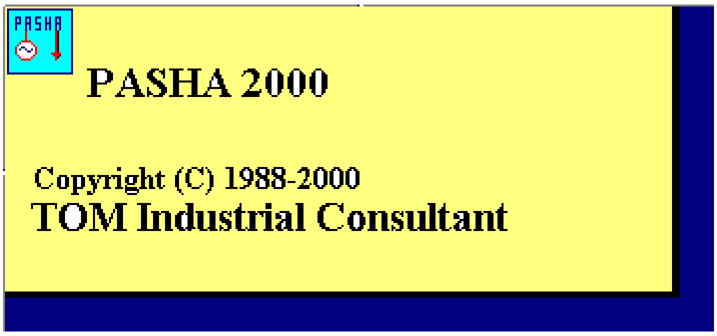

Chapter 8
The transient stability

The transient stability section of PASHA enables the user to simulate the dynamic response of an electrical power system to fault, load, machine and branch switching disturbances, using the step-by-step method and starting from a specific balanced operating condition.

The following analyses are some examples of transients that can be performed by using transient stability run of PASHA

1. Transient stability
2. Frequency dynamic analysis
3. Long term dynamics
4. Hunting problems
5. Power system restorations
6. Load shedding
7. Motor starting
8. Out of phase switching
9. Motor recovery from faults
10. Controllers dynamic performances
11. Arc furnace switching
12. Protection relays dynamic performances
13. SVC dynamics
14. Any other transients excluding fast transients, please visit chapter 14 for fast transients

A predictor-corrector method is used for solving the machine and controllers differential equations with the numerical integration, at each time step performed by the implicit trapezoidal method which is numerically stable by using variable step length to minimize numerical errors. The optimally-ordered, sparsity-programmed elimination is used for the solution of the network equations at each step.

8.1 Modelling of machines in the transient section

The models used for synchronous machines, induction motors and the excitation system are described below. The block diagram representations of the AVR and Governor models are shown bench of the figures 4.20 - 4.22.

8.1.1 Synchronous machine models

Four different synchronous machine models are available and the best model is selected for each machine depending on the data entered. The most complete model considers saliency, saturation, transient and subtransient modes and different excitation and speed governor control system arrangements. These provisions can accommodate the representation of round rotor or salient pole machines with slipping or brushless excitation systems, driven by steam or hydro turbine prime movers with flyball or electronic speed governors.

The synchronous machine models are based on the following equations in which the standard notation is used:

$$dw/dt = [w/(2.H)].(Pm-Pe-D.w) \quad (1)$$

$$dEq'/dt = [Efd-(Xd-Xd').Id-Eq']/Tdo' \quad (2)$$

$$dEd'/dt = [(Xq-Xq').Iq-Ed']/Tqo' \quad (3)$$

$$Ed'-Vd = Ra.Id-Xq'.Iq \quad (4)$$

$$Eq'-Vq = Xd'.Id+Ra.Iq \quad (5)$$

$$dEq''/dt = [Eq'-(Xd'-Xd'').Id-Eq'']/Tdo'' \quad (6)$$

$$dEd''/dt = [(Xq'-Xq'').Iq-Ed'']/Tqo'' \quad (7)$$

$$Ed''-Vd = Ra.Id-Xq''.Iq \quad (8)$$

$$Eq''-Vq = Xd''.Id+Ra.Iq \quad (9)$$

If only the Xd' value is entered, the model will be based on (4) and (5), with Xq' = Xd'. Machines with appropriate d-axis transient data are modeled on (2), (4) and (5), with Xq' = Xq. Equation (3) is included when the q-axis values are available, with one default: Xq' = Xd'. Finally equations (6) to (9) are also included when the subtransient data are available, with two possible defaults:

Xq" = Xd" and Tqo" = Tdo".

Modeling of the excitation system is based on the IEEE AVR models, details of which can be found in :

"Computer Representation of Excitation Systems", IEEE Committee Report, Paper 31, IEEE Summer Power Meeting, 1967.

8.1.2 Induction machine models

Induction motors are represented by models, which can include subtransient effects due to double cage rotors, and driving loads with different torque-speed characteristics. Other loads may be represented either as fixed impedance or constant power loads. For the induction motor loads the torque-slip relationship is:

T=T0.(A + B.N + C.N**2) with A = 1.0 -B -C

Constants B and C are set on Induction motor data page 2.

The relationships for the induction motor models are:

$$ds/dt = (Te-Tm)/(2.H) \qquad (10)$$

$$dE'/dt= -j.w.s.E'-[E'-j(Xoc-X').I]/To'' \qquad (11)$$

$$dE''/dt= +j.w.s.(E'-E'')+(dE'/dt)+[E'-E''+j(X'-X'').I]To'' \qquad (12)$$

where

s = slip
w = radial frequency

Equality between transient and subtransient parameters is assumed when data for one cage only is entered.

8.1.3 Static load models

Much of the domestic load and some industrial load consist of heading and lighting, especially in the winter, and these can be considered as constant impedances. Most loads, however, consist of a large quantity of diverse equipment of varying levels and composition and some equivalent model is necessary.

By default PASHA represents the model of the load by fixed impedances. Introducing the models as constant power or constant current, needs to change **L-MODEL** of section 4.5.1.

The variation of the load power with frequency introduced by **D** and **D’** factors as can be entered in section 4.5.2. It will be considered in dynamic frequency studies. Any suddenly reduction of load with voltage can be considered by using under voltage switching as introduced in section 4.5.2 too.

Using UDEM facilities as described in 8.1.4 and chapter 10, enable the user to enter other models of a load. A model such as shown in the following, which both depends to voltage and frequency can be treated in this way.

$$P=Kp\,(V)^{pv} . (f)^{pf} \quad , \quad Q=Kp\,(V)^{pv} . (f)^{pf}$$

8.1.4 User Defined Equipment Modeling

The User Defined Equipment Modeling (UDEM) is an addition to transient stability calculation. The basic function of the UDEM is to allow the user to input a representation of a controller, or a model of the power system radial equipment in a block diagram form and store this for later simulation studies.

The UDEM accomplishes this in a similar way to PASHA: i.e. by drawing the block diagram model graphically and entering the parameters interactively.

The function of UDEM and its features are fully described in chapter 10. Please refer to this chapter for further information.

8.2 Requirements for running the stability calculation

The first requirement for running the stability simulation is to enter sufficient information for the system models to function correctly. This is the users responsibility, as the study can not be run until the data satisfies some stringent test in the initial phase of the stability calculation.

It is also necessary to have carried out a **load flow** calculation before starting the simulation, because the load flow solution is used to set up the initial system conditions.

Finally a switching operation of some kind must have been specified, otherwise the study will run, but produce constant results (as it will continue in its initial state). However, there would be two situations that the results will be varied without a switching operation.

1. Since load flow do not checks the limits of some variables, e.g. Turbine maximum power, the transient stability may experience changes of the system variables if the limits exceed, i.e. the power output is larger than turbine maximum power specified in governor data page.

2. The systems that are marginally unstable under steady state conditions.

8.2.1 Switching operations

Each line, transformer or shunt in the system can be switched twice during a study, at times which can be set on line data page 2 in the edit section.

Induction motors can have up to four pre-set switching operations (including motor starting) as well as automatic under-voltage, under-speed and re-acceleration switching at the levels set on Induction motor data page 2 in edit section.

An amount of loads can be switched in or out during transient stability run, this might be due to a specified switching time set on busbar data 2 or might be as a result of switching due to under-frequency, under-voltage, or over-flux relays set on busbar data 2,4, and 5.

Lines might also be switched out automatically due to the operation of fuses, overcurrent, distance and unit relays. Please refer to chapter 11 for **Dynamic simulation of protection performance**, which illustrates the performance of the switching of the relays in transient stability.

8.3 Accessing the transient stability section

The transient stability section of PASHA is accessed by selecting the [TRANSIENT STABILITY CALCULATION] option on the main menu with either:

(i) The <O> key which does not carry out the calculations but jumps directly into the transient stability display options for use with any existing results.

(ii) The <F> key which does carry Frequency dynamics simulation. The difference between frequency dynamics and transient stability is that in frequency dynamics the variation of load active and reactive power with frequency as entered in busbar data page 2 will be considered. Besides the plot of busbar frequency will be shown instead of machine angles during the study run. From now on both calculations are referred as transient stability in this manual.

(iii) Any other key or a click, which starts the initial data checks and runs the transient stability simulation.

8.3.1 The initial phase

When the transient stability calculation option is selected, data checks are initiated, and the program displays the results of these checks on the screen, as shown in figure 8.1. If an error is found the type of plant whose data is incorrect is indicated, and the user invited to look at the results, using the [FULL LIST] option, and the calculation is terminated.

This phase also recalculates the initial powers of the machines and compares the results with those stored at the last loadflow calculation, provided there is no power mismatch between the load flow and initial conditions. The simulation then enters the sequence of step by step stability calculations.

8.3.2 The step simulation

After the initial phase is complete, the user is invited to press any key or a click and the screen is cleared and whilst the initial conditions are being calculated, a set of axes is drawn.

The axes are used primarily to plot the swing curves for all synchronous machines in the system and are, therefore, scaled to accommodate the study duration time, on the horizontal axis with positive and negative angular displacements, equal to the swing angle limit, in the vertical direction. The rotor angle of each machine is plotted at each step, as it is calculated. If the user has been selected frequency dynamics, the busbars including machine frequencies will be plotted instead of the angular displacement.

In addition if any switch was operated at this time, a vertical yellow line is drawn marking the time at which the switching operation occurred. In windows versions the cause of switching messages will be written in the message box.

This initial plot drawn while the transient stability program is running, gives the user a very compact overall picture of how the study is progressing and is particularly useful in the initial runs. A study can be terminated at any time, simply by pressing the <O> key, for interrupt. In Windows platform you may select interrupt from the option menu. Figure 8.2 shows an example of this initial plot.

TRANSIENT STABILITY IN PROGRESS...

NO ERRORS IN GENERATOR DATA.

NO ERRORS IN AVR DATA.

NO ERRORS IN GOVERNOR DATA.
NO ERRORS IN MOTOR DATA.

PRESS ANY KEY TO START CALCULATIONS AND PLOTTING OF RESULTS

Figure 8.1

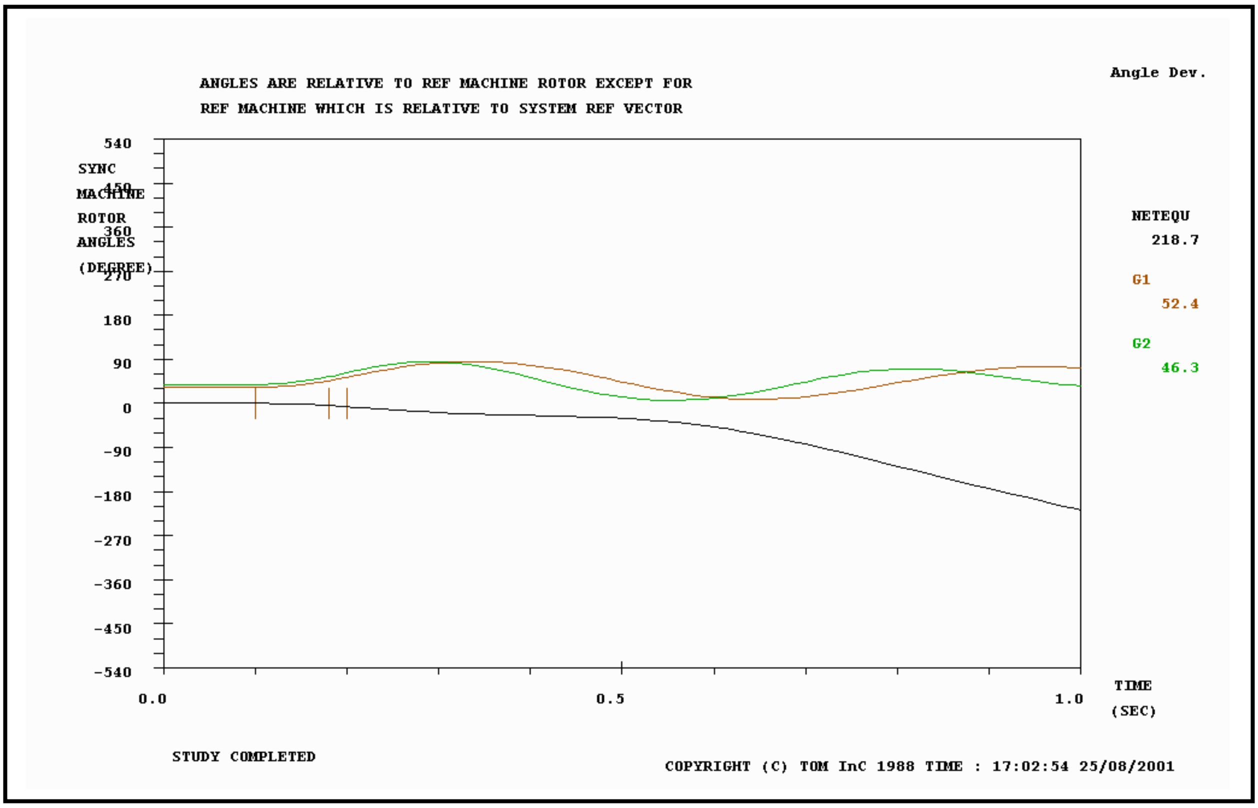

Figure 8.2

PASHA uses a variable step length. The step is reduced after switching operations and when machine conditions are changing rapidly, but is increased when the rates of change are slow, thus minimizing the solution time. To ensure appropriate entries in the 'RESULTS' file the step length is adjusted to relate to the printout interval as follows:

Printout interval = (2**N).(step length), where N=0,1,2,3,4

At switching times there will be two calculations. One considers the condition of the system just before switching and the other is for the condition of the system just after the switching.

Any switching action performed by the relays during the transient stability run will be written in message box together with a beep to inform the user about the relays actions.

The end of a run is indicated by the appearance of the cursor on the screen and the maximum deviation of the angles (or frequencies) and the stability options become available for selection, by pressing the <O> key or just a click. The system data, initial conditions and the results of the study are automatically written into a file, which can now be displayed, page by page, on the terminal, or can be printed to a printer file. Other options can be used to produce further graphical output, through the [PLOT] options.

The maximum deviation of angles of generators (or maximum deviation of frequencies of generators in case of frequency dynamics calculation) will also be written in message box. The user may scroll the message box with small arrows in front of it as described in chapter two.

8.4 The transient stability display menu

These options can be accessed either immediately after completion of a transient stability calculation (by pressing the <O> key or just a click) or through the PASHA main options (by selecting the transient stability calculation option, using the cursor and pressing <O>. The latter is useful only if a transient stability study was run previously, and the disc file created by the run was retained.

The transient stability display menu is shown in figure 8.3, and the options are described below.

8.4.1 [PRINT]

Sends the results of the transient stability calculation to a printer file. This routine has been extended in PASHA 9.2A to allow partial listings of the RESULTS file, and to start printing at a specified step. For details of this see the FULL LIST option below.

When printing starts a message is displayed as shown in figure 8.4, 'PRINTING STARTED...', the user should then wait until the 'PRINTING COMPLETED.' message is displayed. The printer file as for the other studies is named PRINTER.92.

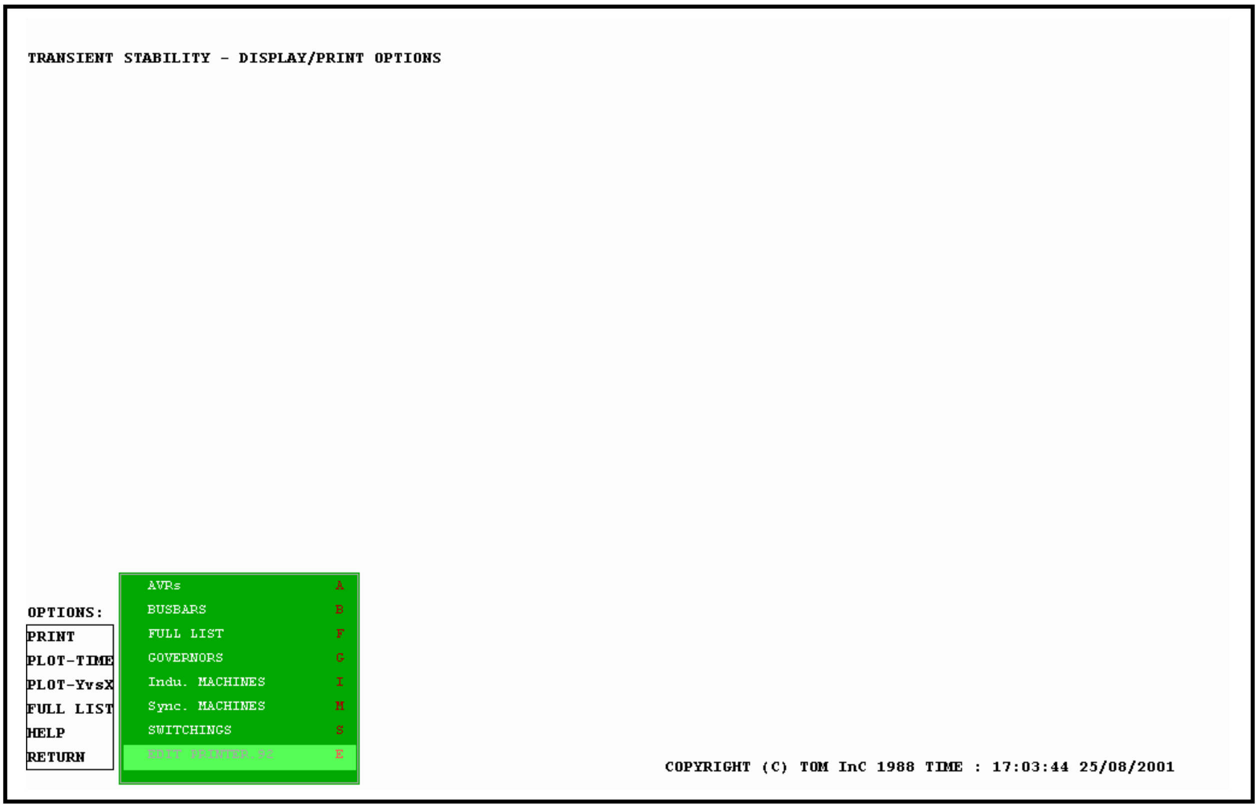

Figure 8.3

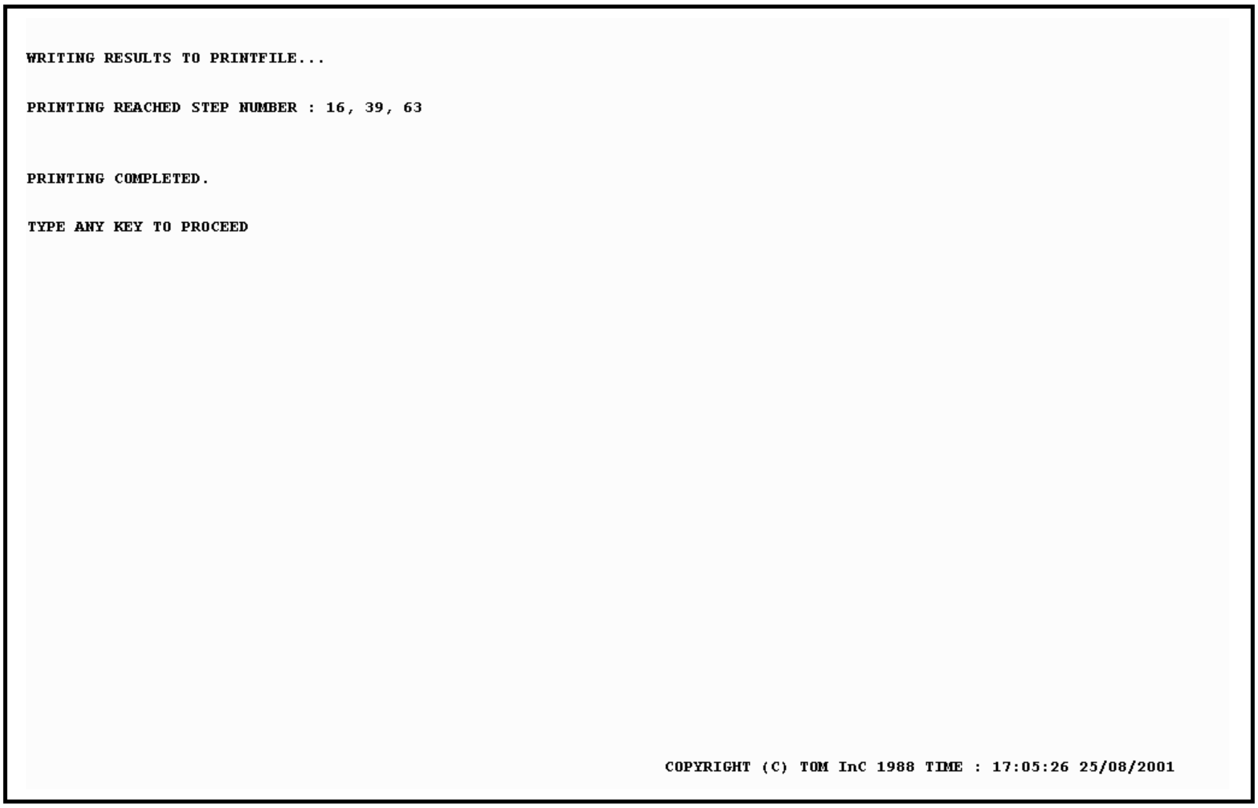

Figure 8.4

8.4.2 [PLOT TIME]

The plotting facilities in PASHA allow the user to plot almost all the system variables including the relays dynamics behavior, as well as the outputs of any UDEM module elements used in the study. This page is shown in figure 8.5, and is described in section 8.5.

8.4.3 [PLOT X-Y]

This is like the PLOT-TIME as referred in previous section but it provides a facility to plot the variables against each other. The root locus of the variables may be plotted in this way, however, in the period of the study range.

8.4.4 [FULL LIST]

Initiates the display, on the terminal, of the tabulated results of the last transient stability calculation. A sample printout is shown in figure 8.6. This routine has been written in such a way that to increase the flexibility of the screen listings. The following keys may be pressed to skip to the results file immediately or press SPACE bar or a click to enter to another entry page which the following options can be selected through an editing menu. These also apply to the PRINT option above.

F - produce a full listing

A - list only AVR results

G - list only Governor results

M - list only Synchronous machine results

I - list only Induction motor results

B - list only Busbar results, Line flows and Relays operations are included.

S- list the switchings

These special keys may also be selected from green box menu as it appears when the cursor is located over FULL LIST or PRINT menu.

When looking at the result files you can skip to a specific page by entering the number in response to the prompt at the bottom of the screen, which is shown in figure 8.6.

8.4.5 [RETURN]

Exits from the transient stability section and displays the PASHA main options.

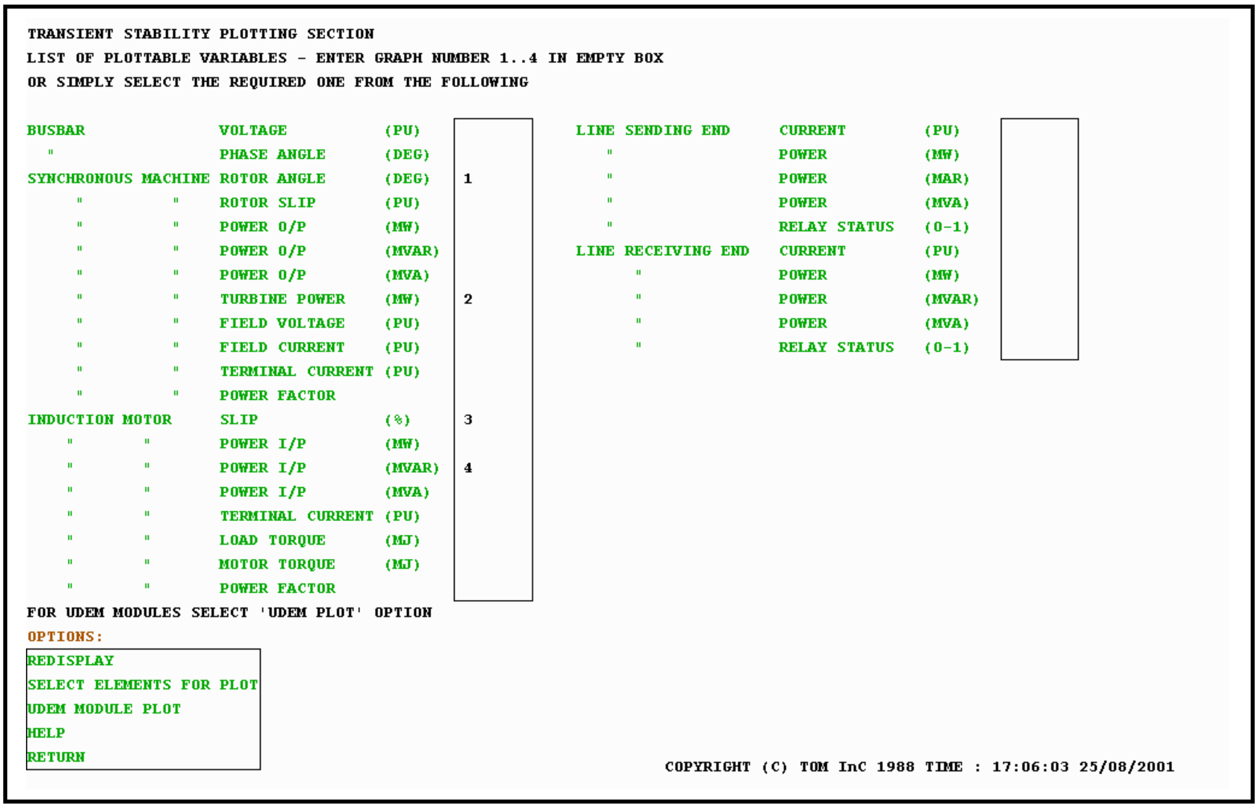

Figure 8.5

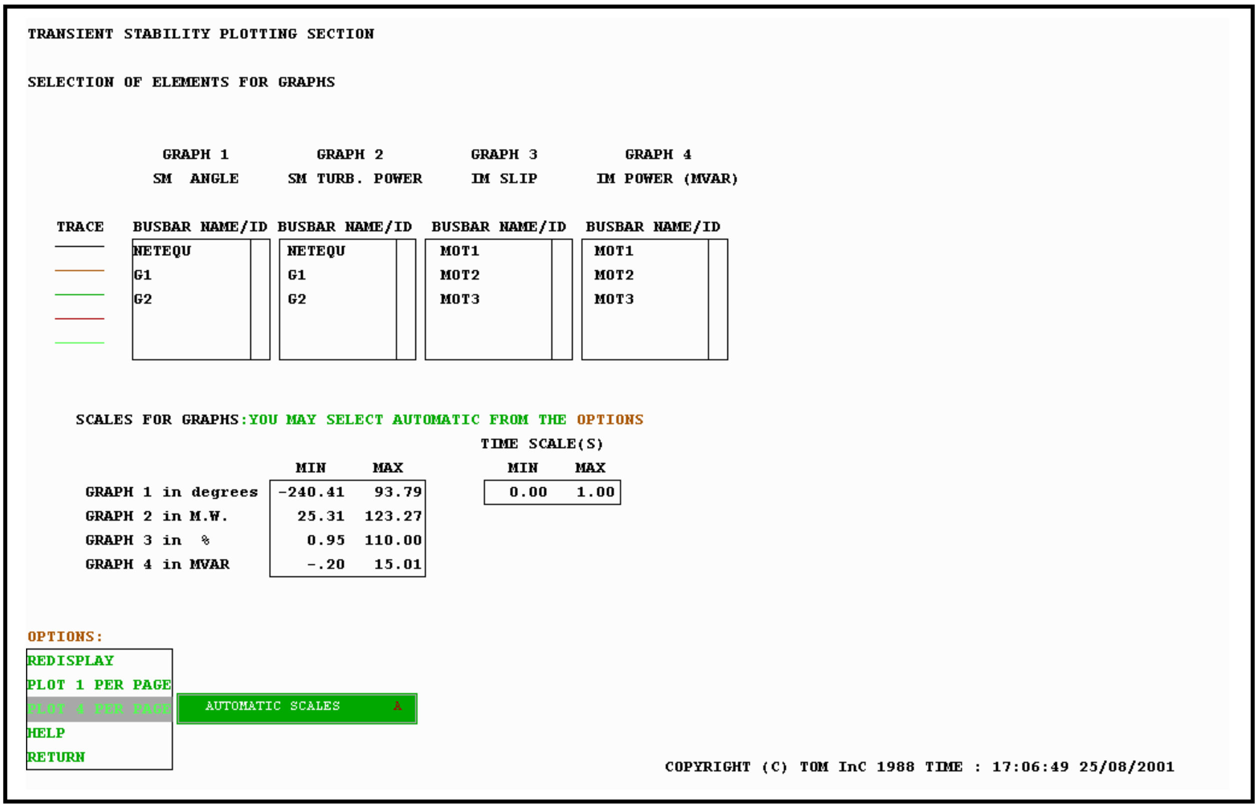

Figure 8.6

8.5 The Transient Stability Plotting Section

Two RESULTS files are produced by the transient stability study, one stores the normal results in a digitized form, and the other stores the automatic scaling factors used for plotting UDEM variables.

They are quite distinct from the result files used to store load flow and fault level results. They are however overwritten each time a new study is called for, and it may be necessary to retain either a print of listings and graphical displays, or to rename the results files before calling for another study.

You can plot almost all the system variables that are tabulated in the result file. This page is shown in figure 8.5. It gives a list of all the plotable quantities and allows you to select up to four graphs at one time.

To plot any variable simply click on the variable option you wish to plot **or** position the cursor over the box to the right of the variable you wish to plot, and press the space bar or a click. Then enter the number of the graph on which you wish to see the plot. You can enter all four graph numbers on one line to enable you to plot four graphs of the same quantity, or select each graph to be of a different plot variable.

Note that if you have previously entered a '2' say on one line and you re-enter it on another line, the previous entry is cleared.

Note also that, in order to plot those variables relating to the lines or transformers including the status of the relays, you must select these lines as to be monitored in LINE DATA 2 edit page. However, if the dynamic variation of a relay during the transient is more than 10% the line that the relay is located on will be automatically monitored and the results are available for plotting.

Once you have selected the graphs you wish to plot, position the cursor over the [SELECT ELEMENTS FOR PLOT] option and you will proceed to the next page to enter the names of the Busbars etc. you wish to plot. For more information on this see the help provided on the HELP option on entry to this page.

The following options are available:

[REDISPLAY]	: redisplays this page.
[SELECT ELEMENTS FOR PLOT]	: plots graphs specified on this page.
[UDEM MODULES PLOT]	: plots UDEM modules variables.
[HELP]	: displays this information.
[RETURN]	: returns to T/S options.

8.5.1 [SELECT ELEMENTS FOR PLOT]

This page enables you to specify which elements you wish to see on the system variable plots. It sets up each graph entry box with the title of the system variable that you are plotting (or tells you it is not specified if you did not select it). It is shown in figure 8.7.

Each of the four boxes has five lines so you can plot up to five elements on each graph. To enter a Busbar name position the cursor over the box you require, and move it over the trace line you want (traces are shown to the left of the screen) and press the space bar or a click. Then type in the name followed by <CR> or a click, the cursor then positions itself on the next line for you to enter the next name. If you do not wish to enter any more names type <CR> or click at this point. The names can also be selected from green boxes. In this case just select the busbar name from the green box by clicking over the name.

Certain of the plots (i.e. SM and IM quantities) may require that you enter an ID code that refers to a specific machine. Enter this by positioning the cursor over the small box to the right of the main box, and pressing the space bar or a click, then enter the ID code.

In order to save some time it is also possible to enter busbar names and ID's by using the 'FILL' key. This fills the box with the ordered names of all the SMs, IM or busbars depending on the graph title. To use this facility simply position the cursor over the box you wish to fill, and press a <F>. Note that if you are plotting the same quantity on all four graphs, the fill option will only fill the boxes until all the element names have been entered.

If you wish to remove all the names from any box, you can do so by using the 'CLEAR' key. Type a C when you have positioned the cursor over the box that you wish to empty.

Below the four main element entry boxes are two more which, enable you to enter the scales for the graphs. An automatic scaling is also provided which removes the requirement for scales being entered. If you like to use automatic scaling, you may leave these boxes blank and choose green box automatic scales or type <A> over the [PLOT] option from the following options.

The scale boxes are set up to display the units of the system variable that you are plotting, and you can set the upper and lower limits to whatever you wish. To enter the scales, select the line of the box that you wish to enter the scale for and press the space bar. Then enter the lower and upper limits for the graph followed by <CR> or a click.

The time scale is also entered in the same way, but the lower limit should not be set less than zero. The time scale initially takes the amount of the study time as default value.

The following options are available:

[**REDISPLAY**] : Redisplays the page or if selected by pressing a <T> transfers to the UDEM plot page.

[**PLOT 1 PER PAGE**] : Plot the graphs one on each page, to get the next graph type a space after the graph is complete, or type an N to enter notes on the graph. Type <A> to select automatic scales.

[**PLOT 4 PER PAGE**] : Plot all the graphs on one page notes can be added as above. Type <A> to select automatic scales.

[**HELP**] : Displays help information.

[**RETURN**] : Returns to the previous page, or if entered with an X returns to the main TS options.

8.5.2 [UDEM MODULE PLOT]

This page enables you to plot the outputs of any of the elements in an UDEM module that you have used in a transient stability study. It is shown in figure 8.8.

The page provides you with up to four graphs of five plots, so you can plot up to 20 different outputs.

To select a specific module, position the cursor over the box marked BUSBAR NAME, and press the space bar or a click when you are over the graph line you want. Then enter the busbar name associated with the SM that the controller is situated on. Then press <CR> and position the cursor over the ID column, and press the space bar or a click, then enter the ID of the SM. The UDEM type must then be entered in the TYPE box, in the same way as above. This must be AVR or GOV or GEN or I-M or LOAD depending on the module type. The UDEM ID code will then appear to the right of this.

The actual number of the element of the UDEM module is entered in one of the four boxes headed ELEMENT NUMBER. You must select the box that corresponds with the graph number next to the busbar name. Enter the element number by pressing the space bar or a click and typing the number followed by <CR>. A number will appear to the right of your entry which is the value of the automatic scaling factor used in the plotting (see SCALES below).

If you wish to plot all of the outputs of all the elements of only one module, a short cut is possible. As above enter the busbar name, ID and TYPE, then instead of entering the element numbers by hand. Then position the cursor over the BUSBAR NAME box on the line of the just entered data, and type an F. This then 'fills' the graph boxes etc. with all the UDEM numbers for the plot. (Note you will still have to enter the time scale).

The UDEM plotting section has an automatic scaling feature which removes the requirement for scales being entered. The scales are in terms of percentages of the elements maximum value during the study.

These scaling factors are stored in a file produced during the stability run, and are displayed on this page next to the element numbers. If this file does not exist then you must repeat the study, i.e. the O option on entry to the Transient stability section cannot be used.

```
STEP NUMBER =    4     TIME = 0.0400      MAXIMUM ITERATIONS PER STEP =   3     STEP LENGTH = 0.0100      ITS/PRINT =    7
----------------------------------

SYNCHRONOUS MACHINES

 BUSBAR   M/C    ROTOR    POLE    ROTOR      MECH.        POWER OUTPUT        TERM.      TERM.      FIELD      FIELD      POWER
  NAME    NO.    ANGLE    PRS     SLIP       POWER      ACTIVE    REACTIVE    VOLTAGE    CURRENT    VOLTAGE    CURRENT    FACTOR
                DEGREES   SLPD    P.U.        MW          MW        MVAR        P.U.       P.U.       P.U.       P.U.

NETEQU      *     0.13*    0     -.0000    112.064    112.086     30.548     1.000      1.162      1.001      1.001      0.9648
G1               33.00     0     -.0000     40.024     40.022     29.949     1.021      0.490      0.906      0.907      0.8006
G2               39.01     0     0.0000     30.012     29.997     19.023     1.021      0.348      0.831      0.832      0.8445

AUTOMATIC VOLTAGE REGULATORS

 BUSBAR  M/C  CONTROLLED  I/P FILTER   AMPLIFIER   FEEDBACK
 NAME    NO.  BUS  VOLTS    SIGNAL      SIGNAL      SIGNAL

NETEQU           1.000       1.000       1.170
G1               1.021       1.021       0.126
G2               1.021       1.021       0.095

THERMAL TURBINE GOVERNOR(S)

 BUSBAR  M/C        FLYBALL      CONTROL SYSTEM     CONTROL VALVE
  NAME   NO.        SIGNAL        SIGNALS (MW)      SETTING   (MW)
                    (SLIP)         C1          C2          C3

G1                  -.0000       0.001       0.000       40.024
G2                  0.0000       0.000       0.000       30.012

INDUCTION MOTOR LOAD

 BUSBAR  M/C       ROTOR     MECH.      POWER INPUT       TERM.     TERM.       TORQUE (MJ)        POWER
  NAME   NO        SLIP      POWER    ACTIVE  REACTIVE   VOLTAGE   CURRENT    LOAD      MOTOR      FACTOR
                   P.C.       MW        MW      MVAR       P.U.      P.U.

MOT1              1.7961     1.000     1.061    0.755     1.016     0.013     1.0183    1.0189     0.8147
MOT2              1.7979     2.000     2.123    1.511     1.016     0.026     2.0368    2.0379     0.8147
MOT3              1.0531     4.803     4.872    2.418     1.016     0.054     4.8544    4.8095     0.8958
PAGE    8; Type X to exit, any other for next page  or step number=
                                                                  COPYRIGHT (C) TOM InC 1988 TIME : 17:07:36 25/08/2001
```

Figure 8.7

```
TRANSIENT STABILITY PLOTTING SECTION

SELECTION OF MODULE ELEMENTS FOR GRAPHS

GRAPH SELECTION
          BUSBAR      MODULE                                  SCALES(%)
          NAME  ID   TYPE   ID      TIME SCALE             MIN        MAX
GRAPH 1  EMERG-G     LOD    FINL    MIN      MAX         -105.00    105.00
GRAPH 2  G2          AVR    WBCO     0.00     1.00       -105.00    105.00
GRAPH 3                                                  -105.00    105.00
GRAPH 4                                                  -105.00    105.00

ELEMENT SELECTION
          GRAPH   1          GRAPH   2          GRAPH   3          GRAPH   4
      ELEMENT  SCALING   ELEMENT  SCALING   ELEMENT  SCALING   ELEMENT  SCALING
TRACE  NUMBER  FACTOR     NUMBER  FACTOR     NUMBER  FACTOR     NUMBER  FACTOR
 ____   14      14.62      14      25.45
 ____   17       0.10      16       0.33
 ____   15       0.10
 ____   16       0.10
 ____   21       1.55

OPTIONS:
REDISPLAY
PLOT 1 PER PAGE
PLOT 4 PER PAGE
HELP
RETURN
                                                                  COPYRIGHT (C) TOM InC 1988 TIME : 17:12:48 25/08/2001
```

Figure 8.8

The scaling on the graphs runs from -100% to +100%, but this can be changed to whatever you wish by selecting the appropriate line with the cursor, pressing the space bar and entering the new scales.

The time scale box is in seconds, and the data is entered in the same way as the above.

The following options are available:

[**REDISPLAY**] : Redisplays the page, or if selected by pressing a <T> transfers to the system plot page.

[**PLOT 1 PER PAGE**] : Plot the graphs one on each page, to get the next graph type a space after the graph is complete, or type an N to enter notes on the graph.

[**PLOT 4 PER PAGE**] : Plot all the graphs on one page. When you select this option a question will be asked you to whether or not you want to display any system graphs on unspecified graphs. This means that if you answer yes, the unspecified graph will have the system variable graphs plotted instead. i.e. if you don't call for a graphs 3 and 4, say, you will get whatever you specified on the system variable page for these graphs plotted.

[**HELP**] : Displays help information.

[**RETURN**] : Returns to the previous page, or if entered with an X returns to the main TS options.

8.6 Examples of transient stability studies

The best way to illustrate the use of the transient stability section is to give an example. In this section two examples are presented:

(i) A three phase fault caused by a transformer failure

(ii) An induction motor start

Both examples use the power system developed throughout this manual, and they describe all the changes made to the system data and network diagram.

8.6.1 Example 1: the application of a fault

In order to simulate the effects of a fault the network diagram has to have a shunt added to the busbar. In this case a shunt is applied to the EMERG-G busbar, to simulate a short circuit on the transformer leading to it. This is added to the diagram by selecting the [MODIFY THE PRESENT NETWORK DIAGRAM] and positioning the cursor over the EMERG-G busbar and pressing the <S> key to select it. The cursor is then moved to the desired position for the shunt, and a <Y> pressed. You may also use the green tool bars to add shunt. In this case just select the shunt symbol from the tool bars and click on substation to select it. Then move cursor to the desired position and click again. A shunt will be added to substation as before. The resulting diagram is shown in figure 8.9.

Since a new piece of plant has been drawn, an extra entry has been created in the edit section. For a shunt this entry is in the line data. Figure 8.10 shows the new Line data 1 page, with the entry of 0.0001 for the reactance of the shunt. You may leave this blank (i.e. assume ZERO) for three phase fault. For L-G, L-L, or L-L-G fault you can enter an appropriate impedances. That is Thevenan equivalent of (Z0+Z2) for L-G, (Z2) for L-L and (Z0*Z2)/(Z0+Z2) for L-L-G fault. The Thevenan equivalents can be obtained from the fault studies.

For the study it is desired that:

(i) The shunt is initially switched out, and is switched in at 0.01 seconds after the study starts, and that it is then cleared at 0.18 seconds.

(ii) The fault is cleared by switching the transformer circuit out, and this has to be specified as a line switching operation at 0.18 seconds, but is specified 0.2 to show flexibility.

The line and shunt switching operations are specified on line data page 2. The STATUS column specifies whether a line is initially switched in or out, and the SW-TIM1 and SW-TIM2 specify the switching times. (See 4.5.2.)

Figure 8.11 shows the required values entered on line data page 2.

The STATUS value affects the diagram, in that pieces of plant that are initially switched out are shown disconnected. Figure 8.12 shows the diagram after the above switching operations have been specified. It should be noted that a piece of plant that is shown switched out will take no part in either fault level or load flow calculations, i.e. the same results detailed in chapters 6 and 7 could be obtained using the network shown in figure 8.12.

The transient stability is then run, and the resulting synchronous machine rotor angle plot that is displayed as the study progresses is shown in figure 8.13. This shows that the system is stable, and recovers fairly quickly.

Once the study is complete the mouse cursor is in action again. To display the options the user presses the <O> key or just a click. It is then possible to select the plotting section by choosing the [PLOT] option from the menu.

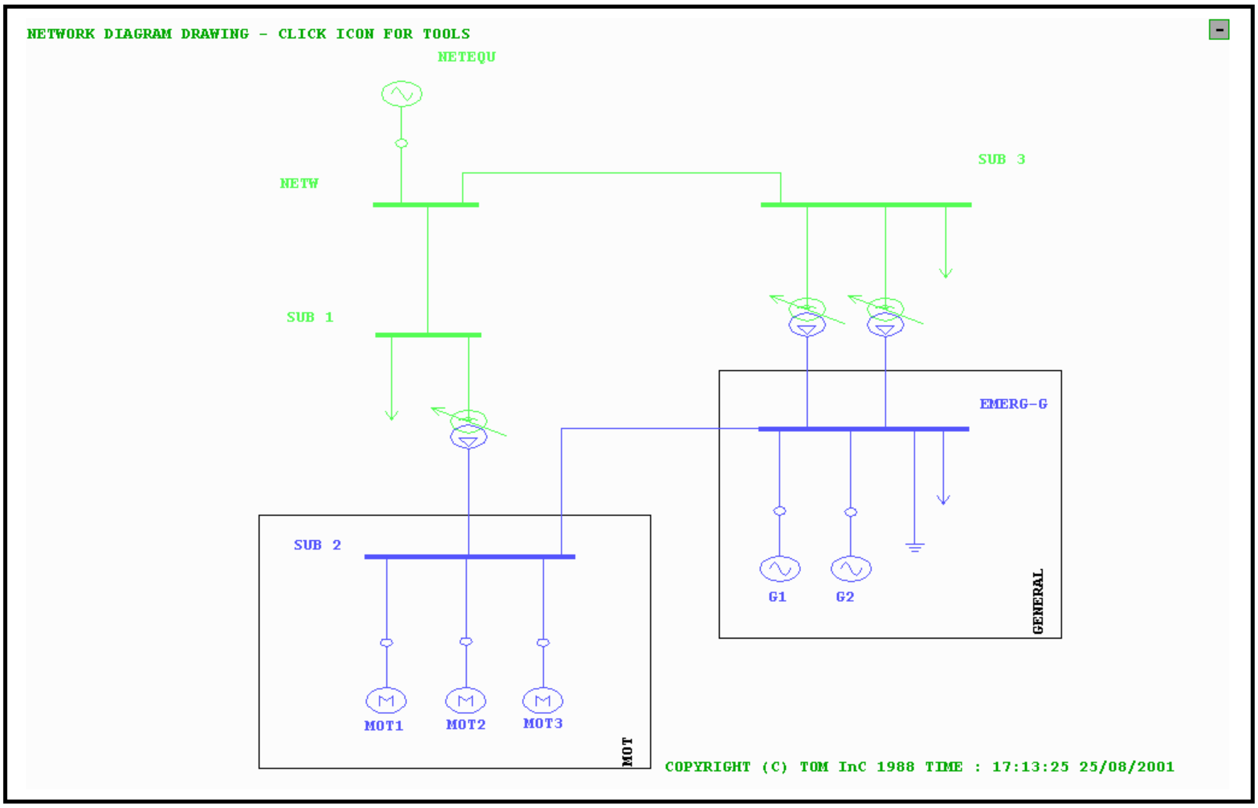

Figure 8.9

LINE DATA 1 PAGE 1 OF 1

BUS-SEND	BUS-REC	I	RESIST-PU	REACT-PU	SUSC-PU	ZSQ-R-PU	ZSQ-X-PU	AREA-TO-AREA	
NETW	SUB 1	C	0.03080	0.09729	0.02112	0.10392	0.27172		
SUB 1	SUB 2	T	0.01870	0.37500		0.01590	0.31900		MOT
NETW	SUB 3	C	0.09900	0.21870	0.04500	0.30510	0.81090		
SUB 3	EMERG-G	T	0.01870	0.37500		0.01590	0.31900		GEN
SUB 3	EMERG-G	T	0.01870	0.37500		0.01590	0.31900		GEN
EMERG-G	SUB 2	C	0.00674	0.00413	0.00390	0.02023	0.01238	GEN	MOT
NETEQU	NETW	C	0.00027	0.00085	0.00033	0.00099	0.00300		
MOT1	SUB 2	C	0.02023	0.01239	0.00005	0.06070	0.03715	MOT	MOT
MOT2	SUB 2	C	0.02023	0.01239	0.00005	0.06070	0.03715	MOT	MOT
MOT3	SUB 2	C	0.00506	0.00310	0.00021	0.01518	0.00929	MOT	MOT
G1	EMERG-G	C	0.00135	0.00083	0.00078	0.00405	0.00248	GEN	GEN
G2	EMERG-G	C	0.00202	0.00124	0.00052	0.00607	0.00372	GEN	GEN
EMERG-G	EMERG-G	C		0.00010				GEN	GEN

OPTIONS:

REDISPLAY SYSTEM BASE MVA= 100.0

HELP

RETURN

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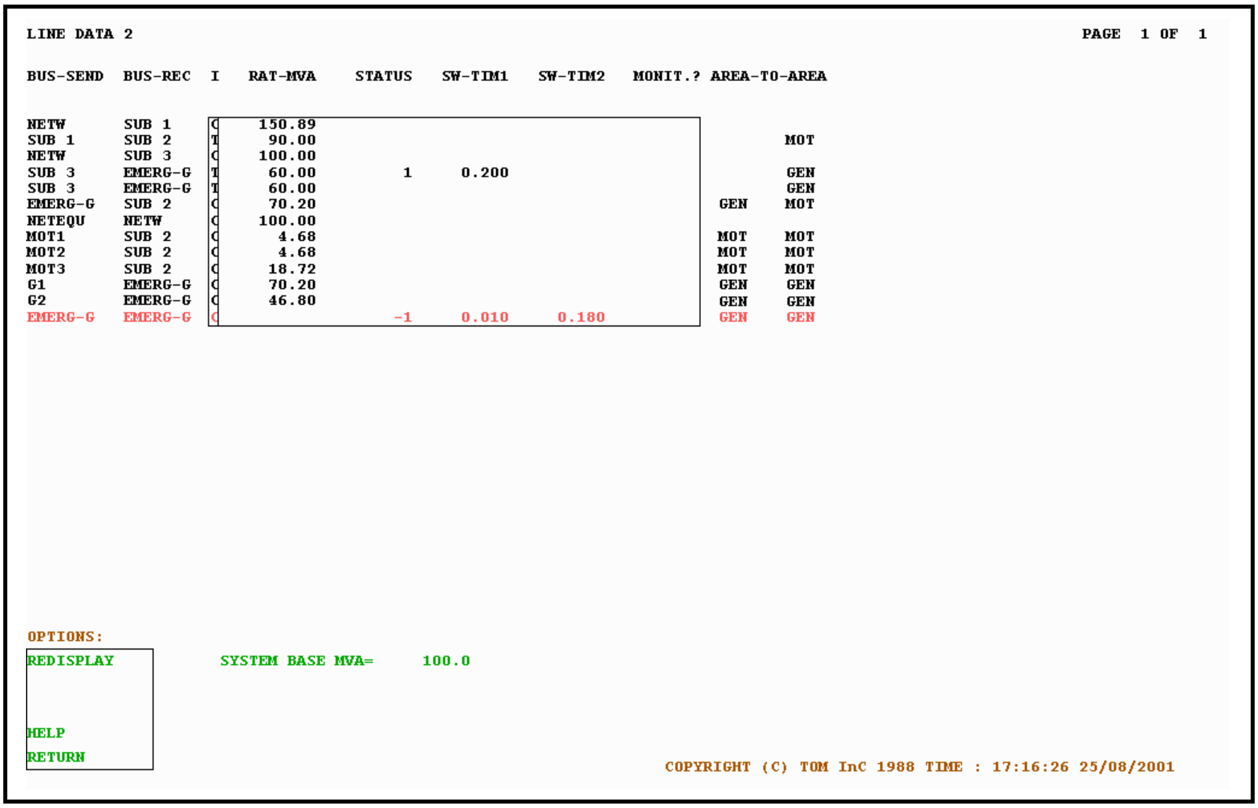
Figure 8.10


LINE DATA 2 PAGE 1 OF 1

BUS-SEND	BUS-REC	I	RAT-MVA	STATUS	SW-TIM1	SW-TIM2	MONIT.?	AREA-TO-AREA
NETW	SUB 1	C	150.89					
SUB 1	SUB 2	T	90.00					MOT
NETW	SUB 3	C	100.00					
SUB 3	EMERG-G	T	60.00	1	0.200			GEN
SUB 3	EMERG-G	T	60.00					GEN
EMERG-G	SUB 2	C	70.20					GEN MOT
NETEQU	NETW	C	100.00					
MOT1	SUB 2	C	4.68					MOT MOT
MOT2	SUB 2	C	4.68					MOT MOT
MOT3	SUB 2	C	18.72					MOT MOT
G1	EMERG-G	C	70.20					GEN GEN
G2	EMERG-G	C	46.80					GEN GEN
EMERG-G	EMERG-G	C		-1	0.010	0.180		GEN GEN

OPTIONS:
REDISPLAY
HELP
RETURN

SYSTEM BASE MVA= 100.0

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Figure 8.11

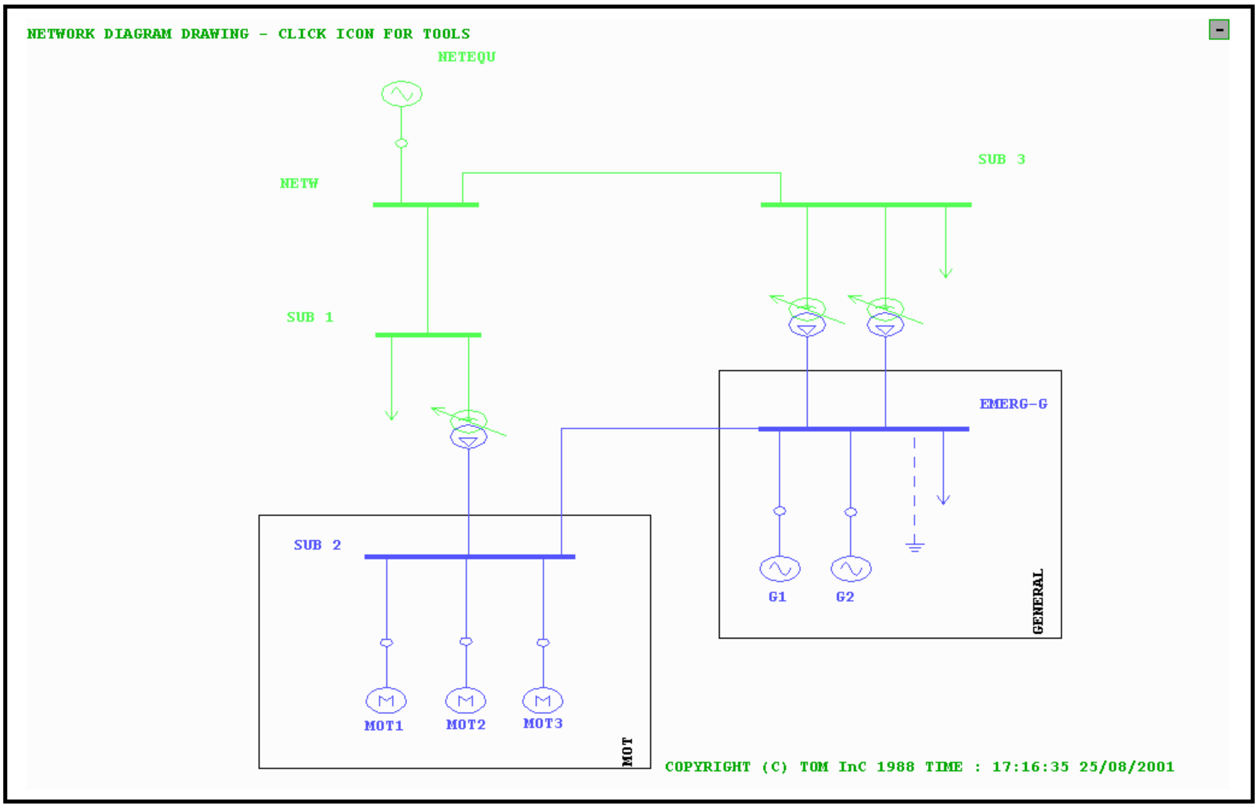

Figure 8.12

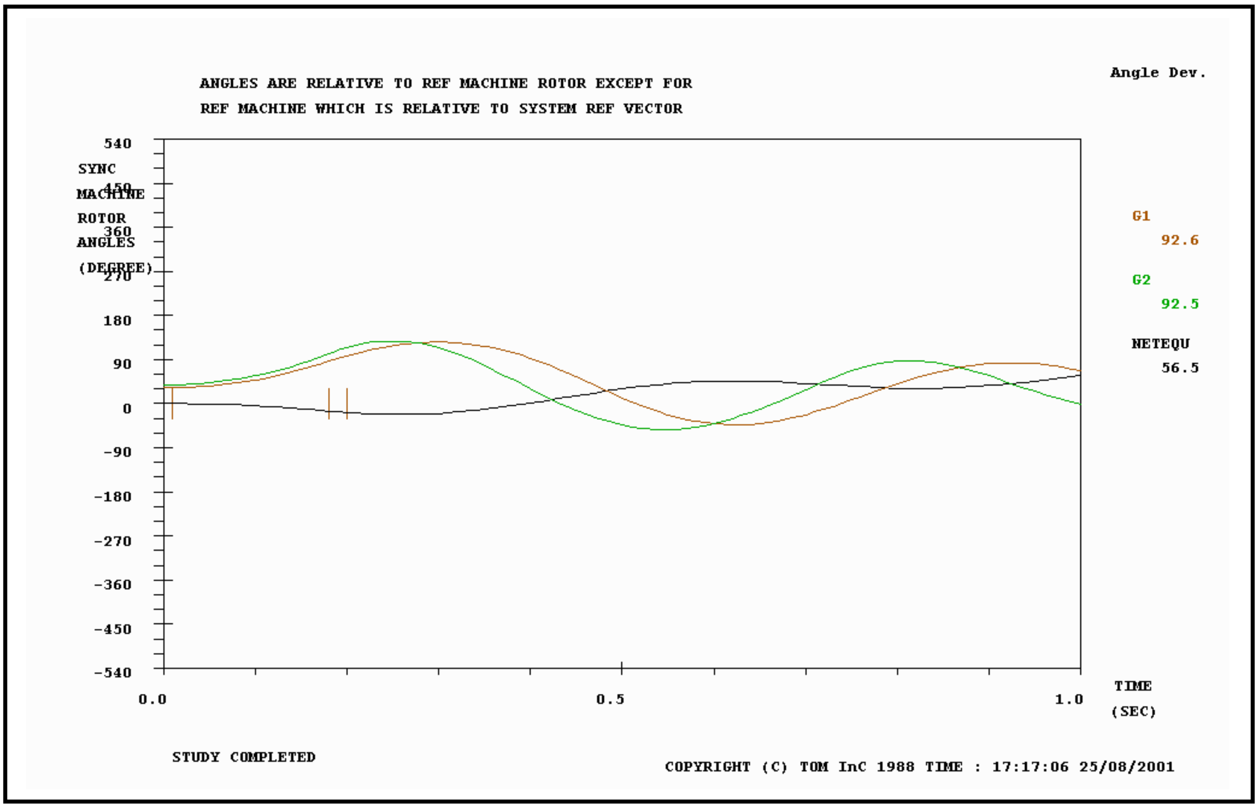

Figure 8.13

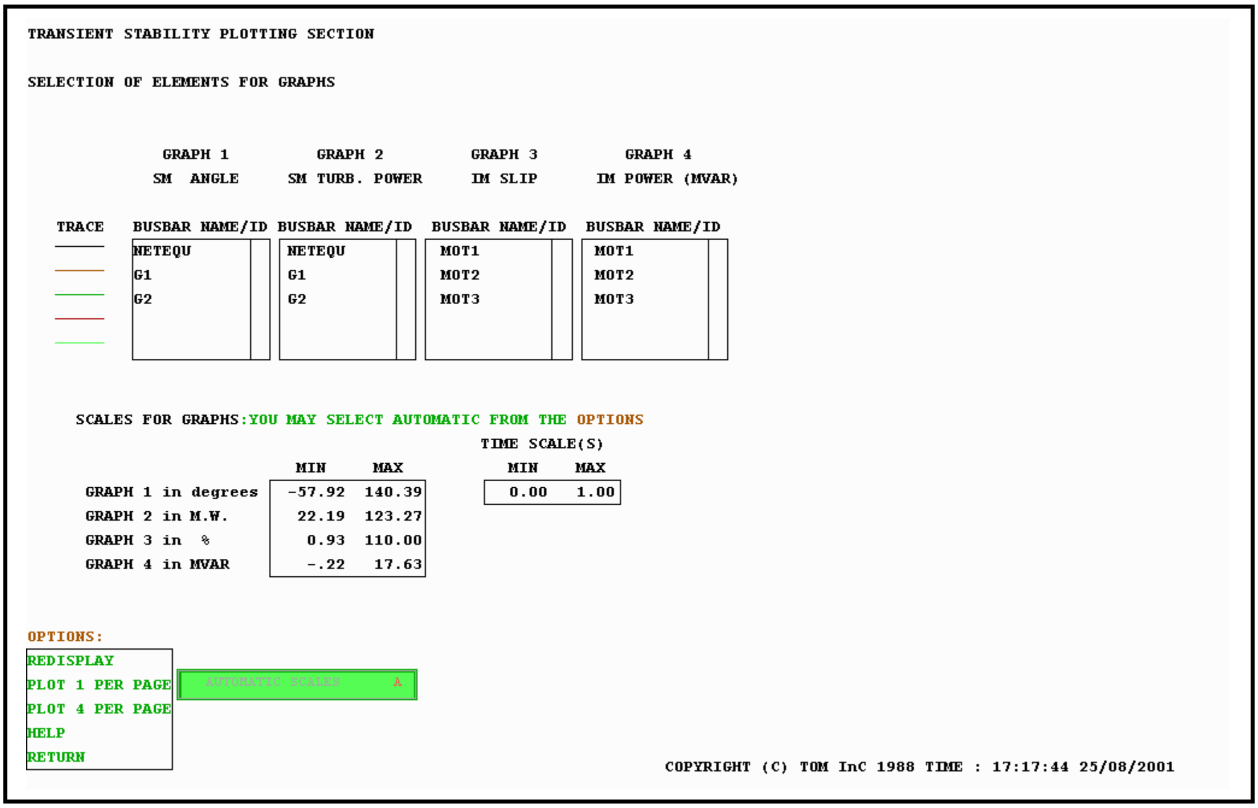

Figure 8.14

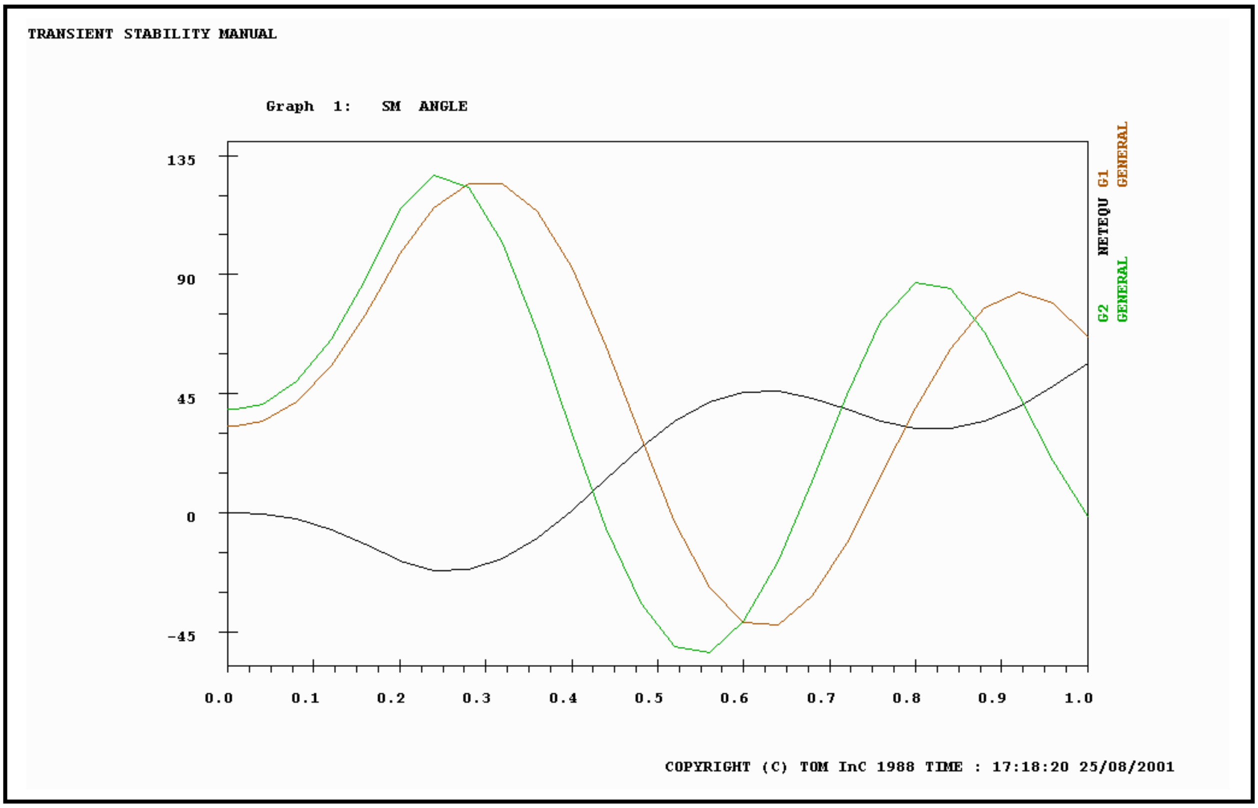

Figure 8.15

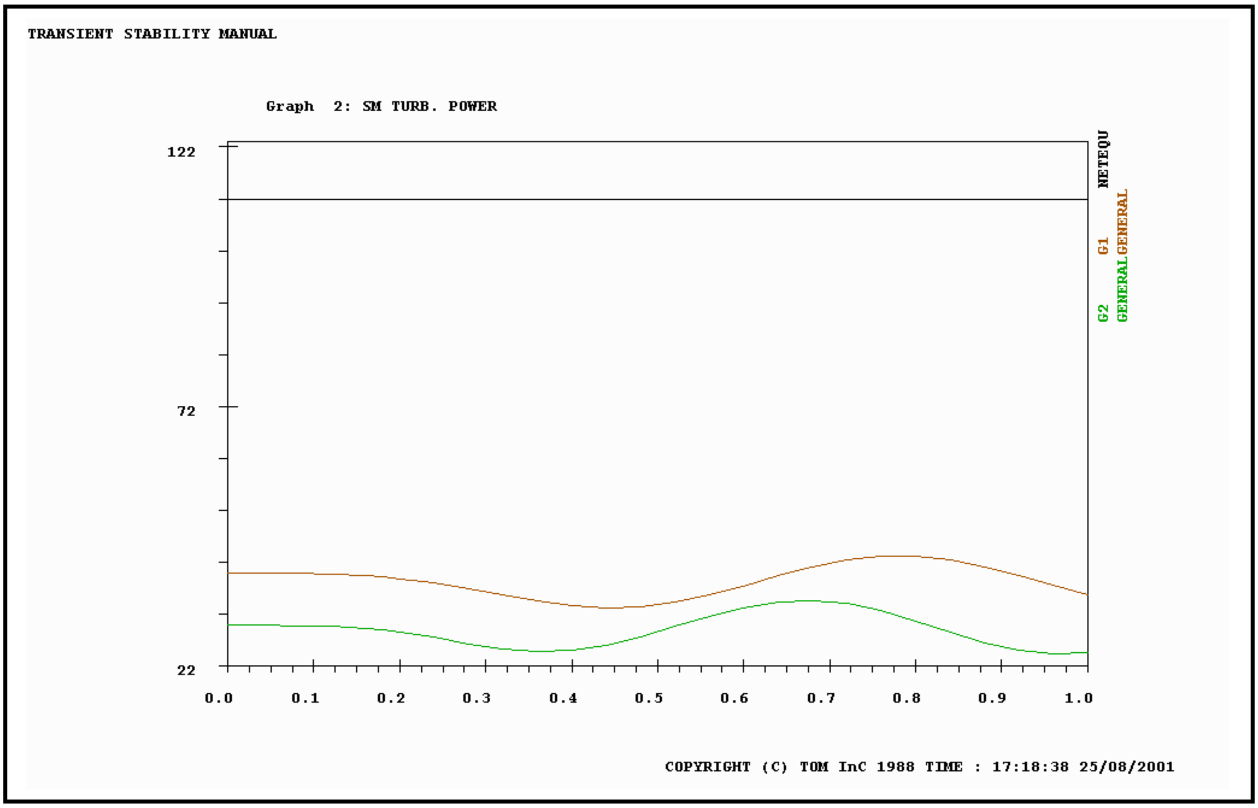

Figure 8.16

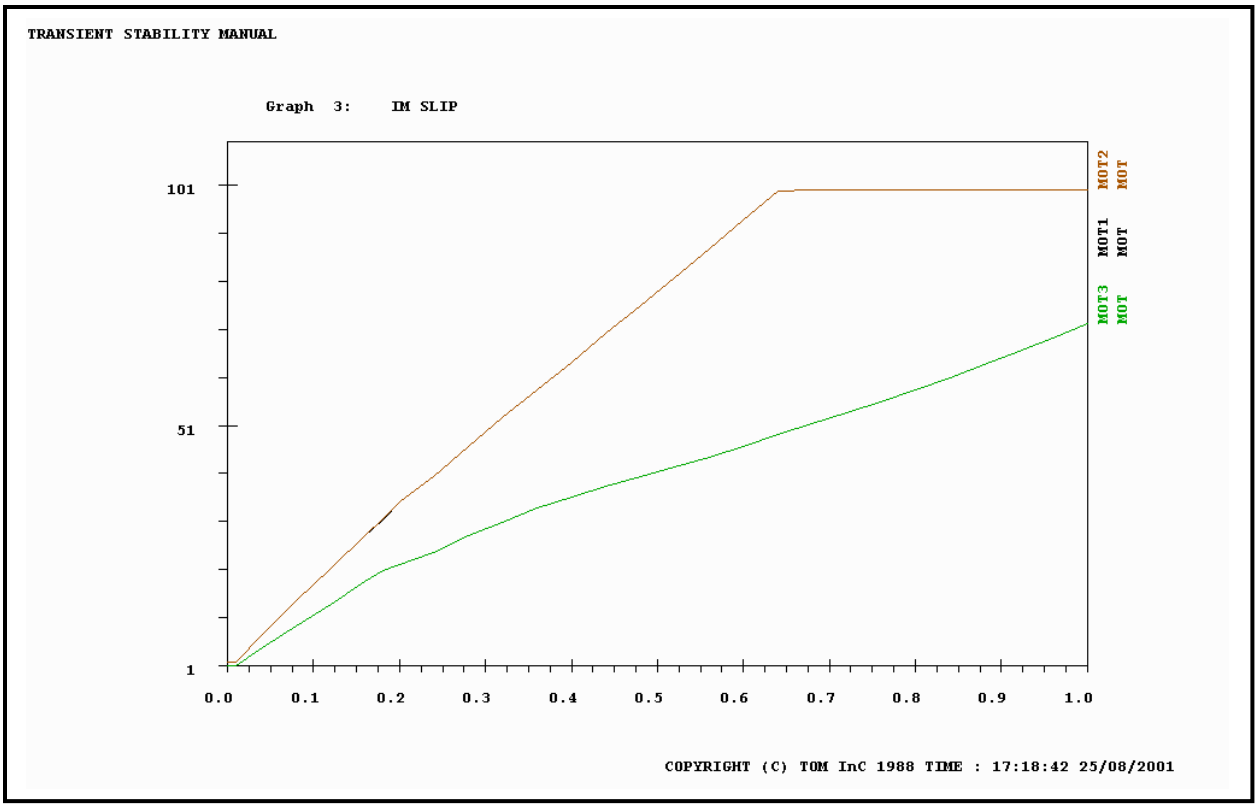

Figure 8.17

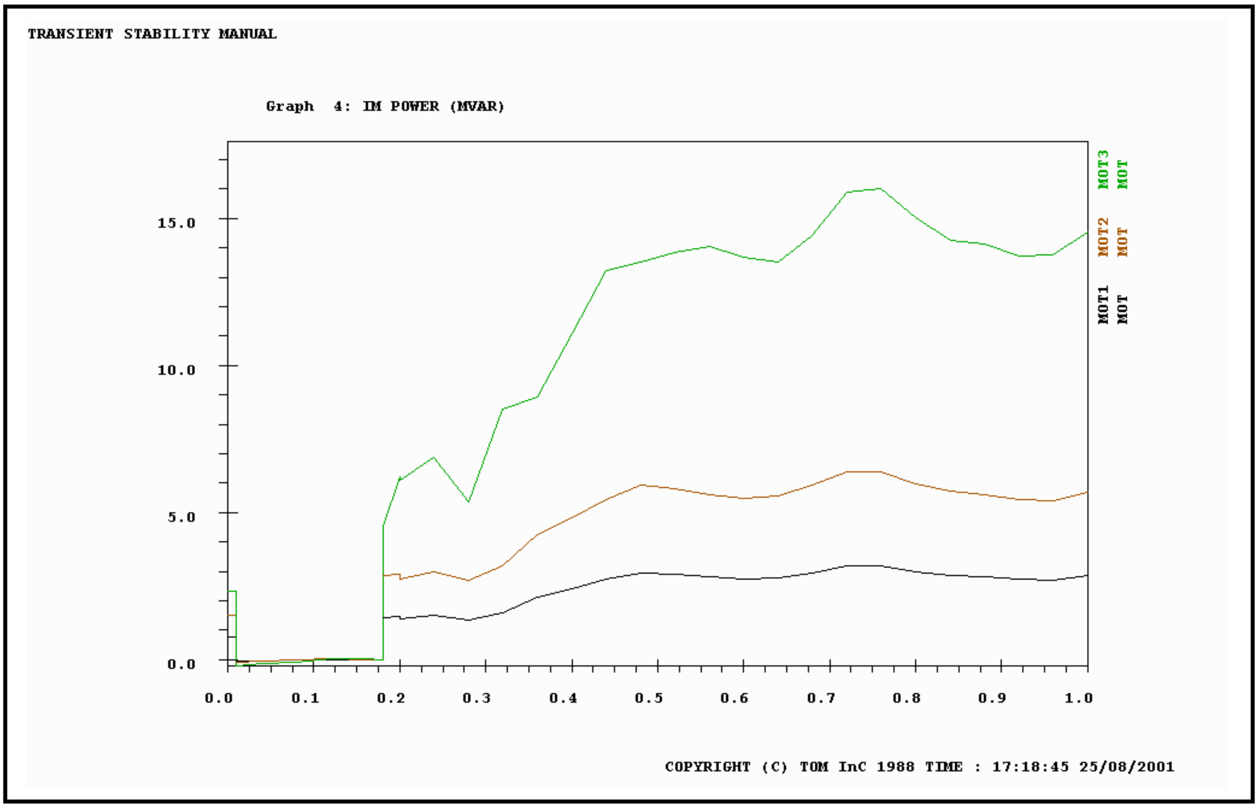

Figure 8.18

Figure 8.14 shows the plotting section page with the required scales and plant identifiers entered.

The [PLOT ONE PER PAGE OPTION] is then selected and the resulting graphs of :

(i) Synchronous machine rotor angles shown in figure 8.15

(ii) Synchronous machine turbine power shown in figure 8.16

(iii) Induction motor slip shown in figure 8.17

(iv) Induction motor MVAR shown in figure 8.18

These can be contrasted with the [PLOT FOUR PER PAGE] option, which is shown in figure 8.19.

It should be noted that the graphs shown are not smooth, because the print interval is long.

To produce a smoother graph the print interval should be decreased and the study run again (see 4.5.9).

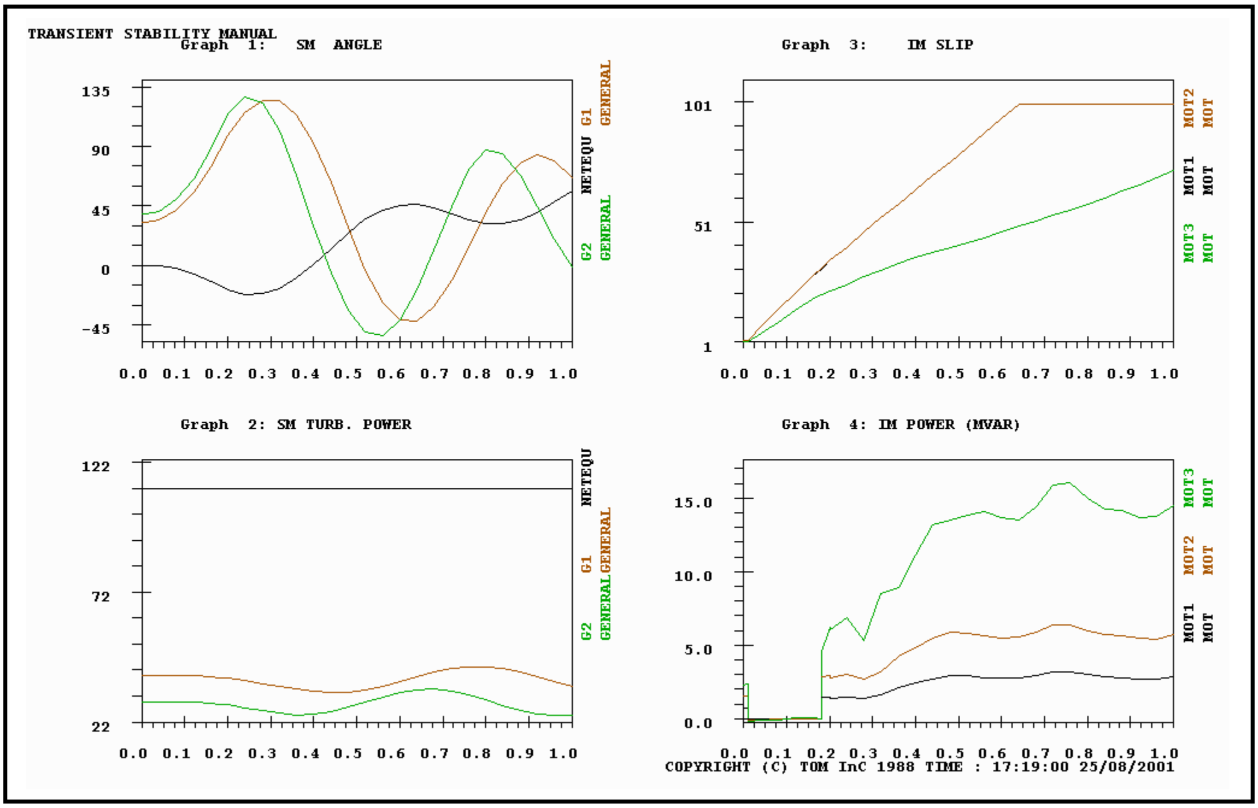
TRANSIENT STABILITY MANUAL
Graph 1: SM ANGLE
Graph 3: IM SLIP
Graph 2: SM TURB. POWER
Graph 4: IM POWER (MVAR)
G1 GENERAL
NETEQU
G2 GENERAL
MOT2 MOT
MOT1 MOT
MOT3 MOT
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Figure 8.19

8.6.2 Example 2 : An induction motor start

In order to simulate the starting of an induction motor it must be initially switched out, and switched in during the study. This is done by specifying the following:

(i) a switch in time for the motor on induction motor data 1

(ii) a STATUS of -1 on induction motor data 2 to have the motor initially disconnected

The induction motor data 1 and 2 edit pages are shown in figures 8.20 and 8.21, and it can be seen that motor is to be started 0.01 seconds after the study begins.

Once again the entry of a -1 status changes the network diagram to show that this plant has been disconnected with dotted lines. This is shown in figure 8.22 with the result of load flow shown on the diagram. It should be noted that the two examples given in this section do not 'follow' on, i.e. there is no shunt in the system diagram of this example, because the starting point was the original system introduced in chapter 3.

The initial rotor angle plot is shown in figure 8.23, which also shows the study being terminated with the <O> key, and the use of the 'notes' facility.

When the study is complete, the user can enter text anywhere on the screen by selecting the position with the mouse cursor, and pressing the <N>, or F9, or F10 key. The note facility may also be selected from mouse right click menu. The text can then be entered and terminated with a <CR> key. This can be done as frequently as required.

The <O> key has then been pressed and the [PLOT] option selected. The plot selection page has been filled with the required scales and plant identifiers, as shown in figure 8.24.

The [FOUR PER PAGE PLOTS] for this study are then shown in figure 8.25. The successful motor start can be seen by inspecting the induction motor slip graph, which shows the slip starting at 1 pu and being reduced as the motor accelerates until running speed is attained.

The user may try other sort of graphs. For instant he may try to plot the voltage sage impact of the motor starting, by selecting the busbar voltages from the plotting menu.

Other study of motor behavior like induction motors recovery from fault may be proceeded with PASHA transient stability sections.

Please also refer to chapter 11 for the option of starting the induction motors in relay automatic checking.

INDUCTION MOTOR DATA 1 PAGE 1 OF 1

BUSBAR/ID	PMECH-MW	SLIP-PC	MAG-X	ST-R-PU	ST-X-PU	ROT-R-PU	ROT-X-PU	S-OUT-T1	SW-IN-T1	S-OUT-T2	SW-IN-T2	AREA
MOT1	1.000	1.798	313.828	2.5902	16.6048	1.2951	16.6048					MOT
MOT2	2.000	1.800	156.914	1.2951	8.3024	0.6476	8.3024		0.010			MOT
MOT3	4.800	0.974	153.191	0.2172	4.9702	0.1546	2.7612					MOT

OPTIONS:

REDISPLAY SYSTEM BASE MVA= 100.0

HELP

RETURN

 TIME : 17:20:04 25/08/2001

Figure 8.20

INDUCTION MOTOR DATA 2 PAGE 1 OF 1

BUSBAR	ID	STATE	PAR-IDX	ST-ROT-R	ST-ROT-X	TQ-SP-B	TQ-SP-C	INERT-C	D-OFF-V	DO/PU-T	L-OUT-T	UN-SPED	AREA
MOT1								0.00303					MOT
MOT2		-1						0.00606					MOT
MOT3				0.4676	1.2481			0.02138					MOT

OPTIONS:

REDISPLAY SYSTEM BASE MVA= 100.0

HELP

RETURN

 TIME : 17:20:18 25/08/2001

Figure 8.21

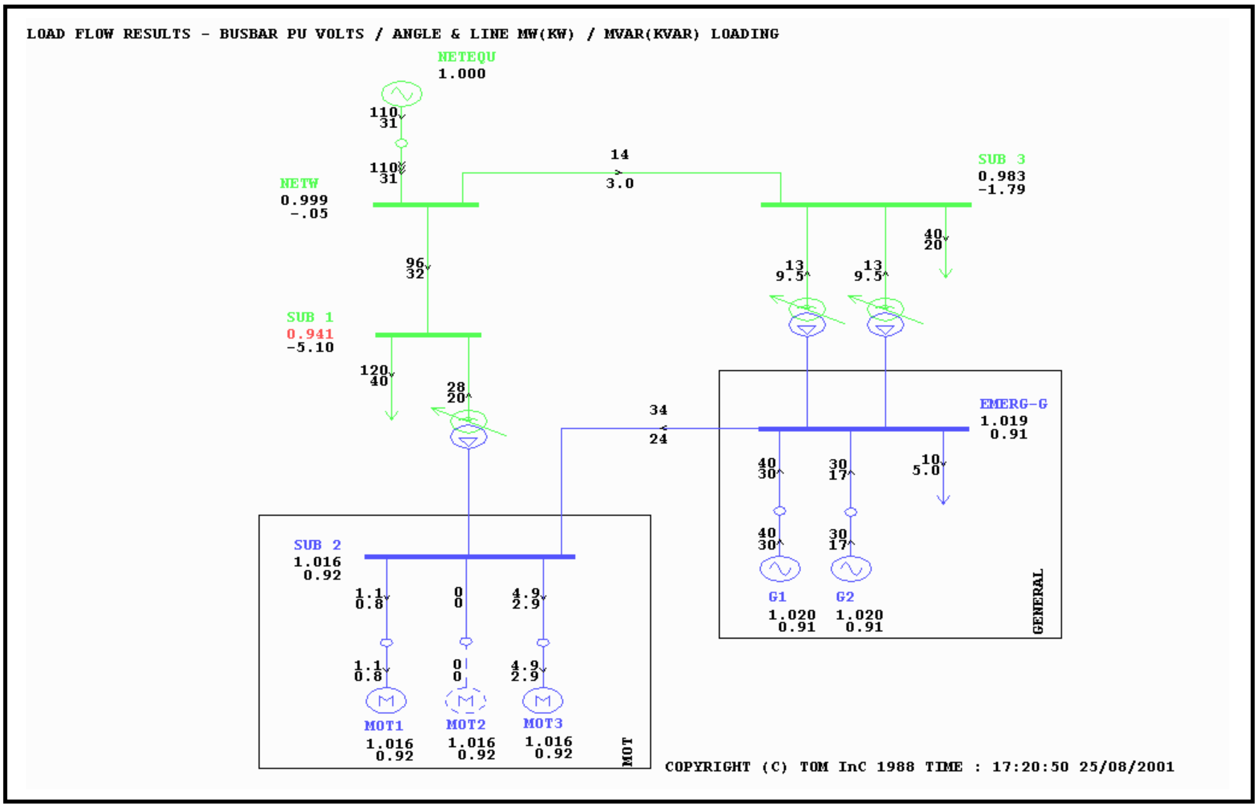


Figure 8.22

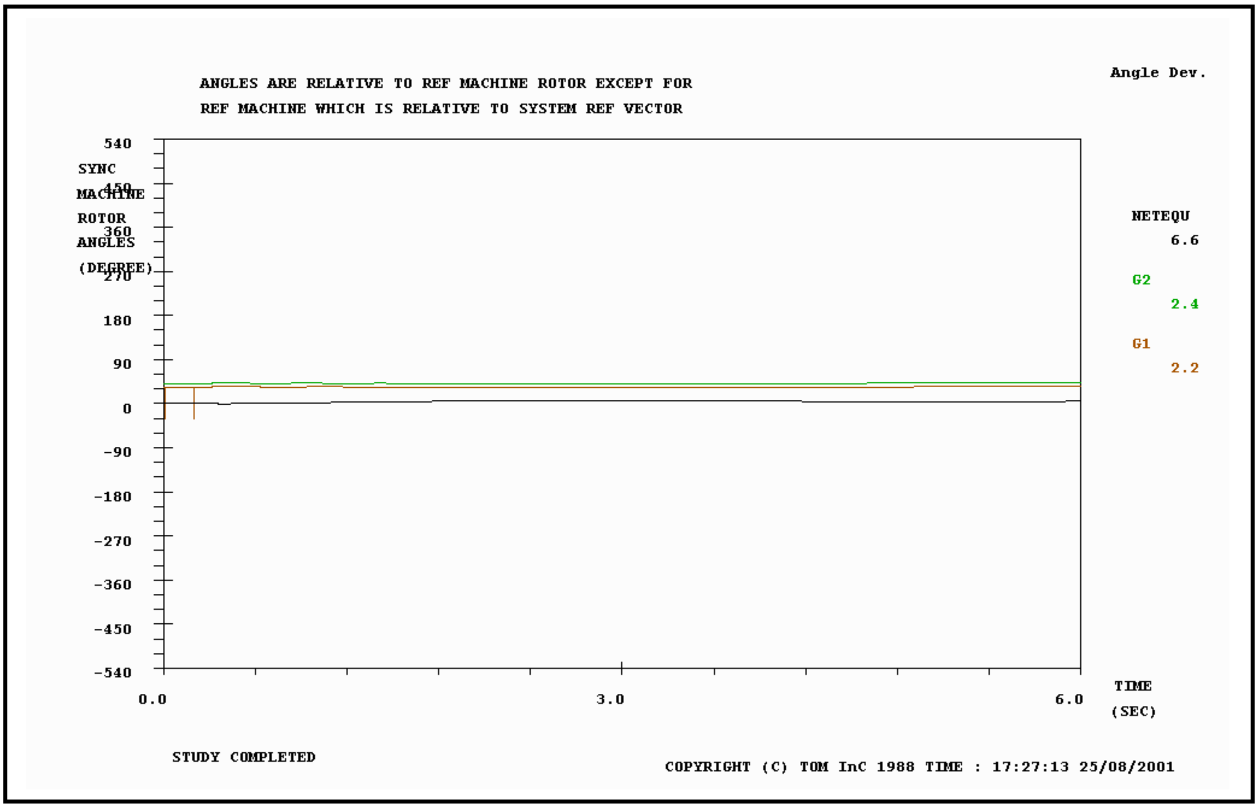


Figure 8.23

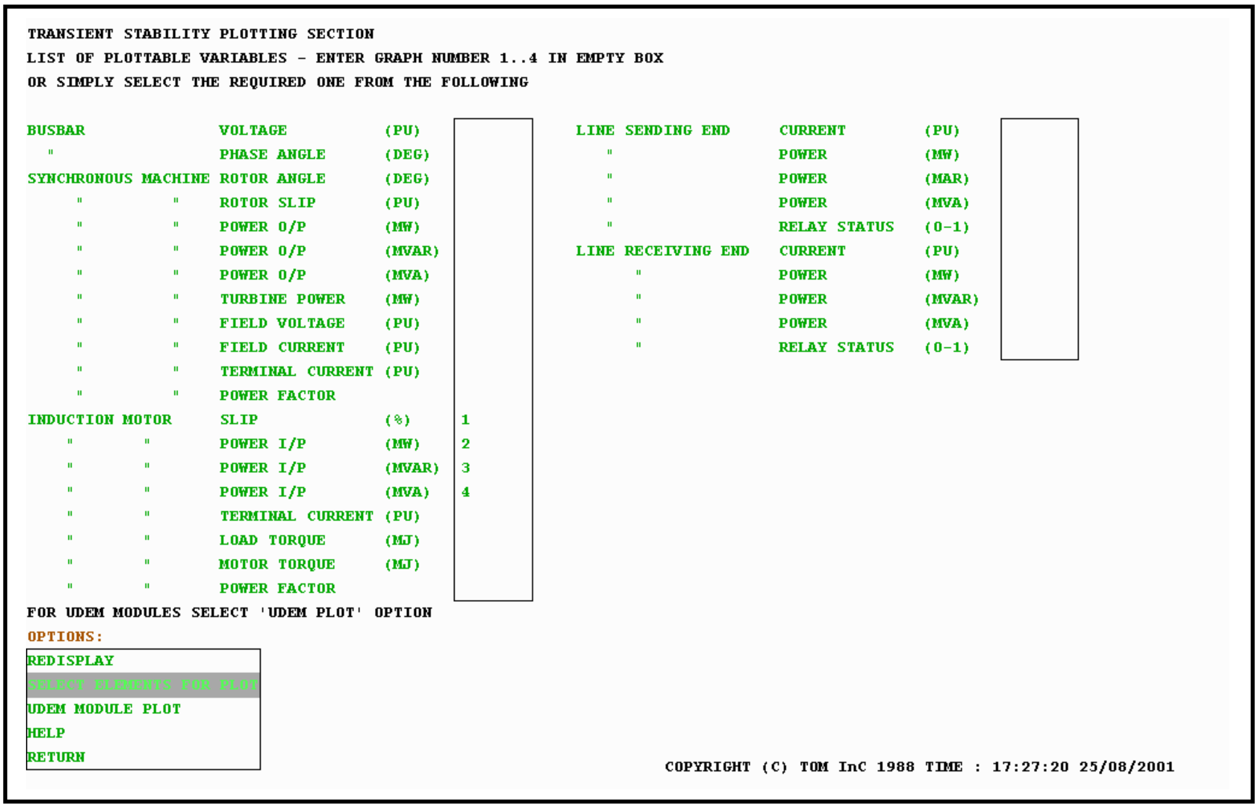


Figure 8.24

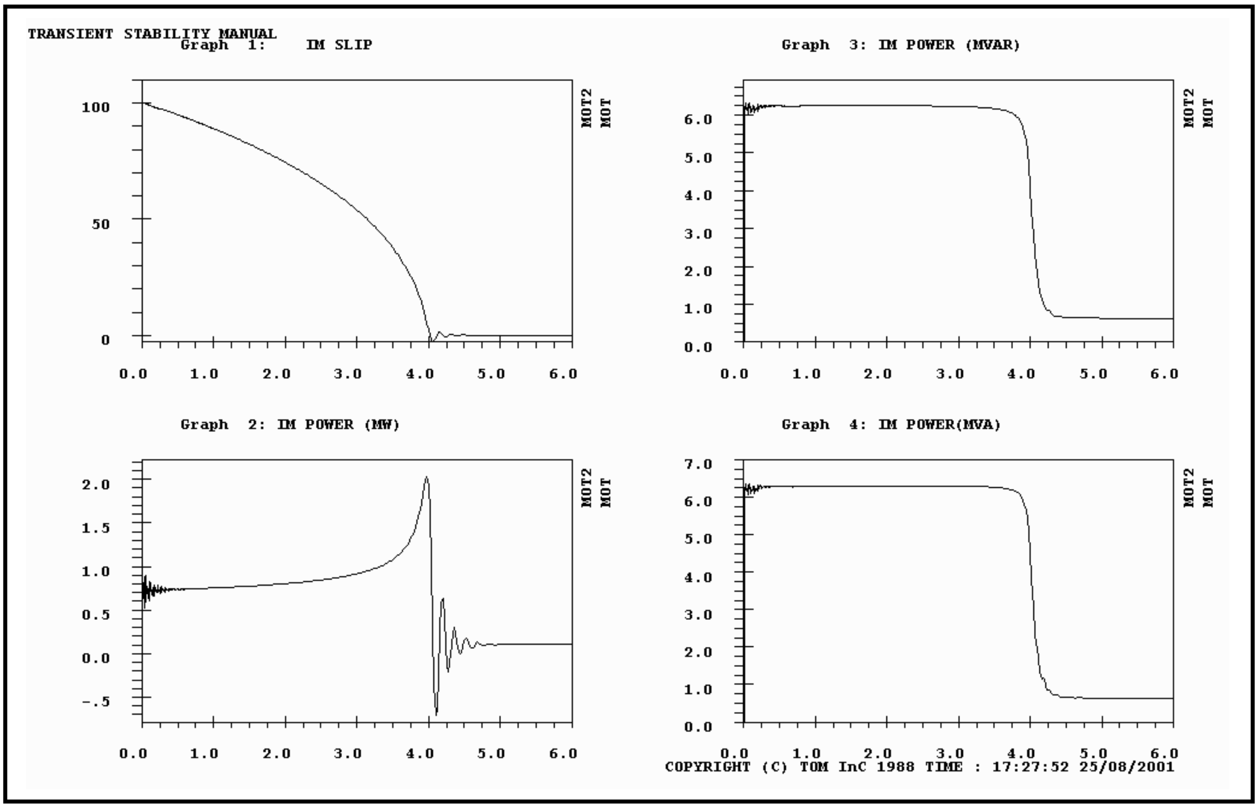


Figure 8.25

8.7 Possible failure of the transient stability calculation

Omission of essential data, initial power unbalances, or failure to obtain a solution at any step, will abort the calculation. This is also indicated by the appearance of the cursor and allows the options to be accessed. The program contains a comprehensive range of diagnostic messages, which are written into the result file when necessary and can, therefore, be accessed through the [FULL LIST] or [PRINT] options.

Failure to converge usually implies too large a step length, but may also be due to bad data. The size of the residual errors printed in the result file indicates the area of difficulty. In PASHA, if the maximum number of iterations is reached without convergence, the step is halved and another round of iterations is started. The study is aborted only if convergence is not attained after the third consecutive step length reduction in any single step.

8.8 An example of Dynamic Frequency study

Figure 8.26 shows a single-line diagram consisting of two separate parts. The part enclosed in window W is nearly the same network used in the previous examples, we call it W. The other part enclosed in window T is also the same network but is added to network W by using <V> and <A> keys after drawing window T located inside window W. The process for adding a network inside a window is described in chapter 3.7. Another slack busbar is also specified for network T. To do this we first change the busbar name, to avoid name contradiction, which we would like to become slack and then we introduce it as the second slack busbar in analysis parameter 1 edit page. The result of load flow study is shown in figure 8.27, where the T window has been set such that does not show the names and the results, please refer to chapter 3 section 3.7.

The shunts are also removed since we do not want to simulate short circuit. Instead we just consider that the transformers which connect two parts of the network will be disconnected at time 0.18 sec in both networks W and T. An under-frequency relay is located in busbar BP1 in BUSBAR DATA 4 as shown in figure 8.28 and as described in chapter 4.

The frequency dynamic is then run and the results of frequency deviations are shown in Figure 8.29. The user may notice that by using appropriate under-frequency load shedding scheme the frequency of a part of the network W has brought to the normal frequency of the system. Note that in this part of the network no governor is assigned to the generators.

8.9 An example of out of phase switching

This is left to the user to bring out the related file from PASHA network files, which come by the package. He can just run the transient stability and observe the torque stress produces on the machine turbines when the angles of switching will be increased. The switching angle can be changed using the slack busbars angles, chapter 6 section 6.3.2.

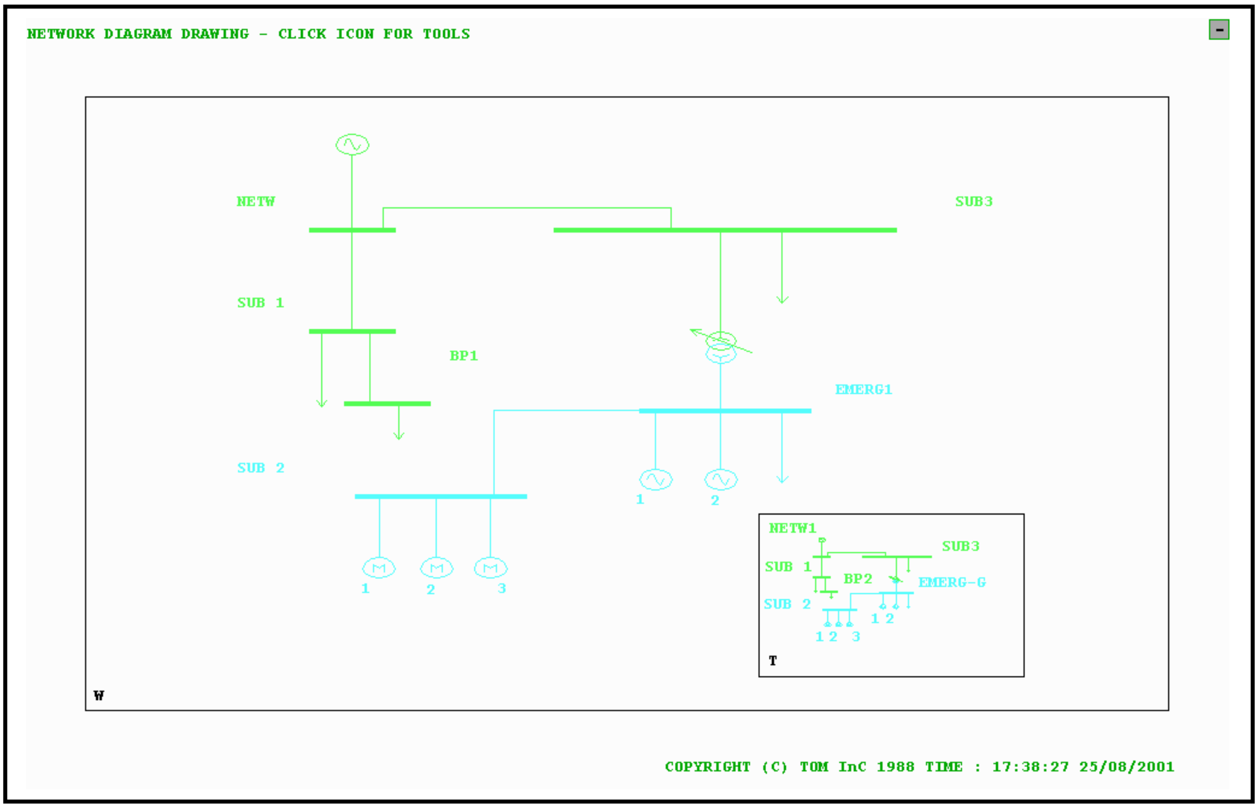


Figure 8.26

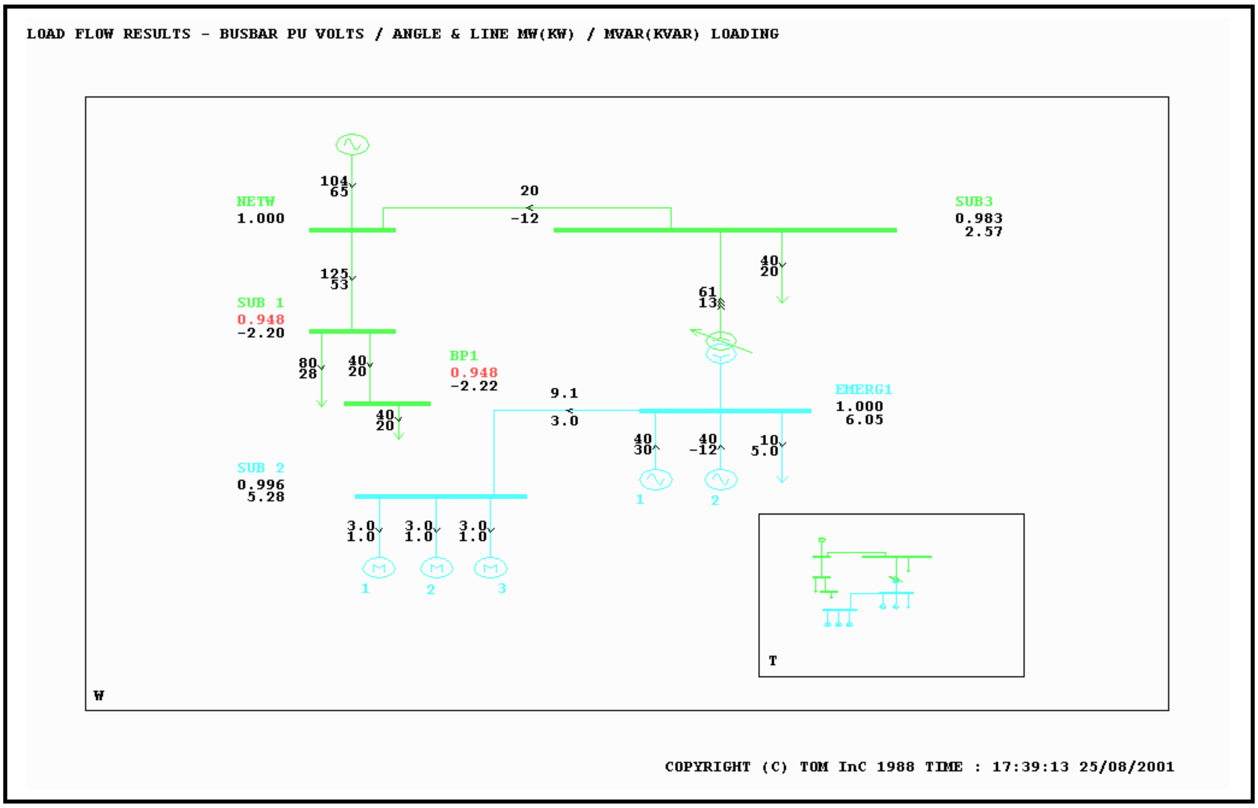
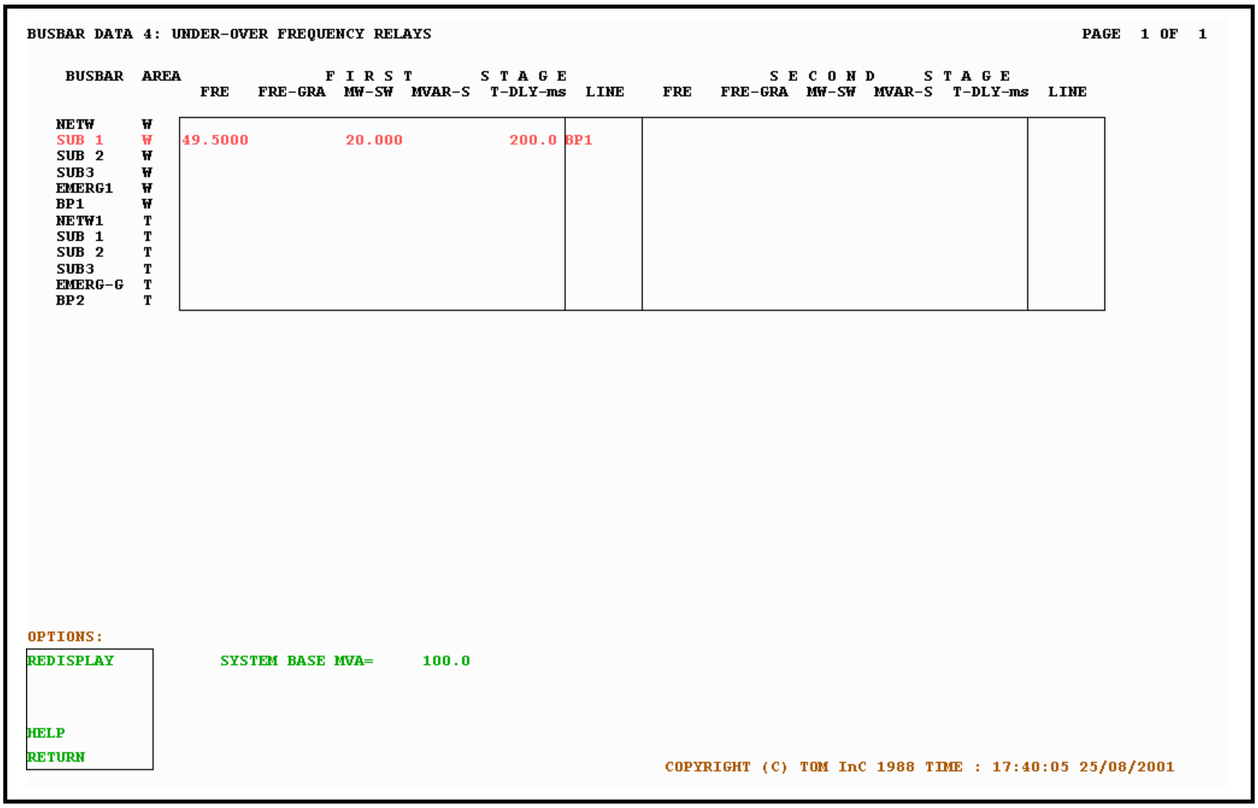


Figure 8.27



BUSBAR DATA 4: UNDER-OVER FREQUENCY RELAYS PAGE 1 OF 1

BUSBAR	AREA	FIRST STAGE FRE	FRE-GRA	MW-SW	MVAR-S	T-DLY-ms	LINE	SECOND STAGE FRE	FRE-GRA	MW-SW	MVAR-S	T-DLY-ms	LINE
NETW	W												
SUB 1	W	49.5000		20.000		200.0	BP1						
SUB 2	W												
SUB3	W												
EMERG1	W												
BP1	W												
NETW1	T												
SUB 1	T												
SUB 2	T												
SUB3	T												
EMERG-G	T												
BP2	T												

OPTIONS:
REDISPLAY
HELP
RETURN

SYSTEM BASE MVA= 100.0

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Figure 8.28

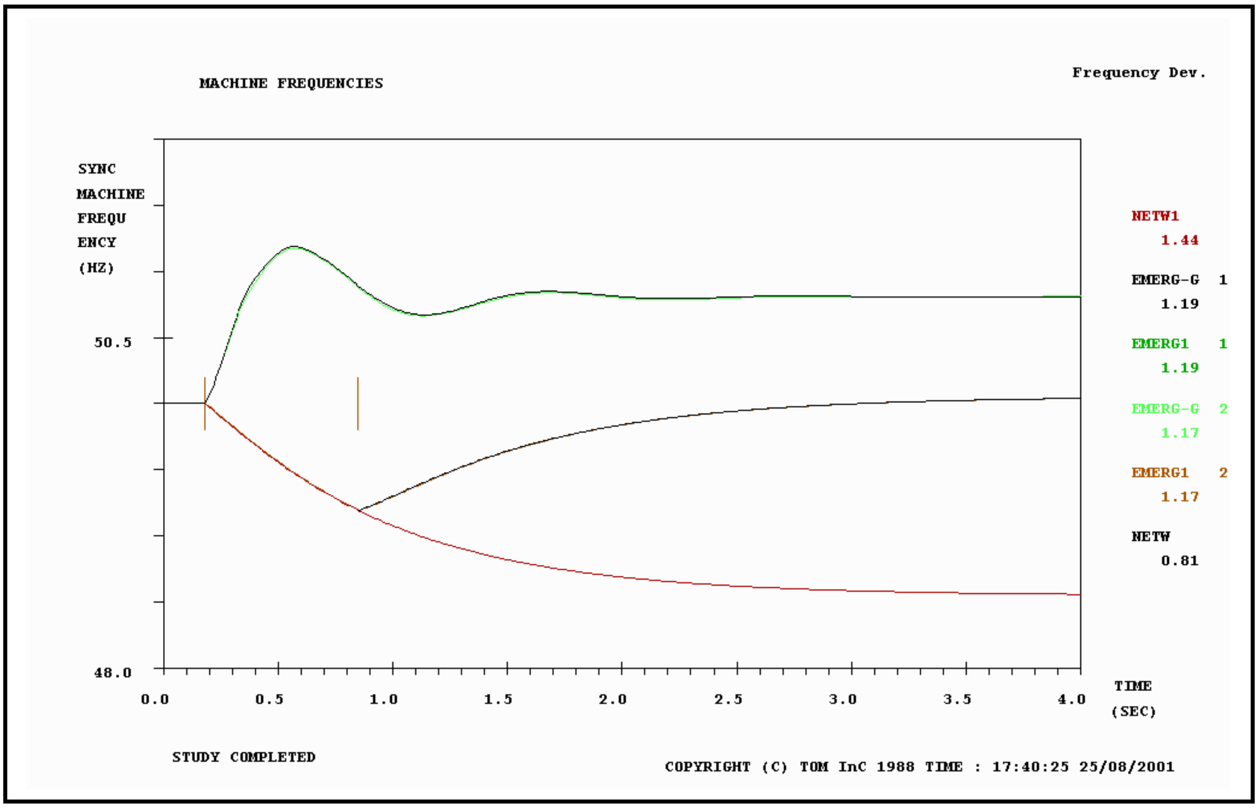

Figure 8.29

8.10 Summary

The transient stability section provides a very powerful and fast method to simulate the dynamic response of the power system to many different types of switching operations.

It is possible to simulate short circuits in all the plant, the clearing of these faults, induction motor starts etc.

Full checks are made on the system data before the step simulation commences.

A comprehensive analysis/display section is provided to display the results in a tabular or graphical form.

In chapter 11 another powerful facility in PASHA i.e. Protective device performance simulation is described, This is a powerful facility especially when the dynamic performance of the relays are simulated in transient stability section. For more information refer to chapter eleven.