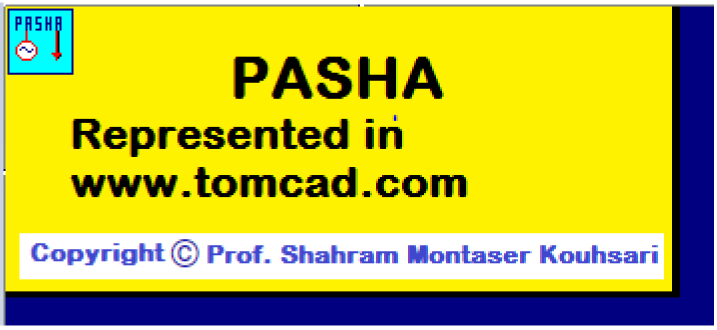

Chapter 13
Harmonic analysis

The Harmonic Analysis section of PASHA incorporated the current injection algorithm and has provisions for diagrammatic and tabular display for the results, harmonic sensitivity calculations, frequency spectrum plot of impedance, design of single tuned and high pass filters, optimization of filter design and harmonic voltage conversion.

Selecting the [HARMONIC PENETRATION CALCULATION] option from the main menu activates the harmonic penetration Calculation section.

13.1 The initial step of harmonic analysis

The harmonic penetration calculation starts by checking for existence of harmonic sources, then for the system configuration and available system parameters and data. If any essential data is found to be missing, an appropriate error message is displayed and the solution process is terminated. Otherwise, if the missing item is not crucial, a warning message will be displayed and the program will continue with harmonic penetration calculation.

If no harmonic source (i.e. AC/DC converter, arc furnace or SVC) is found in the system, the program will not proceed with harmonic penetration calculation. However, other analyses such as sensitivity calculation, impedance spectrum calculation and filter design will be available. In order to proceed with the harmonic penetration you either need to assign harmonic data to these devices or have done a load flow before. For DC load flow please refer to chapter 17.

13.1.1 Overview

To find out about the place of harmonic 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 harmonic data of the components stems from already available data of that component, and PASHA converts these to data required for harmonic models of the components. Harmonic source models may also be generated automatically, however, the user may override it by entering data in harmonic data edit pages as described in chapter 4 section 4.5.23.

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). There is no databases related to harmonic analysis. This is because the basic data required for harmonic models are already available in other data pages and the sources have too wide characteristics to categorize in databases.

13.2 The harmonic analysis main menu

The harmonic analysis main menu is displayed automatically after harmonic penetration calculation and can be called after diagrammatic display of results by pressing <O> key. Figure 13.1 (as well as in the following figure) shows a full menu of harmonic analysis section that is displayed after a successful harmonic penetration calculation. As described in section 13.1, if harmonic penetration calculation was terminated due to some errors and still other types of harmonic analysis are available, this menu will be displayed partially.

OPTIONS:

- DISTORTION FACTORS DISPLAY
- IMPEDANCE SENSITIVITY REPORT
- FREQUENCY SPECTRUM PLOT
- HARMONIC VOLTAGE CONVERSION
- FILTER DESIGN
- LOAD FLOW
- FULL LIST
- PRINT
- HELP
- RETURN TO MAIN OPTIONS

Chapter 2 13.2.1 [DISTORTION FACTORS DISPLAY]

Selection of this option draws the system diagram and displays the branch current THD and IT and the busbar voltage THD and TIF distortion factors on the diagram. The voltage THDs and TIFs, respectively, are shown immediately beneath the busbar names, and the current THDs and ITs are displayed next to the lines, transformers, shunts, motors, generators and loads, as shown in figure 13.2. The example network is shown in figure 13.4.

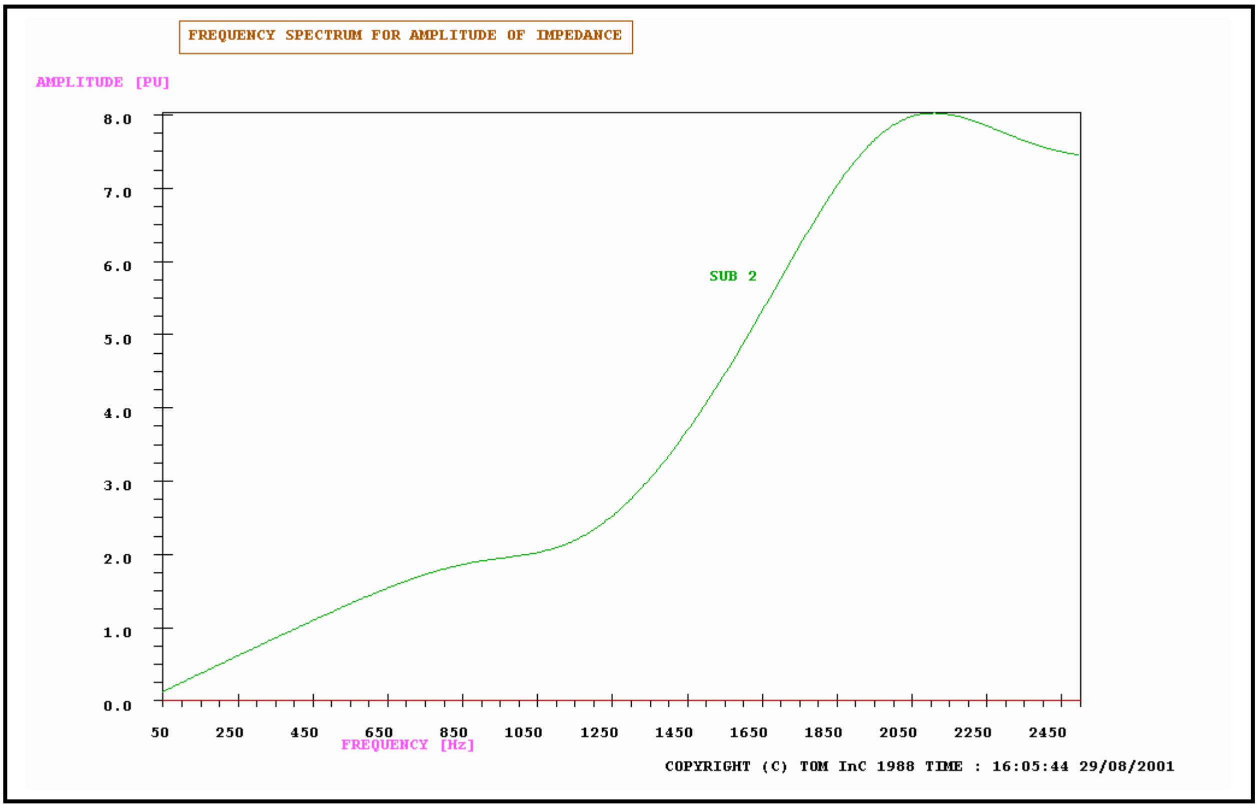

Figure 13.1

```
         G2              0.95542        1.56538        1.83392        58.60256

         IMPEDANCE CALCULATED AT HARMONIC ORDER 18.00
         -----------------------------------------------------------------
          BUSBAR         REAL{Z}        IMAG{Z}         ARG{Z}        PHASE{Z}
         -----------------------------------------------------------------
         NETW            0.00259        0.05065        0.05072        87.06794
         SUB 1           0.67187        0.29762        0.73483        23.89205
         SUB 2           1.01118        1.61859        1.90849        58.00584
         SUB 3           2.20330        0.19196        2.21165         4.97937
         EMERG-G         1.00753        1.56872        1.86440        57.28873

         NETEQU          0.00101        0.03570        0.03572        88.37374
         MOT1            1.04757        1.84069        2.11791        60.35501
         MOT2            1.04660        1.83952        2.11642        60.36228
         MOT3            1.02596        1.67325        1.96274        58.48544
         G1              1.01016        1.58134        1.87644        57.42958

         G2              1.00800        1.58529        1.87862        57.55002
       * IMPEDANCE TO GROUND FOR BUS SUB 3    HAS A PARALLEL RESONANCE AT   933.204 Hz

         IMPEDANCE CALCULATED AT HARMONIC ORDER 19.00
         -----------------------------------------------------------------
          BUSBAR         REAL{Z}        IMAG{Z}         ARG{Z}        PHASE{Z}
         -----------------------------------------------------------------
         NETW            0.00285        0.05343        0.05350        86.94448
         SUB 1           0.68972        0.28262        0.74538        22.28195
         SUB 2           1.04336        1.64295        1.94625        57.58235
         SUB 3           2.20869       -0.09879        2.21090        -2.56092
         EMERG-G         1.03849        1.58858        1.89791        56.82639

         NETEQU          0.00113        0.03767        0.03769        88.27449
         MOT1            1.08061        1.87746        2.16624        60.07646
         MOT2            1.07962        1.87627        2.16471        60.08357
         MOT3            1.05855        1.70072        2.00325        58.10138
         G1              1.04126        1.60202        1.91067        56.97737

         G2              1.03909        1.60633        1.91311        57.10237

         IMPEDANCE CALCULATED AT HARMONIC ORDER 20.00

Continue listing? (Y or N or S)|
                                                  COPYRIGHT (C) TOM InC 1988 TIME : 16:03:09 29/08/2001
```

Figure 13.2

13.2.1.1 Bar Charts/Graphs

Bar charts/graphs of harmonic components of system voltages and currents are available through network diagram. In order to access mentioned bar charts, mouse pointer should be placed on desired component (e.g. busbar, line, transformer, shunt, motor, and generator) and <P> key pressed. There is an exception for loads. In order to access the bar chart of the current flowing through a desired load, mouse pointer should be placed on the busbar connected to that load and <L> key pressed. A sample bar chart is shown in figure 13.3.

13.2.2 [IMPEDANCE SENSITIVITY REPORT]

By selecting this option you will be asked for a harmonic order. If you specify no harmonic order, its default value, that is 25, will be considered. Starting from harmonic order 1, sensitivity calculation module calculates the equivalent harmonic impedance at all system busbars and junctions and reports those impedance values in a tabular format that is available by selecting [FULL LIST] after completion of calculation. This process continues up to the specified harmonic order or its default value. If any resonance occurred during transition from one harmonic order to the other, the precise resonance frequency will be reported in full list for relevant busbar or junction. A sample of impedance sensitivity report has been shown in figure 13.4. A converter with the data shown in figure 4.5.23 is added to the example network of this manual.

Note: If you select this option by pressing <3> key, zero sequence impedances of all components will be considered is impedance sensitivity calculation.

13.2.3 [FREQUENCY SPECTRUM PLOT]

By selecting this option you will be guided to frequency spectrum plotting environment, figure 13.5, where you should provide following data for the program:

FREQUENCY RANGE [Hz]: This is actually the sweeping range of frequency in Hertz. Equivalent busbar impedance calculation will be performed starting from the MINIMUM up to the MAXIMUM values entered by user. Their default values ranges from 1^{st} up to 50^{th} harmonic orders.

AMPLITUDE/PHASE/RESISTANCE/REACTANCE RANGE [PU]: This is actually the scale of vertical axis for the Cartesian plots of frequency spectrum of impedance. Only that part of the plot will be shown on the graph that lies between MINIMUM and MAXIMUM values entered by user.

AUTOSCALE: By clicking inside provided box, this option may be activated and deactivated. If autoscale option is activated (an asterisk will be shown inside the box), the range of vertical axis provided by user will be ignored and proper values will be assigned to MINUMUM and MAXIMUM of vertical axis by the program itself. Note that activation of this option will delay plotting process due to required additional computations.

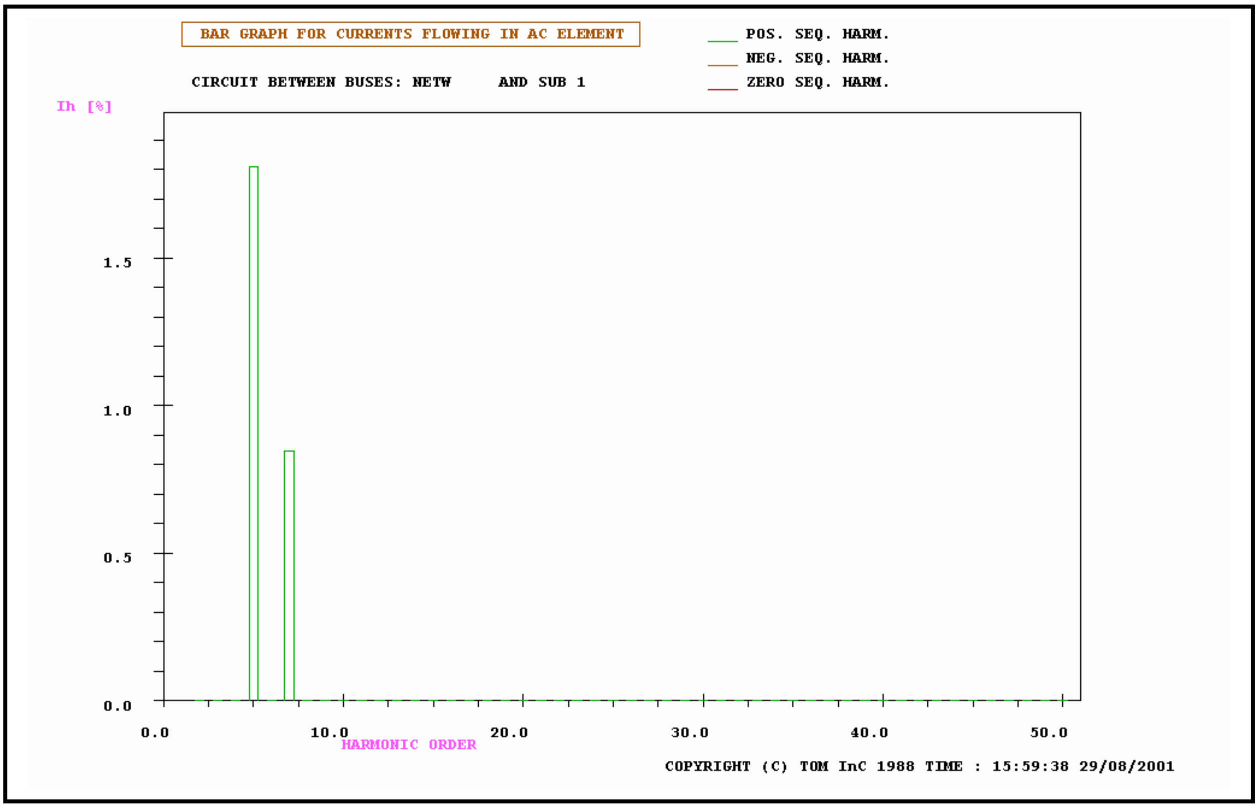

Figure 13.3

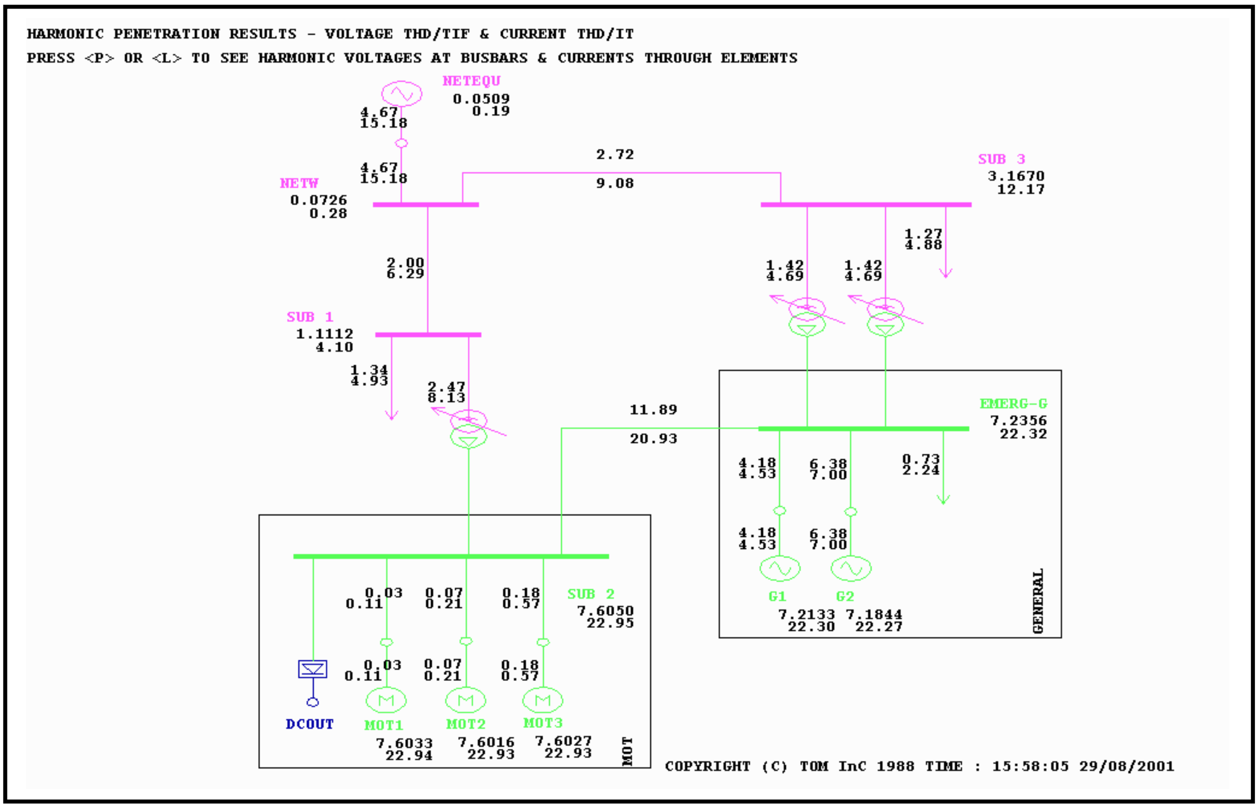

Figure 13.4

TRACE 1-TRACE 8: Impedance frequency spectrum may be plotted for at most eight AC BUSES. In front of each TRACE you should enter the name of desired busbar or junction. User can either type the name or choose it from a list that will automatically be provided by PASHA.

PLOTTING VARIABLE: In Cartesian plotting mode, four types of plot may be chosen by user, namely impedance AMPLITUDE, PHASE, RESISTANCE or REACTANCE. User can choose desired plotting variable by clicking inside relevant box. Mentioned four types of variables will be change cyclically.

PLOT ONE BY ONE: If you have already entered more than one busbars or junctions in AC-BUS list, you can select to plot the required frequency spectrum plots together for comparison purposes, for example, or in separate axis frames. Clicking inside this box will activate/deactivate one by one plotting feature of this section. Figures 13.6 and 13.7 show the effect of this option on the output diagram.

POLAR PLOT: By activating this option (clicking inside relevant box) the impedance frequency spectrum will be plotted in polar format and impedance reactance will be plotted versus resistance, figure 13.8. When this option is activated, two additional boxes will be displayed as follows:

MAXIMUM ORDER: To specify the maximum order of harmonic up to which the polar plot should be plotted. Its default value is set to 50.

WRITE ORDERS: In order to force the plotting program to write harmonic orders on the polar plot, this option should be activated.

13.2.3.1 Options menu

As other sections of PASHA, a menu is provided in frequency spectrum plot of harmonic analysis section. Most options in this menu such as [REDISPLAY], [FULL LIST], [PRINT], [HELP] and [RETURN] have been described in previous sections and will not be discussed here. However, by selecting [PLOT] option, the frequency spectrum plot of chosen busbars and junctions will be plotted according to all set parameters.

13.2.4 [HARMONIC VOLTAGE CONVERSION]

It may not be possible to calculate the value of harmonic currents injected into the power system by known harmonic sources, or due to their highly nonlinear behavior those currents are difficult to estimate. Harmonic voltage conversion is a tool that helps engineers predict the harmonic current components of nonlinear loads (harmonic sources) within the system. Figure 13.9 shows the environment of harmonic voltage conversion section. Following data should be provided for the program in order to be able to calculated injected currents:

HARMONIC ORDER: This is the order of harmonic in which you have performed voltage measurements and intend to predict injected harmonic currents by harmonic sources.

MESAURED VOLTAGES: Name of busbar or junction at which measurements has been performed together with the value of measured voltage amplitude (AMP.) [pu] and phase angle (ANG.) [degrees] should be entered in appropriate spaces. Note that busbars or junctions names may be typed or selected from a list provided by the program.

INJECTED CURRENTS: You should need ONLY to provide names of busbars or junctions where harmonic sources are located. Note that number of measured voltages should be equal to number of buses where harmonic currents are injected into power system. Amplitude and phase angle of injected currents at desired harmonic order will be shown after performing harmonic voltage conversion calculation.

13.2.4.1 Options menu

As other sections of PASHA, a menu is provided in frequency spectrum plot of harmonic analysis section. Most options in this menu such as [REDISPLAY], [FULL LIST], [PRINT], [HELP] and [RETURN] have been described in previous sections and will not be discussed here. However, by selecting [CALCULATE] option, the harmonic voltage conversion calculation at specified harmonic order will be performed and the final results will be displayed under INJECTED CURRENTS title and will also be available through selection of [FULL LIST] option.

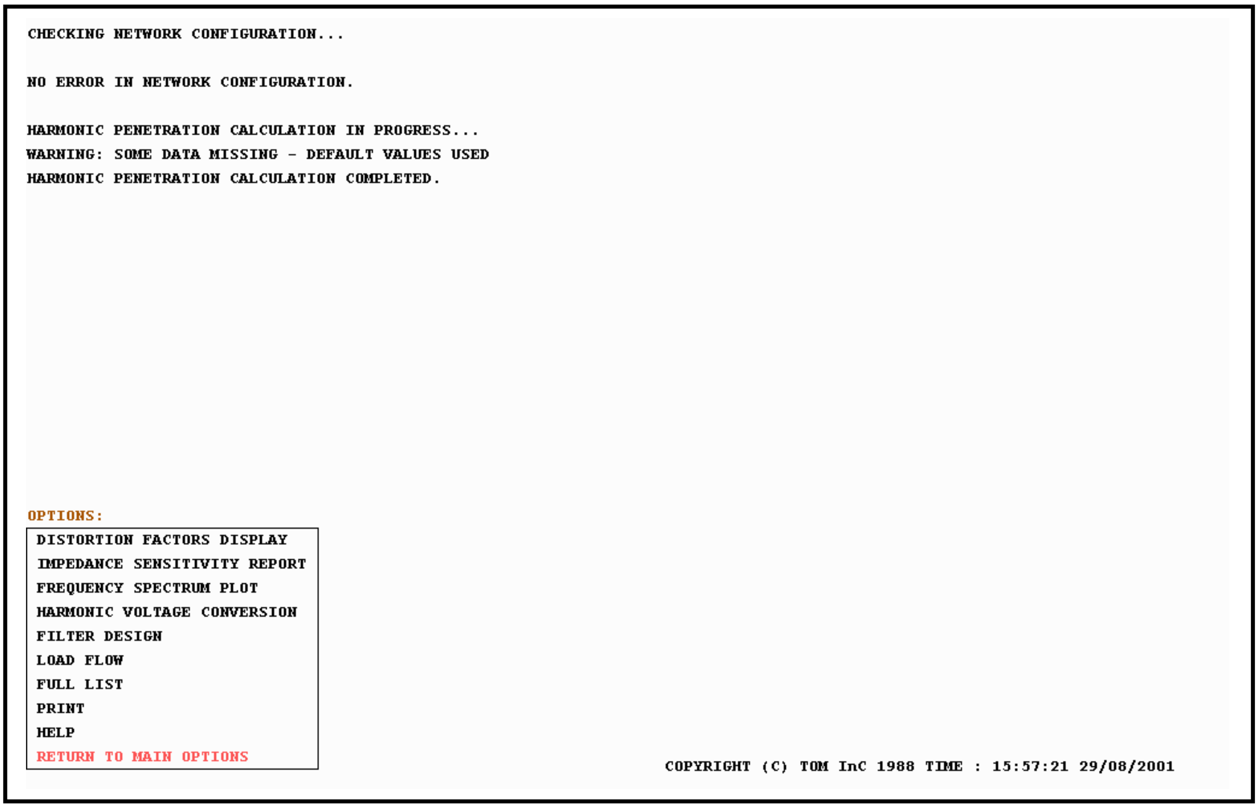

Figure 13.5

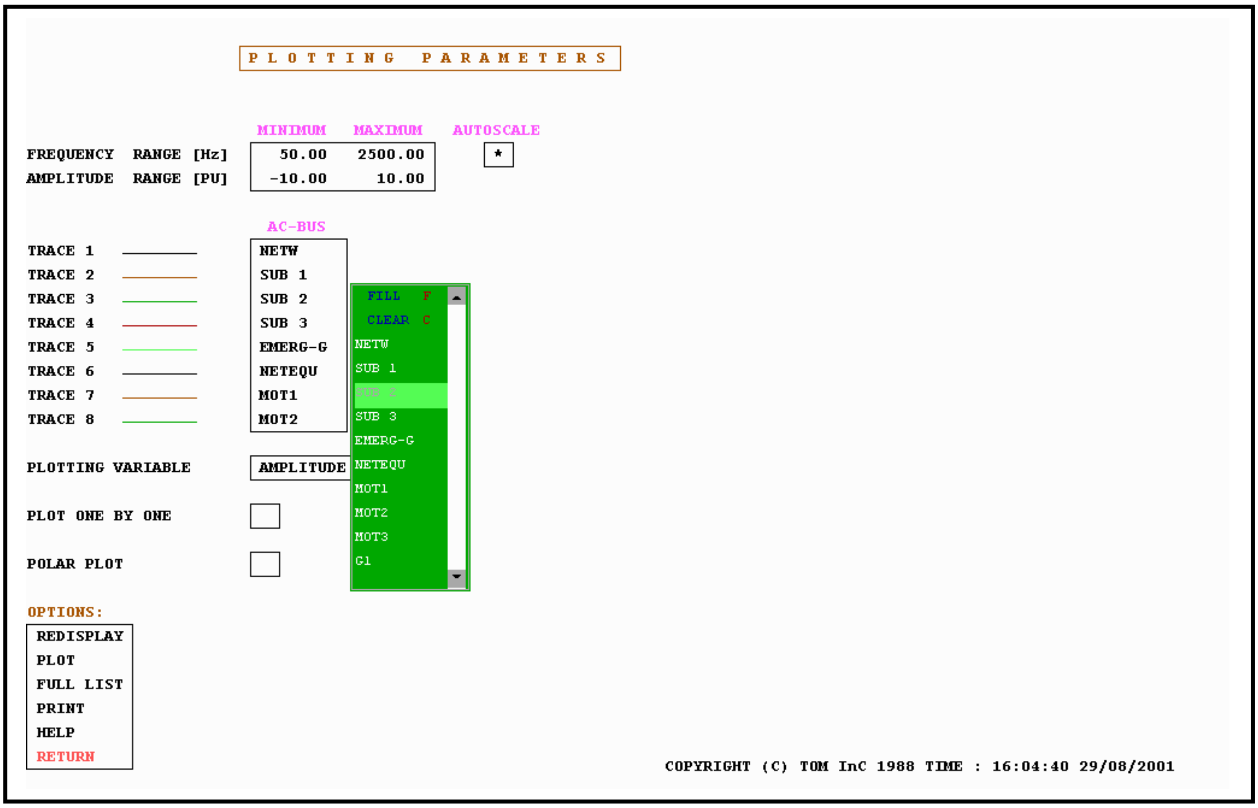

Figure 13.6

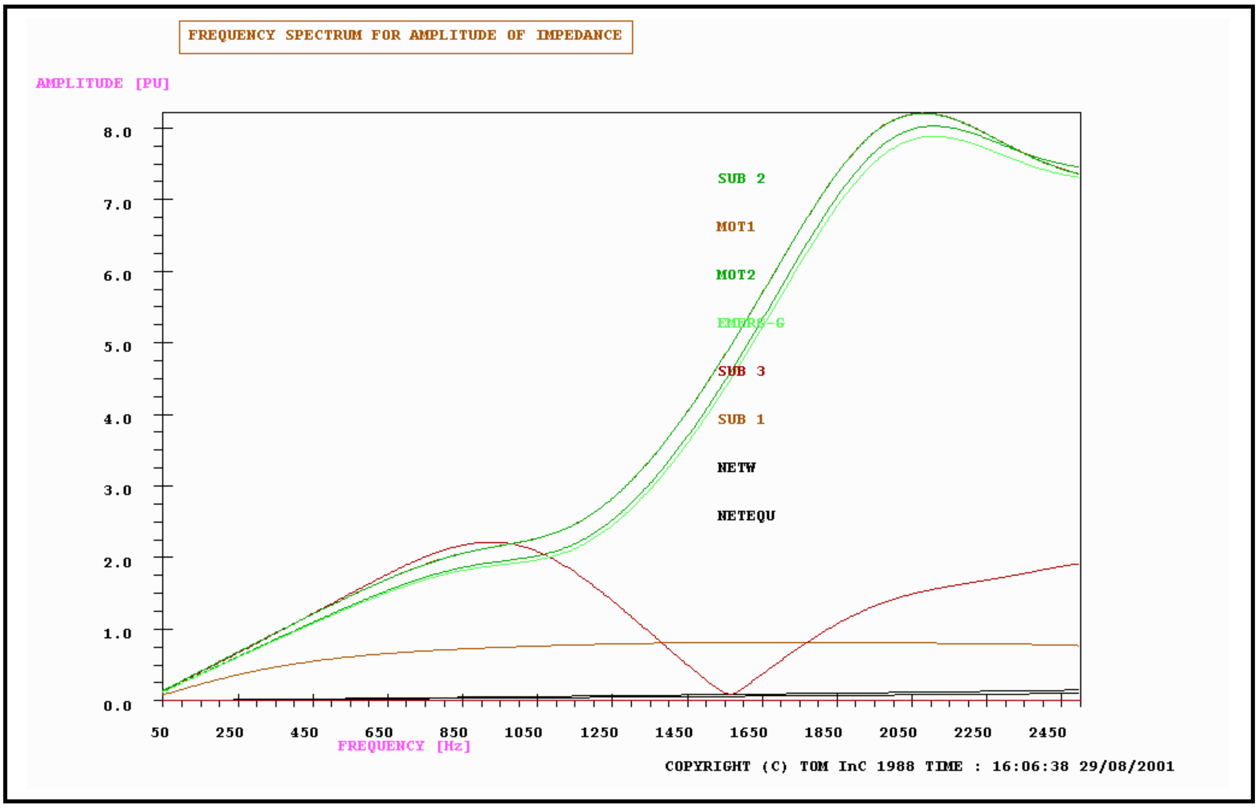

Figure 13.7

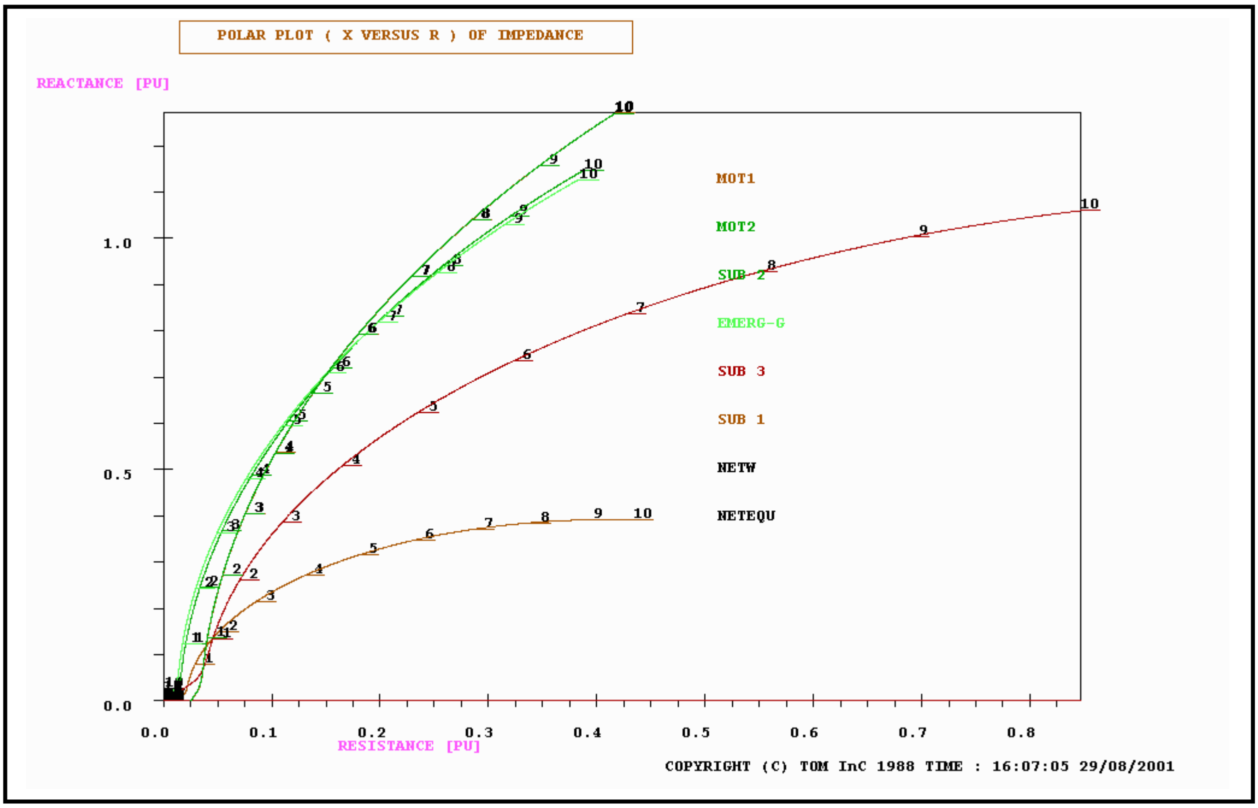

Figure 13.8

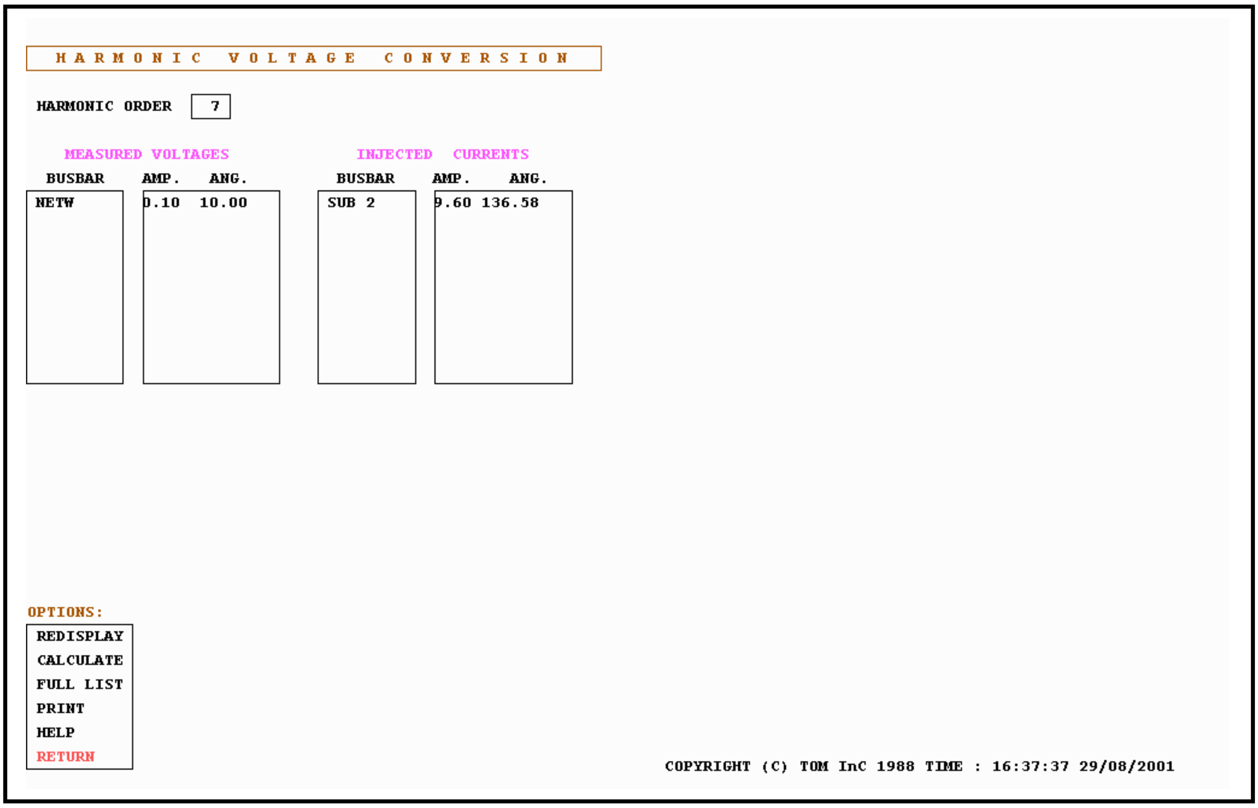
H A R M O N I C   V O L T A G E   C O N V E R S I O N
HARMONIC ORDER
7
MEASURED VOLTAGES
INJECTED CURRENTS
BUSBAR
AMP.
ANG.
NETW
0.10
10.00
BUSBAR
AMP.
ANG.
SUB 2
9.60
136.58
OPTIONS:
REDISPLAY
CALCULATE
FULL LIST
PRINT
HELP
RETURN
COPYRIGHT (C) TOM InC 1988 TIME : 16:37:37 29/08/2001

Figure 13.9

13.2.5 [FILTER DESIGN]

By selecting this option, filter designing and optimization algorithms will be available for user, figure 13.10. Filters design algorithms are available for Single Tuned and High Pass filters. Optimization is conducted by implementation of Simulated Annealing technique considering the criteria of cost reduction. Required data and parameters in this environment are as follows:

BASBAR NAME: Name of you desired busbar or junction for which you are going to design or optimize a harmonic filter

FILTER TYPE: Type of filter you intend to design. By clicking inside relevant box, filter type will toggle between SINGLE TUNED and HIGH PASS.

OBJECTIVES: RESONANCE ORDER, COMPENSATING MVAR at power frequency, QUALITY FACTOR of the filter and DETUNING FACTOR in percent are essential and basic required data for a filter design procedure.

By providing data discussed so far, harmonic filters can easily be design just by clicking on [DESIGN] option in the menu. Followings are those additional data that should be supplied to the program for implementing optimization technique in filter design.

PERMISSIBLE LIMITS [%]: MINIMUM and MAXIMUM deviation permitted for TUNING, COMPENSATION and QUALITY are set in this table. Optimal harmonic filter parameters will be chosen to lie within specified limits in this table

COST COEFFICIENTS [$/MW, MVAR]: As mentioned, objective in optimization procedure of harmonic filter design is cost minimization. Data entered in this table will lead to cost calculation of filter components (i.e. R, L, and C), and hence, total filter cost.

OPTIMIZATION (S.A.): Simulated annealing specific parameters such as INITIAL TEMPERATURE, FREEZING TEMPERATURE, COOLING FACTOR and ITERATIONS PER TEMPERATURE are set in this table. Initial temperature and iterations per temperature should be considered as large as possible. Cooling factor is a real number less than but very close to 1.0. It is recommended to choose freezing temperature equal to a little positive real number. As a quick guide for users, default values are shown in this table.

13.2.5.1 Options menu

As other sections of PASHA, a menu is provided in frequency spectrum plot of harmonic analysis section. Most options in this menu such as [REDISPLAY], [FULL LIST], [PRINT], [HELP] and [RETURN] have been described in previous sections and will not be discussed here. However, by selecting [DESIGN / <O> FOR OPTIMAL DESIGN] option, the filter design procedure will calculate filter components. If the key <O> is pressed when choosing [DESIGN] option in the menu, according to entered data and parameters, optimized filter parameters will be shown in the empty box as the calculation output.

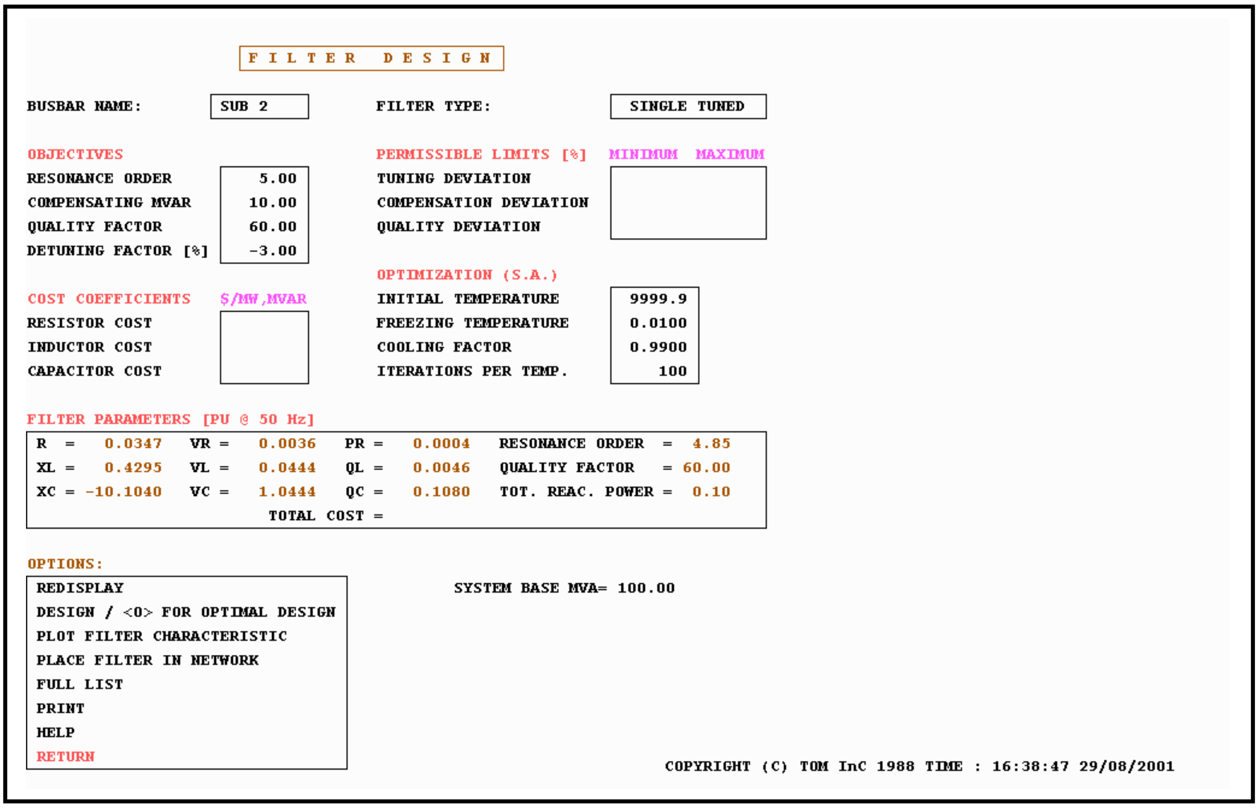
F I L T E R D E S I G N
BUSBAR NAME: SUB 2
FILTER TYPE: SINGLE TUNED
OBJECTIVES
RESONANCE ORDER 5.00
COMPENSATING MVAR 10.00
QUALITY FACTOR 60.00
DETUNING FACTOR [%] -3.00
PERMISSIBLE LIMITS [%] MINIMUM MAXIMUM
TUNING DEVIATION
COMPENSATION DEVIATION
QUALITY DEVIATION
OPTIMIZATION (S.A.)
INITIAL TEMPERATURE 9999.9
FREEZING TEMPERATURE 0.0100
COOLING FACTOR 0.9900
ITERATIONS PER TEMP. 100
COST COEFFICIENTS $/MW,MVAR
RESISTOR COST
INDUCTOR COST
CAPACITOR COST
FILTER PARAMETERS [PU @ 50 Hz]
R = 0.0347 VR = 0.0036 PR = 0.0004 RESONANCE ORDER = 4.85
XL = 0.4295 VL = 0.0444 QL = 0.0046 QUALITY FACTOR = 60.00
XC = -10.1040 VC = 1.0444 QC = 0.1080 TOT. REAC. POWER = 0.10
TOTAL COST =
OPTIONS:
REDISPLAY
DESIGN / <O> FOR OPTIMAL DESIGN
PLOT FILTER CHARACTERISTIC
PLACE FILTER IN NETWORK
FULL LIST
PRINT
HELP
RETURN
SYSTEM BASE MVA= 100.00
COPYRIGHT (C) TOM InC 1988 TIME : 16:38:47 29/08/2001

Figure 13.10

13.2.6 [LOAD FLOW]

Enters the load flow section and perform required AC or AC/DC load flow calculation.

13.2.7 [FULL LIST]

Initiates the display, on the terminal, of the results of the last harmonic penetration calculation. Selecting this option by pressing the <SP> key gives the full listing. Pressing key <1> to <3> starts the display at one of the main sections as listed under [PRINT] below.
Figures 13.11, 13.12, and 13.13 show the output generated for a sample power system. The <S> key on the bottom of the map is provided for searching.

13.2.8 [PRINT]

Sends the results of the last harmonic penetration calculation to a line printer file. The listing contains system and study titles and details on:

For each harmonic order
(1) Location and values of injected harmonic currents
(2) Detail information for harmonic voltages at all busbars and junctions
(3) Detail information for harmonic currents flowing through AC components

Distortion factors
(1) Voltage Distortion Factor (V.D.F.) and Telephone Influence Factor (T.I.F.) at all busbars and junctions
(2) Current Distortion Factor (C.D.F.) and IT factor for all AC components.

13.2.9 [HELP]

Displays the on-line HELP information on the terminal.

13.2.10 [RETURN]

Exits from the harmonic analysis section to the Main PASHA menu.

```
HARMONIC PENETRATION CALCULATION RESULTS
========================================

SYSTEM TITLE: PASHA 2000 MANUAL FOR CHAPTER 13


         HARMONIC CURRENT(S) OF ORDER  ( 3) IS/ARE INJECTED TO FOLLOWING BUSBAR(S):

         SUB 2    WITH MAGNITUDE OF  0.1000000 P.U. & ANGLE OF   30.00000 DEGREES
         ==============================================================================================================

         HARMONIC VOLTAGES(PU) AT EACH BUSBAR
         ====================================

         -BUSBAR-    --------------------HARMONIC VOLTAGES----------------------
                     ---REAL-PU---   ---IMAG-PU---   ---MAG.-PU---   --ANGLE-Deg--

         NETW          0.00000E+00     0.00000E+00     0.00000E+00     0.00000E+00
         SUB 1         0.00000E+00     0.00000E+00     0.00000E+00     0.00000E+00
         SUB 2        -0.18198E-01     0.42968E-01     0.46663E-01     0.11295E+03
         SUB 3         0.00000E+00     0.00000E+00     0.00000E+00     0.00000E+00
         EMERG-G      -0.19061E-01     0.38168E-01     0.42663E-01     0.11654E+03

         NETEQU        0.00000E+00     0.00000E+00     0.00000E+00     0.00000E+00
         MOT1         -0.18198E-01     0.42969E-01     0.46664E-01     0.11295E+03
         MOT2         -0.18198E-01     0.42969E-01     0.46664E-01     0.11295E+03
         MOT3         -0.18198E-01     0.42969E-01     0.46664E-01     0.11295E+03
         G1           -0.19146E-01     0.37793E-01     0.42366E-01     0.11687E+03

         G2           -0.19194E-01     0.37340E-01     0.41985E-01     0.11720E+03
         ========================================================================


         HARMONIC CURRENT PENETRATION INTO THE NETWORK
         =============================================

                                      ----------------------------HARMONIC CURRENTS----------------------------
         ------BUSBARS------          ---REAL-PU---  ---IMAG-PU---  ---MAG.-PU---  --ANGLE-Deg--  ---LOSS-PU---

         BRANCHES
         --------                 Yes
Continue listing? (Y or N or S)   No
                                  Search
                                                          COPYRIGHT (C) TOM InC 1988 TIME : 16:41:47 29/08/2001
```

Figure 13.11

```
         --FROM--    ---TO---
         NETW        SUB 1        SEND    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
                                  RECV    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
         SUB 1       THROUGH    T/XD11    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
         NETW        SUB 3        SEND    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
                                  RECV    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
         SUB 3       THROUGH    T/XD11    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
         SUB 3       THROUGH    T/XD11    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00

         EMERG-G     SUB 2        SEND   -0.87117E-01   -0.50235E-01    0.10056E+00   -0.15003E+03    0.31561E-03
                                  RECV   -0.86643E-01   -0.50017E-01    0.10056E+00   -0.15000E+03
         NETEQU      NETW         SEND    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
                                  RECV    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
         MOT1        SUB 2        SEND    0.13653E-07    0.13687E-07    0.19332E-07    0.45071E+02    0.81446E-09
                                  RECV    0.66928E-05    0.28235E-05    0.19332E-07    0.22874E+02
         MOT2        SUB 2        SEND    0.13653E-07    0.13687E-07    0.19332E-07    0.45071E+02    0.81446E-09
                                  RECV    0.66928E-05    0.28235E-05    0.19332E-07    0.22874E+02
         MOT3        SUB 2        SEND    0.39638E-07   -0.16548E-08    0.39672E-07   -0.23906E+01   -0.72838E-09
                                  RECV    0.26862E-04    0.11375E-04    0.39672E-07    0.22952E+02

         G1          EMERG-G      SEND   -0.35103E-01   -0.18227E-01    0.39553E-01   -0.15256E+03    0.98017E-05
                                  RECV   -0.35014E-01   -0.18182E-01    0.39553E-01   -0.15256E+03
         G2          EMERG-G      SEND   -0.53432E-01   -0.27948E-01    0.60300E-01   -0.15239E+03    0.30168E-04
                                  RECV   -0.53373E-01   -0.27918E-01    0.60300E-01   -0.15239E+03

         SYNCHRONOUS MACHINES
         --------------------

         NETEQU                           0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
         G1                               0.35103E-01    0.18227E-01    0.39553E-01    0.27440E+02    0.16756E-04
         G2                               0.53432E-01    0.27948E-01    0.60300E-01    0.27612E+02    0.18036E-04

         INDUCTION MOTORS
         ----------------

         MOT1                             0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
         MOT2                             0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
         MOT3                             0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00

         STATIC LOADS
         ------------

         SUB 1                    Yes       00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
Continue listing? (Y or N or S)   No
                                  Search
                                                          COPYRIGHT (C) TOM InC 1988 TIME : 16:41:53 29/08/2001
```

Figure 13.12

```
        SUB 3                          0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
        EMERG-G                       -0.12700E-02    0.41345E-02    0.43251E-02    0.10708E+03    0.18201E-03
        ==========================================================================================


        HARMONIC CURRENT(S) OF ORDER  ( 5) IS/ARE INJECTED TO FOLLOWING BUSBAR(S):

        SUB 2    WITH MAGNITUDE OF  0.0800000 P.U. & ANGLE OF   50.00000 DEGREES
        ================================================================================================

        HARMONIC VOLTAGES(PU) AT EACH BUSBAR
        ====================================

        -BUSBAR-   --------------------HARMONIC VOLTAGES----------------------
                   ---REAL-PU---   ---IMAG-PU---   ---MAG.-PU---   --ANGLE-Deg--

        NETW         0.23327E-03    -0.54710E-03     0.59476E-03    -0.66908E+02
        SUB 1        0.19269E-02    -0.91139E-02     0.93153E-02    -0.78062E+02
        SUB 2       -0.31147E-01     0.38204E-01     0.49292E-01     0.12919E+03
        SUB 3        0.11274E-01    -0.23280E-01     0.25866E-01    -0.64160E+02
        EMERG-G     -0.30764E-01     0.36810E-01     0.47973E-01     0.12989E+03

        NETEQU       0.17246E-03    -0.37996E-03     0.41726E-03    -0.65588E+02
        MOT1        -0.31141E-01     0.38186E-01     0.49274E-01     0.12920E+03
        MOT2        -0.31134E-01     0.38168E-01     0.49256E-01     0.12920E+03
        MOT3        -0.31142E-01     0.38177E-01     0.49268E-01     0.12921E+03
        G1          -0.30761E-01     0.36748E-01     0.47923E-01     0.12993E+03

        G2          -0.30750E-01     0.36671E-01     0.47857E-01     0.12998E+03
        ======================================================================


        HARMONIC CURRENT PENETRATION INTO THE NETWORK
        ============================================

                                       ---------------------------HARMONIC CURRENTS---------------------------
        ------BUSBARS------            ---REAL-PU---  ---IMAG-PU---  ---MAG.-PU---  --ANGLE-Deg--  ---LOSS-PU---

        BRANCHES                  Yes
        --------                  No
Continue listing? (Y or N or S)   Search
                                                           COPYRIGHT (C) TOM InC 1988 TIME : 16:41:59 29/08/2001
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Figure 13.13

13.3 Summary

The harmonic analysis section of PASHA provides a variety of reliable algorithms to perform a complete harmonic analysis of power system and determine harmonic distortions at all busbars, junctions and other power system elements. All of the study results can be easily displayed on the network diagram or listed in a tabular form to the terminal or sent to a line printer or plotting file for later printing or plotting.

Harmonic analysis section also provides sensitivity calculations and possible resonance reports at all busbars. Bar charts are available for harmonic components of system voltages and currents directly through network single-line diagram. Graphical representation of frequency spectrum for all busbars in Cartesian and polar coordinates is another powerful feature of this section. Furthermore filter design of single tunes and high pass filters and filter cost optimization subsection incorporates state of the art nonlinear optimization techniques for providing the best suited filter to the power system. Harmonic voltage conversion procedure will help engineers to estimate the amount of harmonic currents injected by harmonic sources where there is not proper means of harmonic current measurements.