculation depending to the cut sets in any further reliability studies. You can use the next option to set this value too.

12.7.1.11 [SET ANALYSIS PARAMETERS]

The layout of the SET ANALYSIS PARAMETERS menu is shown in figure 12.15 as well as in the following figure. The one shown in the figure 12.15, shows the optional settings in front of the options selected.

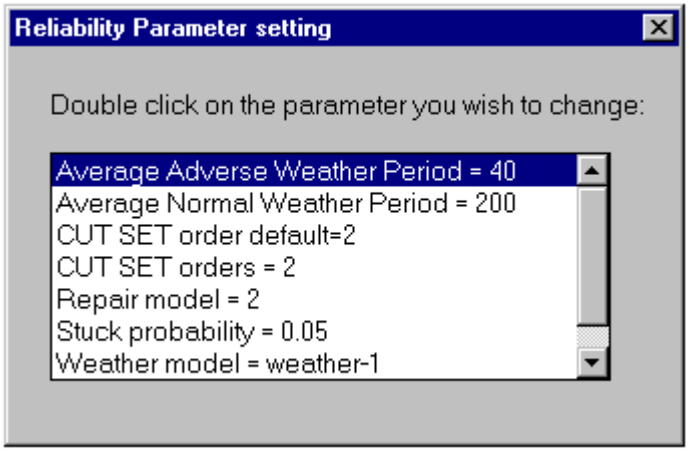


Using the options available two distinct group of setting can be specified. The first one is

related to the active failure, weather model, stuck probability and so. The second one limits the area that the reliability calculation will be proceeded. The meaning of each option described below.

SET ANALYSIS PARAMETERS

Upon selection of this option the following menu will be displayed. It shows the default value considered in the reliability evaluation.



The user may change the values of the variables by double clicking on the parameter he wishes to change.

CLEAR ALL SETTINGS

Clicking on this option clears all the settings that are specified with the following options.

SELECET BUSBARS (TO BE) 100% RELIABLE

Upon selection of this option single-line diagram will be redisplayed and asks the user to select busbar he wishes to be 100% reliable, figure 12.16.

SELECET WINDOWS (TO BE) 100% RELIABLE

Upon selection of this option single-line diagram will be redisplayed and asks the user to select windows that the components inside it must be considered 100% reliable, figure 12.17.

SELECET WINDOWS, OUT (OF WHICH 100)#% RELIABLE

Upon selection of this option single-line diagram will be redisplayed and asks the user to select windows that the busbars supplying it from outside must be considered 100% reliable.

(SELECET) VOLTAGE LEVEL 100% RELIABLE

Upon selection of this option the computer asks for the voltage level that the user wants its and higher voltage levels be considered 100% reliable, figure 12.18.

CUSTOMIZED BY TOM

The user may asks TOM Industrial Consultant. to customize one of his networks according to the client specifications. Please contact TOM.

HELP
Displays the on-line HELP information on the terminal.

RETURN
Exits from the reliability analysis parameter section to the reliability main menu.

12.7.1.12 [PRINT]

Sends the results of the last analysis to a line printer file (PRINTER.92). The listing contains system and study titles and details on paths, cut sets and reliability tables.

12.7.1.13 [FULL LIST]

Initiates the display, on the terminal, of the results of the last reliability calculation. Selecting this option by pressing the <SP> key or a click gives the full listing.

Figures 12.19, 12.20 and 12.21 show the output generated for the example system used throughout this manual. The <S> key on the bottom of the map is provided for searching.

12.7.1.14 [PLOT]

Sends the entire diagram (on the screen and out of the screen) together with the latest reliability results to a plotting file. The plotting diagrams can then be plotted on a plotter device by running PLOT.EXE (See Chapter 20) under the DOS command or its counterpart in Windows or Linux..

12.7.1.15 [HELP]

Displays the on-line HELP information on the terminal.

12.7.1.16 [RETURN]

Exits from the reliability section to the Main PASHA menu.

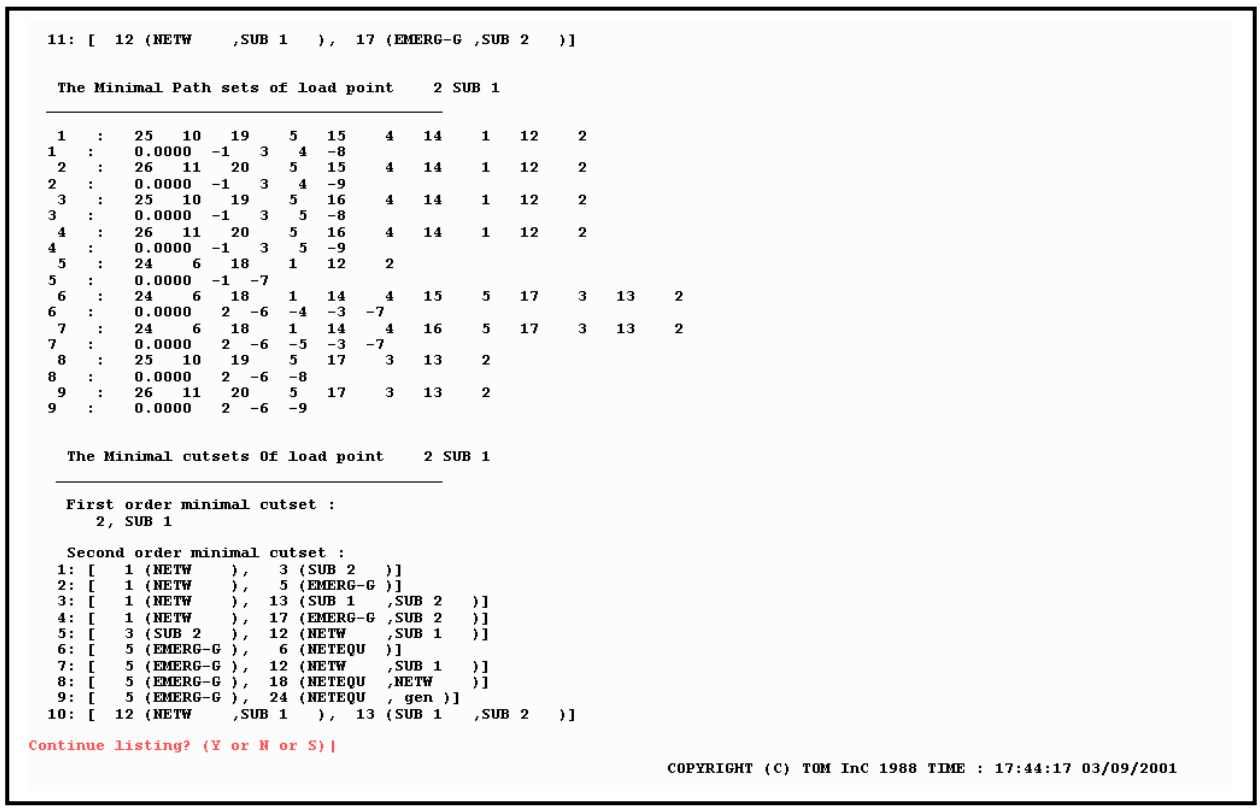


Figure 12.14

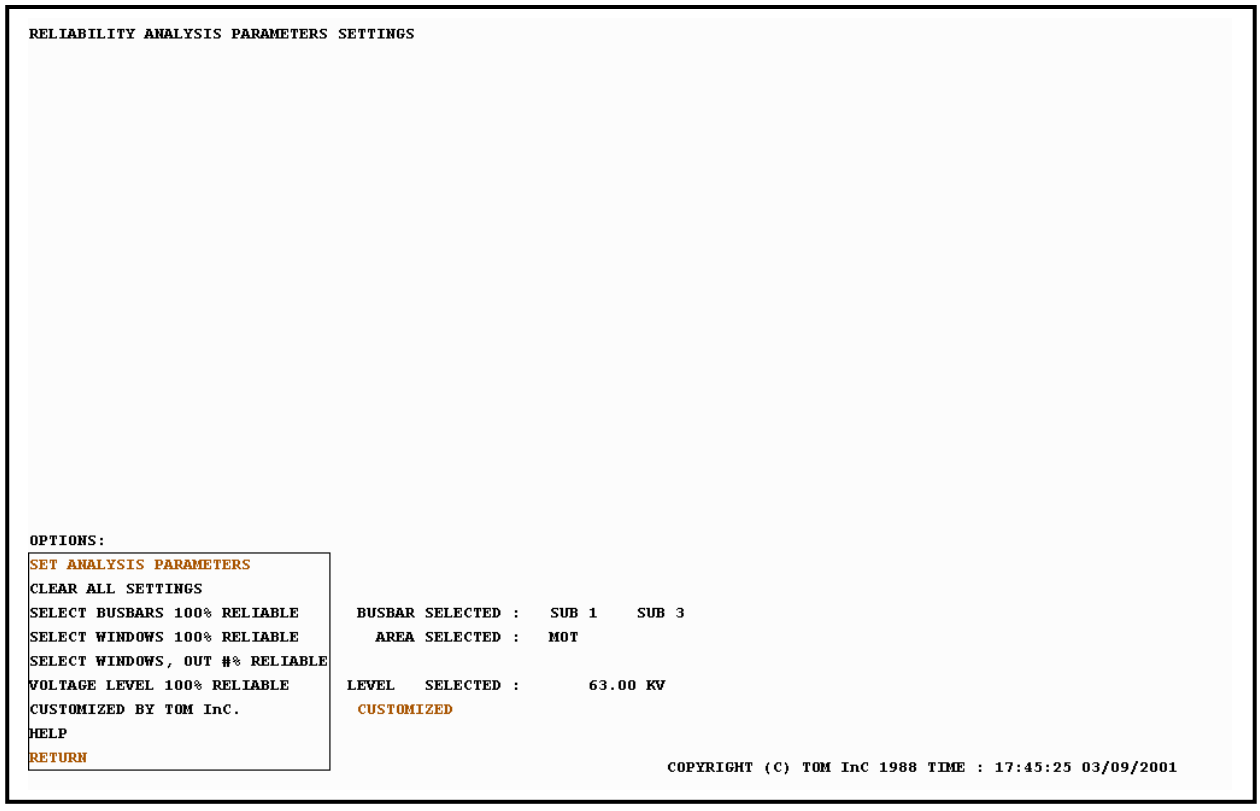


Figure 12.15

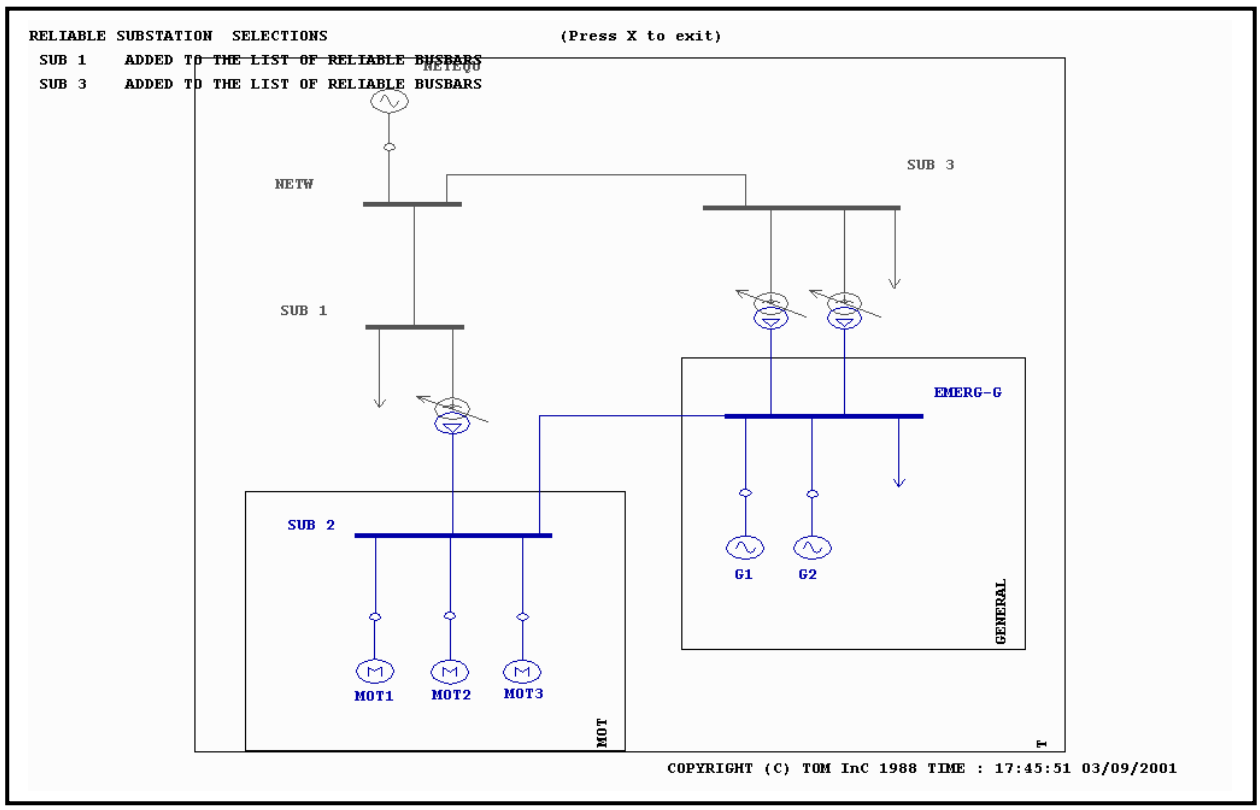


Figure 12.16

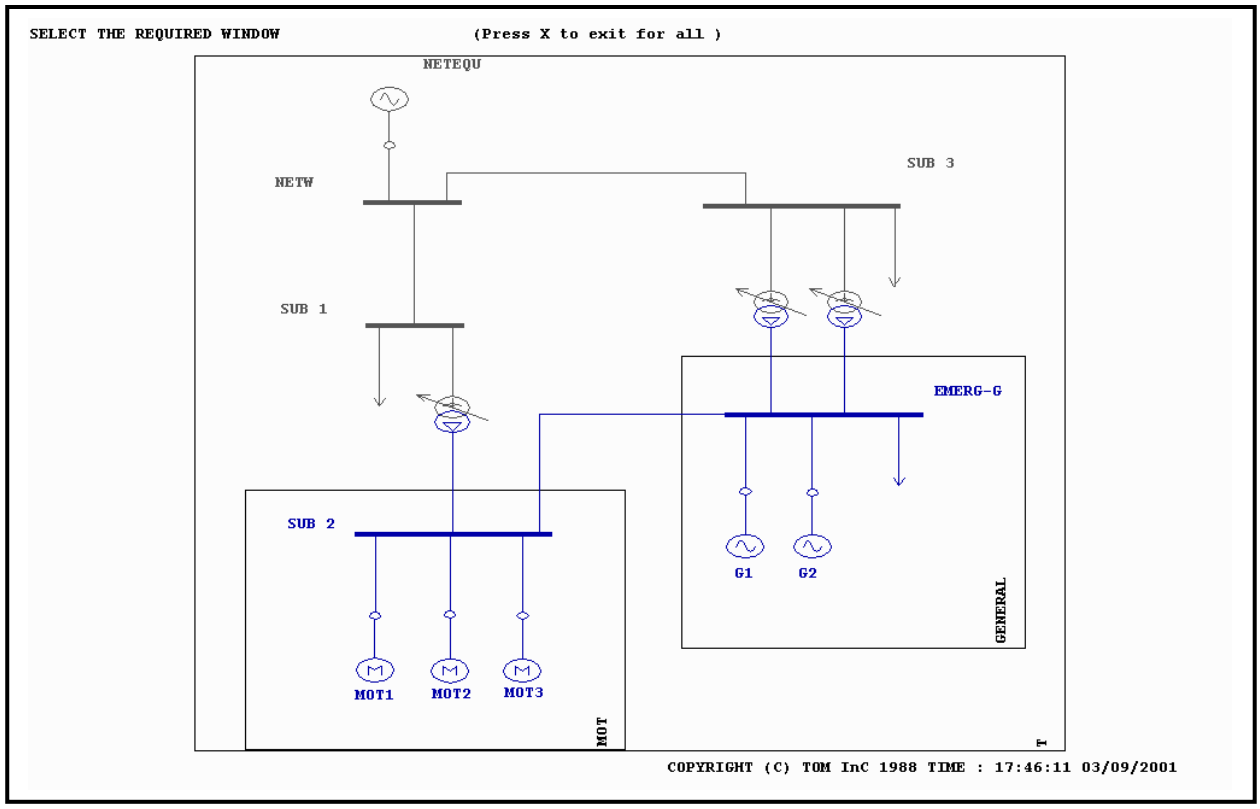


Figure 12.17

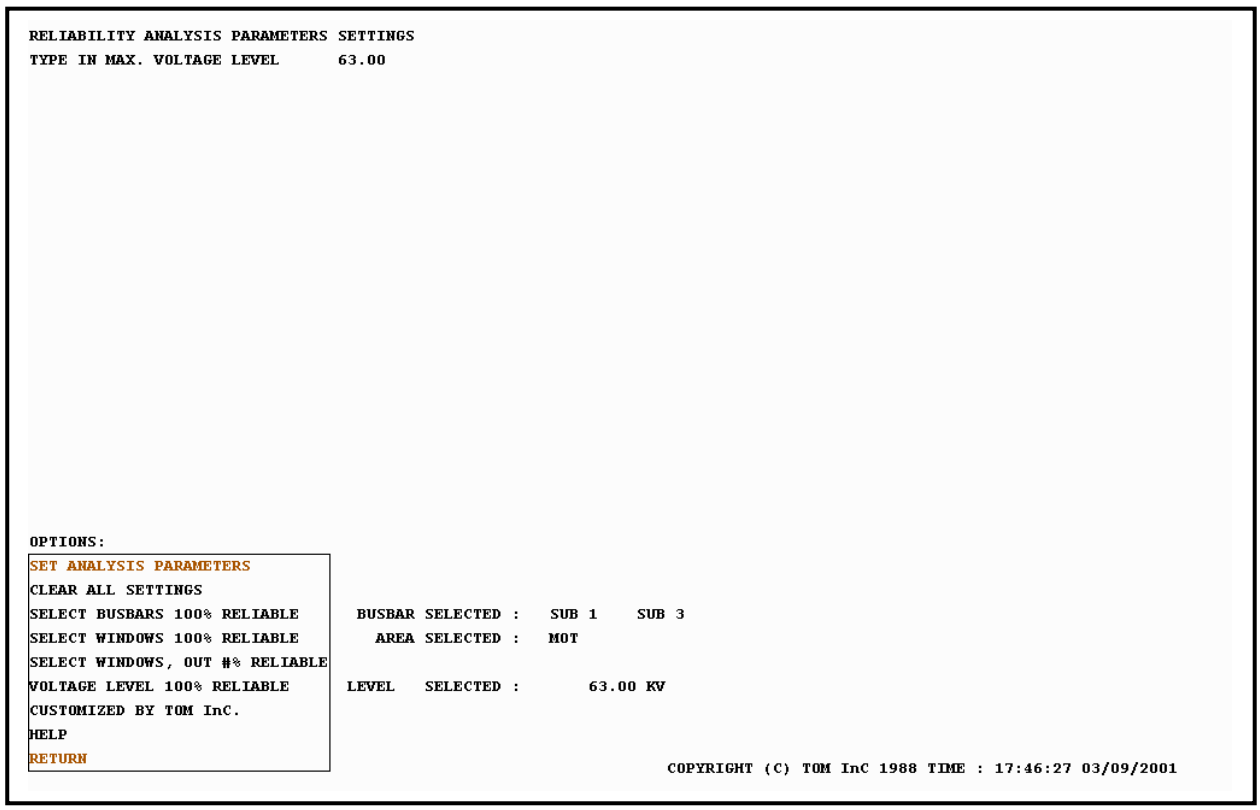


Figure 12.18

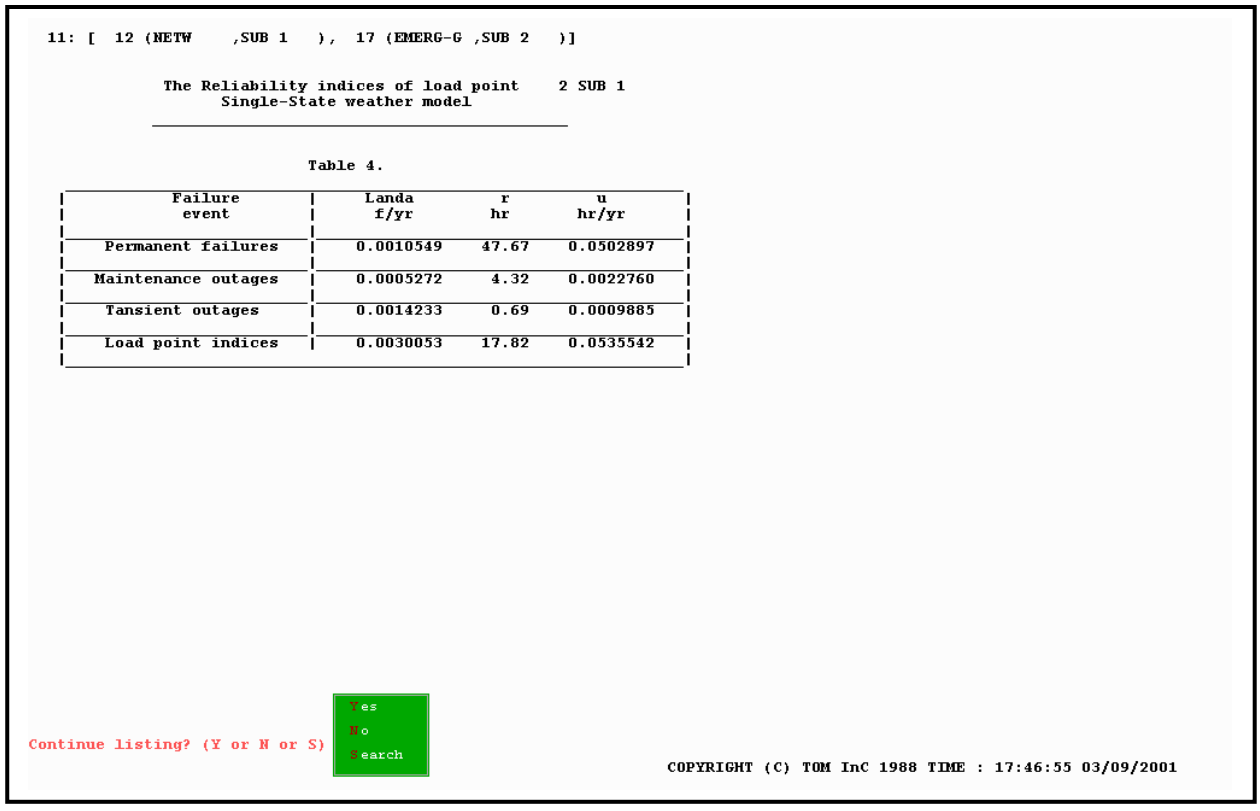


Figure 12.19

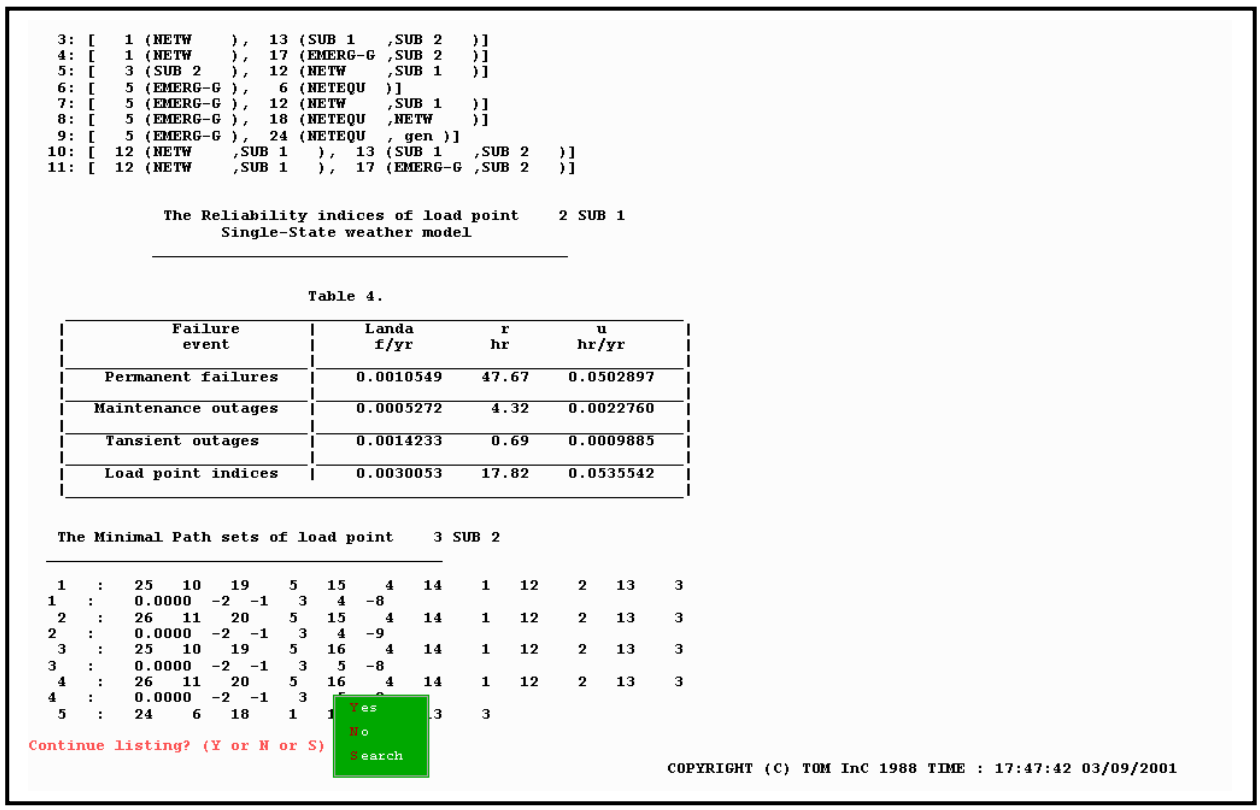


Figure 12.20

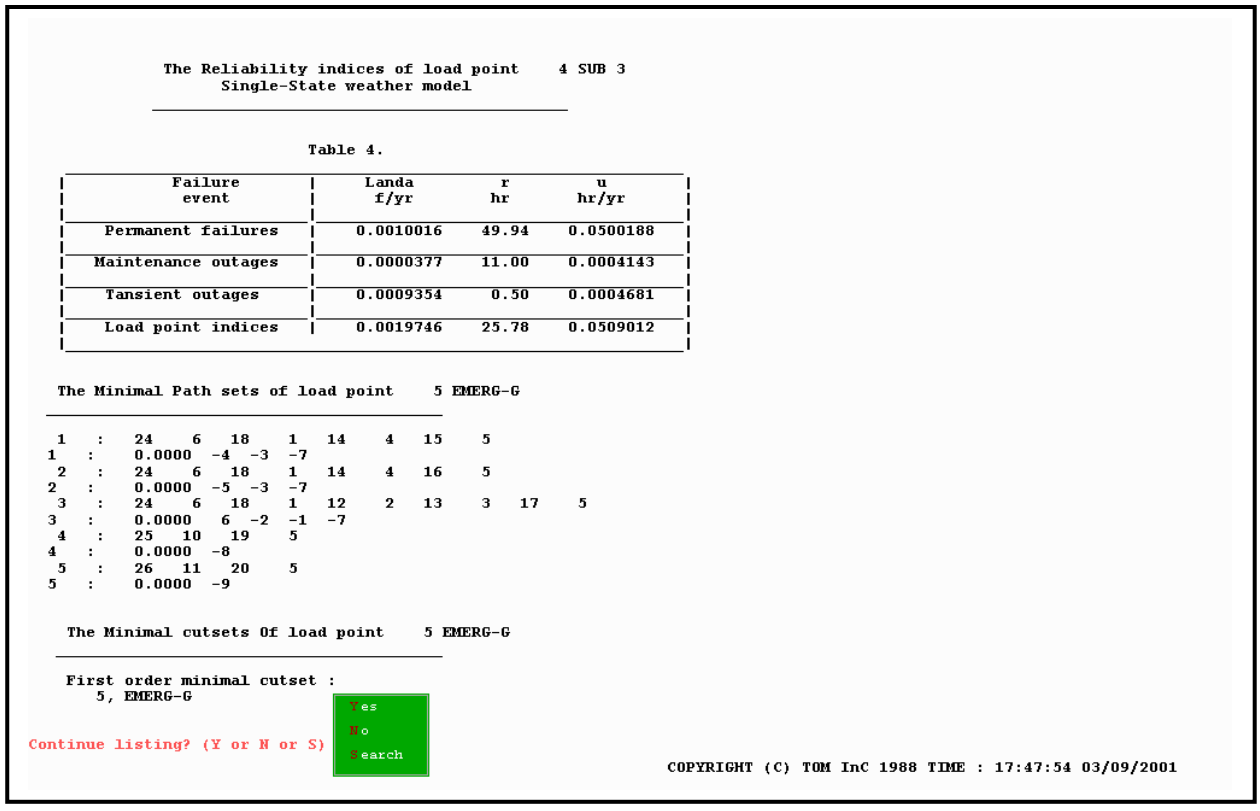


Figure 12.21

12.8 Summary

The implementation of reliability evaluation facilities within the PASHA package is described. These facilities include the calculation of basic indices of reliability analysis. The algorithms implemented provide a user friendly calculation process for more elaborate reliability analysis of LOLE scenario.

The analysis parameters enables the user to select the busbars or the areas he wishes to be considered 100% reliable in the calculation process. This is mostly needed for large scale systems where the number of paths will be enormous otherwise.