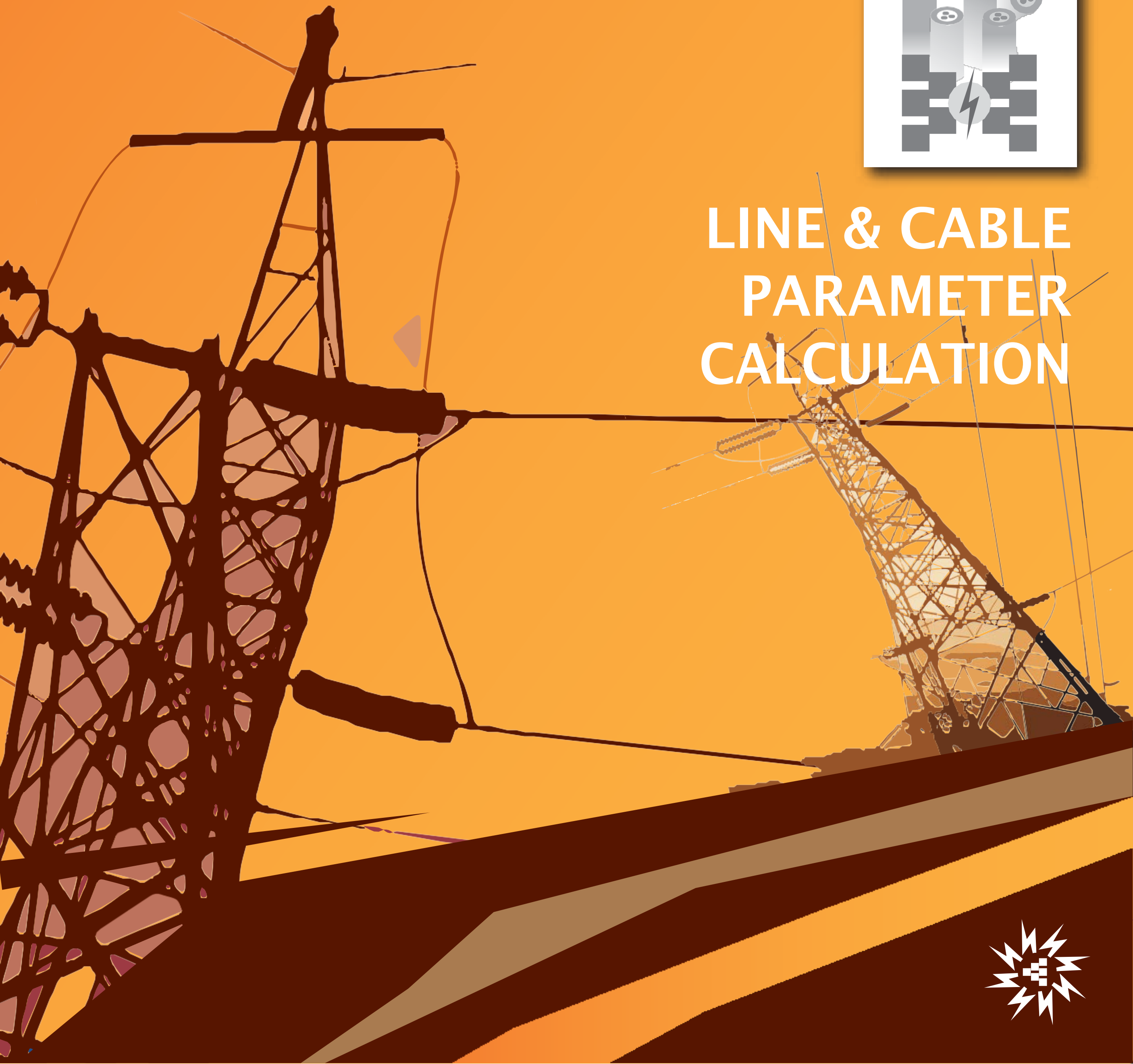
User Manual

PSCT | *Protection Analytic tool*

LINE & CABLE PARAMETER CALCULATION



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1. INTRODUCTION

POWERLPC is designed to compute the overhead transmission line electrical parameters from the design data. The program input data is through an ASCII file. Section-2 gives technical description of the overhead transmission line. How to compute line parameters using MiP-PSCT is explained in Section-3. Section 4 gives the format of the input file. In Section-5, the data file preparation for typical line parameter calculation studies are discussed along with the results. When **POWERLPC** is executed from integrated environment, the input data is automatically generated from the centralized database.

Three-phase transmission lines are used to transfer power from generation points to load points. The voltage levels are selected to be as high as possible to minimize the conductor I^2R losses. However, voltage level is decided by economic considerations and the amount of power transfer. This technical reference gives the mathematical formulation for the computation of the overhead transmission line parameters. Overhead transmission line is represented by an equivalent circuit, with series impedance consisting of line resistance and line inductance and shunt susceptance corresponding to line charging current.

2. TECHNICAL DESCRIPTION

1.1 Mathematical Equations

A general method is used to determine the aerial transmission line parameters. For illustration purpose, the explanation is with 3 phase double circuits (group A and B) and 2 ground wires (group S). But the methodology can be generalized for any number of phases, circuits and ground wires.

1.2 Series Impedance

For each conductor ***i***, the self and mutual series impedances (in the presence of earth) to all other conductors is given by

$$Z_{ii} = r_c + \Delta r_{ii} + j\,(X_a + \Delta X_{ii}) \qquad (2.1)$$

$$Z_{ij} = \Delta r_{ij} + j(\Delta X_{ij} - 0.27942\left(\frac{f}{60}\right)\log_{10}(d_{ij})) \qquad (2.2)$$

where the Δ terms are Carson's corrections.

Carson's corrections with first two terms are given by

$$\Delta r_{ii} = 0.095394\left(\frac{f}{60}\right) - 1.633 \text{ X } 10^{-6}\, h_i \sqrt{\frac{f}{\rho}} \qquad (2.3)$$

$$\Delta r_{ij} = 0.095304\left(\frac{f}{60}\right) - 0.8165 \text{ X } 10^{-6}\,(h_i + h_j)\sqrt{\frac{f}{\rho}} \qquad (2.4)$$

$$\Delta X_{ii} = 0.27942\left(\frac{f}{60}\right)\log_{10}\left(2162.5361\sqrt{\frac{\rho}{f}}\right) + 1.633 \text{ X} 10^{-6}\, h_i\, \frac{f^{3/2}}{\sqrt{\rho}} \qquad (2.5)$$

$$\Delta X_{ij} = 0.27942 \left(f/60 \right) \log_{10} \left(2162.5361\sqrt{\rho / f} \right) + 0.8165 \text{ X } 10^{-6} (h_i + hj)\sqrt{\frac{f}{\rho}} \quad (2.6)$$

r_c: Ac resistance of the conductor at the desired temperature in ohms per mile.

The ac resistance is calculated by accounting for the skin effect.

$$r_{ac\,(t1)} = r_{dc\,(t1)}\, k \quad (2.7)$$

where k depends upon the value of X obtained from table 2.1 :

Table 2.1 : Skin Effect Table

X	k	X	k	X	k	X	k
0.0	1.00000	1.0	1.00519	2.0	1.07816	3.0	1.31809
0.1	1.00000	1.1	1.00758	2.1	1.09375	3.1	1.35102
0.2	1.00001	1.2	1.01071	2.2	1.11126	3.2	1.38504
0.3	1.00004	1.3	1.01470	2.3	1.13069	3.3	1.41999
0.4	1.00013	1.4	1.01969	2.4	1.15207	3.4	1.45570
0.5	1.00032	1.5	1.02582	2.5	1.17538	3.5	1.49202
0.6	1.00067	1.6	1.03323	2.6	1.20056	3.6	1.52879
0.7	1.00124	1.7	1.04205	2.7	1.22753	3.7	1.56587
0.8	1.00212	1.8	1.05240	2.8	1.25260	3.8	1.60314
0.9	1.00340	1.9	1.06440	2.9	1.28644	3.9	1.64051

where ***X*** is given by

$$X = 0.063598\sqrt{\frac{\mu f}{r_{dc(t1)}}} \quad (2.8)$$

where,

□	:	Permeability = 1
f	:	Desired frequency in Hz, at which parameters are computed.
□	:	Earth resistivity in ohm-metre.
dij	:	Center to center distance between conductor (bundle) ***i*** and conductor (bundle) ***j*** in feet.
Hi	:	Height of the conductor ***i*** above ground in feet.
Hj	:	Height of the conductor ***j*** above ground in feet.
Xa	:	Self-impedance to a distance of 1 ft = X_a = 0.27942(f/60) $\log_{10}$ (1/GMR)
GMR	:	Geometric Mean Radius = 0.7788007 x conductor radius

For bundle conductor GMR is given by

$$GMR_b = \sqrt[n]{N \gamma^{N-1} GMR} \qquad (2.9)$$

where ***N*** is the number of sub-conductors in the bundle.
γ is the bundle radius in feet, and
GMR is as defined above.

In the matrix form, the series impedance matrix is given by

$$Z^x = \begin{bmatrix} Z^x_{AA} & Z^x_{AB} & Z^x_{AS} \\ Z^x_{BA} & Z^x_{BB} & Z^x_{BA} \\ Z^x_{SA} & Z^x_{SB} & Z^x_{SS} \end{bmatrix} \qquad (2.10)$$

The sub-matrices of equation 2.10 are defined as

Z^x_{AA}	:	Self and mutual impedances for phase a, b, and c of circuit A of the double-hung line.
$Z^x_{AB} = (Z^x_{BA})^t$	:	Mutual coupling between three-phase circuits A and B.
$Z^x_{AS} = (Z^x_{SA})^t$	:	Mutual coupling between circuit A and shield circuit S.
$Z^x_{BS} = (Z^x_{SB})^t$	:	Mutual coupling between circuit B and the shield circuit.
Z^x_{BB}	:	Self and mutual impedances for phase a, b, and c of circuit B of the double-hung line.
Z^x_{SS}	:	Self and mutual impedances of shield circuits.

If the lines are transposed (L transpositions), then the average impedance for the transposed lines is

$$\bar{Z} = \frac{1}{L}\sum_{l=1}^{L} Z(l) = \begin{bmatrix} \bar{Z}_{AA} & \bar{Z}_{AB} & \bar{Z}_{AS} \\ \bar{Z}_{BA} & \bar{Z}_{BB} & \bar{Z}_{BS} \\ \bar{Z}_{SA} & \bar{Z}_{SB} & \bar{Z}_{SS} \end{bmatrix} \qquad (2.11)$$

After eliminating the ground wires, the series impedance matrix

Z_{av} is given by

$$Z_{av} = \begin{bmatrix} \overline{Z}_{AA} & \overline{Z}_{AB} \\ \overline{Z}_{BA} & \overline{Z}_{BB} \end{bmatrix} - \begin{bmatrix} \overline{Z}_{AS} \\ \overline{Z}_{BS} \end{bmatrix} \overline{Z}_{SS}^{-1} \begin{bmatrix} \overline{Z}_{SA} & \overline{Z}_{SB} \end{bmatrix} \tag{2.12}$$

Series sequence impedance matrix Z_s^{012} is given by

$$Z_s^{012} = \begin{bmatrix} T_s^{-1} & 0 \\ 0 & T_s^{-1} \end{bmatrix} Z_{av} \begin{bmatrix} T_s & 0 \\ 0 & T_s \end{bmatrix} \tag{2.13}$$

The transformation matrix T_s for 3 phase circuit is given by

$$T_s = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \tag{2.14}$$

Wherein operator a is $1\angle 120$ and a^2 is $1\angle 240$.

For 6 phase circuit, transformation matrix T_s is given by

$$T_s = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & b^5 & b^4 & b^3 & b^2 & b \\ 1 & b^4 & b^2 & 1 & b^4 & b^2 \\ 1 & b^3 & 1 & b^3 & 1 & b^3 \\ 1 & b^2 & b^4 & 1 & b^2 & b^4 \\ 1 & b & b^2 & b^3 & b^4 & b^5 \end{bmatrix} \tag{2.15}$$

Wherein operator b is $1\angle 60$.

If the circuits A and B have identical conductors and are symmetric with respect to each other and with respect to grounds, then the series sequence impedance matrix for the equivalent single circuit is given by

$$Z_p^{012} = \frac{1}{2} T_s^{-1} (Z_{AA} + Z_{AB}) T_s \quad (2.16)$$

1.3 Shunt Admittance

Shunt impedance matrix Z_{sh} is given by

$$Z_{sh} = \frac{1}{jw} P \quad (2.17)$$

Wherein element of matrix ***P*** are given by

$$P_{mm^i} = 2.5718 \text{ X } 10^7 \log_{10} \left(\frac{d_{mm^i}}{r_m} \right) \quad (2.18)$$

$$P_{mn} = 2.5718 \text{ X} 10^7 \log_{10} \left(\frac{d_{mn^i}}{d_{mn}} \right) \qquad \forall m \neq n \quad (2.19)$$

where,

d_{mn}	:	Center-to-center distance (feet) from conductor m (or bundle m) to conductor n (or bundle n)
d_{mn}'	:	Center-to-center distance (feet) from conductor m to image n'
r_m	:	Radius (feet) of conductor m or Geometric Mean Radius (GMR'_B in feet) for a bundle conductor

For bundle conductor, GMR'_B is given by

$$GMR_b = \sqrt[N]{N_{\gamma}{}^{N-1} r} \quad (2.20)$$

Elimination of ground wires and computation of zero sequence values is similar to the one described for series impedance.

3. HOW TO DO LINE PARAMETER CALCULATION?

A case study for 3-phase single circuit overhead transmission line with two ground wires has been given here. Two bundle conductors are used in the configuration considered. The line length is 100 km, voltage level 100 kV and lines are perfectly transposed. 100 MVA base is used for calculation purposes. Table 3.1 and 3.2 gives the input data required for the calculation of line parameters.

Table 3.1: Input Data

Parameter	Value	Unit
Number of Phases per circuit	3	
Number of circuits	1	
Number of Ground wires	2	
Number of conductors per bundle	2	
Line transposition status	Transposed	
Base MVA	100	MVA
Base kV	100	KV
Unit type		MKS
Out type		Per unit/km
Conductor material type		Aluminium
Frequency	50	Hertz
Bundle Space	0.45	Meter
Earth Resistivity	250	Ohm-meter
Line length	100	km
Carson correction option		Single term correction
Frequency starting value	50	Hertz
Frequency ending value	50	Hertz
Frequency step value	50	Hertz
Communication line height from ground	50	Meter
Communication line width from center of tower	100	Meter

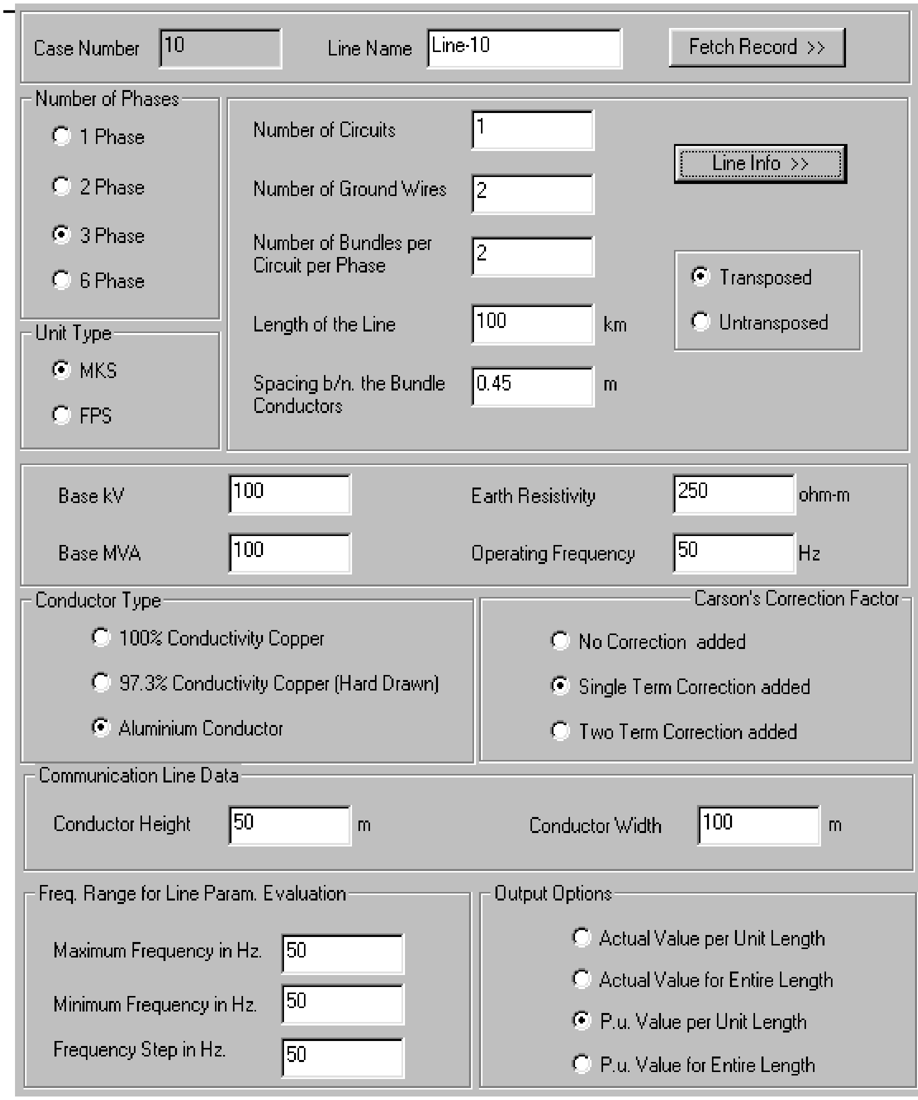
Table3.2: Input Data							
Conductor (no)*	**RDC (ohm)**	**T1 (degree-c)**	**T2 (degree-c)**	**CD (Meter)**	**CH (Meter)**	**CW (Meter)**	**Sag (Meter)**
1	0.06153	25	50	0.03038	22.3	-11	12.9
2	0.06153	25	50	0.03038	22.3	0	12.9
3	0.06153	25	50	0.03038	22.3	11	12.9
4	2.5	25	25	0.011	31	-8	10.2
5	2.5	25	25	0.011	31	8	10.2

* Notation used for conductor information:

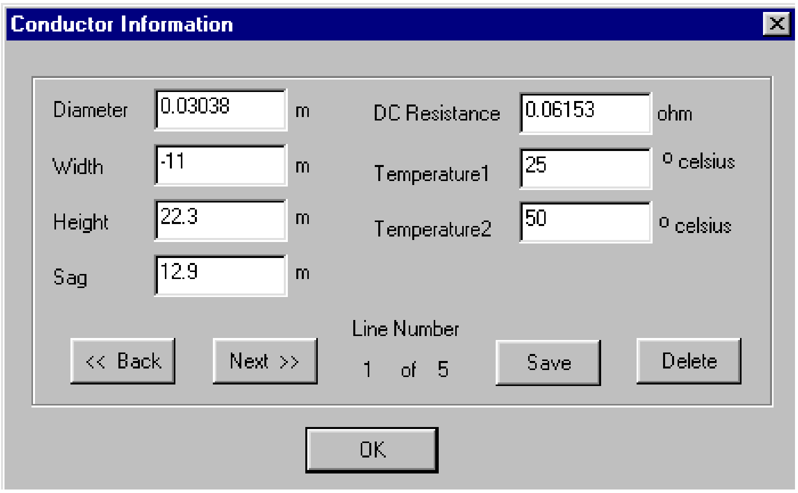
RDC : DC resistance of conductor in ohms at T1 degree-Celsius.
T1 : Temperature in degree Celsius at which RDC value is provided.
T2 : Temperature in degree Celsius at which resistance is to be computed.
CD : Diameter of the conductor in given units.
CH : Height of the conductor above ground in given units.
CW : Distance between the conductor and the center of the tower in given units.

Procedure

Open **Line & Cable Parameter Calculation** module from the MiP-PSCT main screen. A window will be opened as given below. From the **View** menu select **Line**. **Add** a new record to enter the data. Enter all the data as given in the table 3.1. Four output options are provided. Check the relevant option, which specifies the type of output required.


Case Number
10
Line Name
Line-10
Fetch Record >>
Number of Phases
1 Phase
2 Phase
3 Phase
6 Phase
Unit Type
MKS
FPS
Number of Circuits
1
Number of Ground Wires
2
Number of Bundles per Circuit per Phase
2
Length of the Line
100
km
Spacing b/n. the Bundle Conductors
0.45
m
Line Info >>
Transposed
Untransposed
Base kV
100
Base MVA
100
Earth Resistivity
250
ohm-m
Operating Frequency
50
Hz
Conductor Type
100% Conductivity Copper
97.3% Conductivity Copper (Hard Drawn)
Aluminium Conductor
Carson's Correction Factor
No Correction added
Single Term Correction added
Two Term Correction added
Communication Line Data
Conductor Height
50
m
Conductor Width
100
m
Freq. Range for Line Param. Evaluation
Maximum Frequency in Hz.
50
Minimum Frequency in Hz.
50
Frequency Step in Hz.
50
Output Options
Actual Value per Unit Length
Actual Value for Entire Length
P.u. Value per Unit Length
P.u. Value for Entire Length

Click on Line Info to enter the conductor information. A dialog box as shown below appears. Enter the parameters of each conductor. Click on **Next** to add a new record. **Back** button can be used to see the previous records. After entering all the conductor data click on **Save** and **OK.**



After entering all the data in the corresponding field execute the program by **Execute→Line Parameter Calculation**. The report after the execution of the program is as given below.

Report:

```
--------------------------------------------------------------------------
       LINE  PARAMETER CALCULATION
              CASE NO  :  10              SCHEDULE NO : 0
--------------------------------------------------------------------------
NUMBER OF PHASES PER CIRCUIT    :   3
NUMBER OF CIRCUITS              :   1
NUMBER OF GROUND WIRES          :   2
NUMBER OF CONDUCTORS PER BUNDLE :   2
LINE TRANSPOSITION STATUS       :   1 (TRANSPOSED)
BASE MVA                        :  100.000
BASE KV                         :  100.000
UNIT TYPE                       :   0 (MKS SYSTEM)
OUT TYPE                        :   2  - Perunit/km
CONDUCTOR MATERIAL TYPE         :   2  - ALUMINUM
FREQUENCY                       :   50.000 hertz
BUNDLE SPACE                    :  0.45000 metre
```

EARTH RESISTIVITY : 250.000 ohm-metre
LINE LENGTH : 100.000 km
CARSON CORRECTION OPTION : 1 - SINGLE TERM CORRECTION
FREQUENCY STARTING VALUE : 50.00 Hz
FREQUENCY ENDING VALUE : 50.00 Hz
FREQUENCY STEP VALUE : 50.00 Hz

NOTATION USED FOR CONDUCTOR INFORMATION
RDC : DC resistance of conductor in ohms at T1 degree Celsius.
T1 : Temperature in degree Celsius at which RDC value is provided.
T2 : Temperature in degree Celsius at which resistance to be computed.
CD : Diameter of the conductor in the given units.
CH : Height of the conductor above ground in given units.
CW : Distance between conductor and centre of the tower in given units.
Sag : Conductor sag at the mid way of the span in given units.

COND. (no.)*	RDC (ohm)	T1 (degree-c)	T2 (degree-c)	CD (metre)	CH (metre)	CW (metre)	Sag (mtr)
1	0.06153	25.00000	50.00000	0.03038	22.30000	-11.00000	12.900
2	0.06153	25.00000	50.00000	0.03038	22.30000	0.00000	12.900
3	0.06153	25.00000	50.00000	0.03038	22.30000	11.00000	12.900
4	2.50000	25.00000	25.00000	0.01100	31.00000	-8.00000	10.200
5	2.50000	25.00000	25.00000	0.01100	31.00000	8.00000	10.200

COMMUNICATION LINE HEIGHT FROM GROUND : 50.00000 metre
COMMUNICATION LINE WIDTH FROM CENTRE OF TOWER : 100.00000 metre

COMPUTED VALUES ARE FOR AC SYSTEM

SERIES PHASE IMPEDANCE MATRIX FOR ALL THE CONDUCTORS IN SELECTED UNIT
CONVENTION (A1 B1 C1),(A2 B2 C2),...,(G1 G2..)

8.360293e-04+j6.229561e-03 4.935158e-04+j2.903181e-03 4.935158e-04+j2.903181e-03
4.935158e-04+j2.903181e-03 4.935158e-04+j2.903181e-03

4.935158e-04+j2.903181e-03 8.360293e-04+j6.229561e-03 4.935158e-04+j2.903181e-03
4.935158e-04+j2.903181e-03 4.935158e-04+j2.903181e-03

4.935158e-04+j2.903181e-03 4.935158e-04+j2.903181e-03 8.360293e-04+j6.229561e-03
4.935158e-04+j2.903181e-03 4.935158e-04+j2.903181e-03

4.935158e-04+j2.903181e-03 4.935158e-04+j2.903181e-03 4.935158e-04+j2.903181e-03
2.549351e-02+j8.011179e-03 4.935158e-04+j2.903181e-03

4.935158e-04+j2.903181e-03 4.935158e-04+j2.903181e-03 4.935158e-04+j2.903181e-03
4.935158e-04+j2.903181e-03 2.549351e-02+j8.011179e-03

SERIES PHASE IMPEDANCE MATRIX AFTER GROUND WIRE ELIMINATION IN SELECTED UNIT

CONVENTION (A1 B1 C1),(A2 B2 C2),...

1.292763e-03+j5.817201e-03 9.502497e-04+j2.490821e-03 9.502497e-04+j2.490821e-03

9.502497e-04+j2.490821e-03 1.292763e-03+j5.817201e-03 9.502497e-04+j2.490821e-03

9.502497e-04+j2.490821e-03 9.502497e-04+j2.490821e-03 1.292763e-03+j5.817201e-03

SERIES SEQUENCE IMPEDANCE MATRIX AFTER GROUND WIRE ELIMINATION IN SELECTED UNIT CONVENTION (0 1 2),(0 1 2),...

3.193263e-03+j1.079884e-02 0.000000e+00+j2.777874e-10 0.000000e+00+j3.703833e-10

0.00000e+00-j1.851916e-10 3.425134e-04+j3.326380e-03 -1.851916e-10+j4.629791e-11

-2.777874e-10+j4.629791e-11 -9.259581e-11+j2.314895e-10 3.425134e-4+j3.326380e-03

SERIES SEQUENCE IMPEDANCE MATRIX - EQUIVALENT CIRCUIT (0 1 2) IN SELECTED UNIT CONVENTION (0 1 2)

3.193263e-03+j1.079884e-02 9.259581e-11+j4.629791e-01 9.259581e-11+j1.388937e-10

-1.851916e-10-j0.000000e+0 3.425135e-04+j3.326380e-03 0.000000e+00+j9.259581e-11

0.00000e+00+j2.777874e-10 -9.259581e-11+j1.851916e-10 3.425135e-04+j3.326380e-03

SHUNT PHASE ADMITTANCE MATRIX FOR ALL THE CONDUCTORS IN SELECTED UNIT CONVENTION (A1 B1 C1),(A2 B2 C2),...,(G1 G2..)

0.000000e+00+j3.217614e-04 0.000000e+00-j3.902427e-05 0.000000e+00-j3.902427e-05
0.000000e+00-j2.327196e-05 0.000000e+00-j2.327196e-05

0.000000e+00-j3.902427e-05 0.000000e+00+j3.217614e-04 0.000000e+00-j3.902427e-05
0.000000e+000-j2.327196e-05 0.000000e+000-j2.327196e-05

0.000000e+00-j3.902427e-05 0.000000e+00-j3.902427e-05 0.000000e+00+j3.217614e-04
0.000000e+00-j2.327196e-05 0.000000e+00-j2.327196e-05

0.000000e+00-j2.327196e-05 0.000000e+00-j2.327196e-05 0.000000e+00-j2.327196e-05
0.000000e+00+j2.012749e-04 0.000000e+00-j1.387813e-05

0.000000e+00-j2.327196e-05 0.000000e+00-j2.327196e-05 0.000000e+00-j2.327196e-05
0.000000e+00-j1.387813e-05 0.000000e+00+j2.012749e-04

SHUNT PHASE ADMITTANCE MATRIX AFTER GROUND WIRE ELIMINATION IN SELECTED UNIT CONVENTION (A1 B1 C1),(A2 B2 C2),...

0.000000e+00+j3.217614e-04 0.000000e+00-j3.902426e-05 0.000000e+00-j3.902426e-05
0.000000e+00-j3.902426e-05 0.000000e+00+j3.217614e-04 0.000000e+00-j3.902426e-05

0.000000e+00-j3.902426e-05 0.000000e+00-j3.902426e-05 0.000000e+00+j3.217614e-04

SHUNT SEQUENCE ADMITTANCE MATRIX AFTER GROUND WIRE ELIMINATION IN SELECTED UNIT CONVENTION (0 1 2),(0 1 2),...

-3.283886e-12+j2.437129e-04 0.00000e+00-j3.532250e-12 7.064500e-12+j3.532250e-12

0.000000e+0-j1.412900e-11 1.224559e-11+j3.607857e-04 -1.412900e-11-j3.532250e-11

0.00000e+00-j7.064500e-12 7.064500e-12-j1.412900e-11 -8.768535e-12+j3.607857e-04

SHUNT SEQUENCE ADMITTANCE MATRIX - EQUIVALENT CIRCUIT (0 1 2) IN SELECTED UNIT CONVENTION (0 1 2)

-3.283887e-12+j2.437129e-04 7.064500e-12-j1.412900e-11 0.000000e+00-j0.000000e+0

7.06450e-12-j2.119350e-11 5.864087e-13+j3.607857e-04 -7.064500e-12-j3.532250e-11

-7.064500e-12-j1.766125e-11 7.06450e-12-j1.412900e-11 8.140732e-13+j3.607857e-04

A,B,C and D constants :
A = 0.9940053821 +j 0.0006166344
B = 3.4114441872 +j 33.1980094910 (Ohm)
C = -0.0000000742 +j 0.0003600645 (Mho)
D = 0.9940053821 +j 0.0006166344

ATTENUATION CONSTANT (Line-to-Line mode) : 0.00006 neper/km
PHASE CONSTANT (Line-to-Line mode) : 0.00110 rad/km
CHARACTERISTIC WAVELENGTH (Line-to-Line mode) : 5727.90753 km
PROPAGATION VELOCITY (Line-to-Line mode) : 286395.37627 km
SURGE IMPEDANCE (REAL, including losses) : 304.04269 Ohms
SURGE IMPEDANCE (IMAGINARY, including losses) : -15.61218 Ohms
ATTENUATION CONSTANT (Line-to-Ground mode) : 0.00024 neper/km
PHASE CONSTANT (Line-to-Ground mode) : 0.00164 rad/km
CHARACTERISTIC WAVELENGTH (Line-to-Ground mode) : 3832.24737 km
PROPAGATION VELOCITY (Line-to-Ground mode): 191612.36850 km

MUTUAL INDUCTANCE IN SELECTED UNIT
BETWEEN PHASE LINE 1 & COMMUNICATION LINE 0.00159
BETWEEN PHASE LINE 2 & COMMUNICATION LINE 0.00165
BETWEEN PHASE LINE 3 & COMMUNICATION LINE 0.00172

% Line parameters per circuit
%CS Type Rp Xp Bp/2
% Rz Xz Bz/2
LN 0 3.425134e-04 3.326380e-03 1.803929e-04
3.193263e-03 1.079884e-02 1.218565e-04

4. INPUT FILE FORMAT

The program requires one input data file viz., "**LPCIN**".

"**LPCIN**" file contains the user defined data for the study considered. This file is to be created by the user of **POWERLPC**. If the line parameter computation is invoked from integrated environment, then "**LPCIN**" file in the required format is automatically created from the centralized data base.

The input data is read in free format. Input data is divided into different heads called streams for explanation purposes. `*int*' is used to indicate that the data type is an integer. `*float*' is used to reference the floating point (real) variable. `*char*' is used to reference the character streams (string).

Stream 1 : System Description

This consists of 3 lines of data for the line parameter study description. Each line data is of char type, and maximum number of alphanumeric characters (including blanks) in a line should not exceed 179. Any useful information, which has to appear in the report file ("**LPCOUT**") can be given in this stream. After the three lines of system description (stream 1), comment lines can be given in the data file by entering % in the first column. Comment line is not written in the output file. These lines are simply read and skipped. If the comment line has to appear in the output file then % should be given in the second column also.

Stream 2 : System Specification

This consists of one line of data which specifies the transmission line, parameters of which are to be computed. Data types/specifications are separated by blanks. Table 4.2 gives the data appearing under different columns.

In table 4.2,

- Number of phases is either 3 or 6. Any other value is reported as error by the program.

Line transposition status is interpreted as -
  - 0 : Line is not transposed
  - 1 : Line is transposed
- Base MVA is used to compute the line parameter values in Per Unit.
- Base kV is used to compute the line parameter values in Per Unit.

Table 4.2 : System Specification

Col.No.	Description	Type	Min	Max
1.	Number of phases	int	1.0000	00006.0
2.	Number of circuits	int	1.0000	00006.0
3.	Number of ground wires	int	0.0000	00004.0
4.	Number of bundle conductors	int	0.0000	00009.0
5.	Line transposition status	int	0.0000	00001.0
6.	Base MVA	float	0.0010	10000.0
7.	Base kV	float	0.0010	10000.0
8.	Unit type	int	0.0000	00001.0
9.	Output option	int	0.0000	00003.0
10.	Conductor type	int	0.0000	00002.0
11.	Frequency	float	1.0000	10000.0
12.	Bundle spacing	float	0.0001	00100.0
13.	Earth resistivity	float	0.0001	10000.0
14.	Line length	float	0.0001	10000.0
15.	Carson correction	int	0.0000	2.00000
16.	Starting frequency	float	0.1000	10000.0
17.	Ending frequency	float	0.1000	10000.0
18.	Frequency step	float	0.1000	10000.0

- Number of phases is either 1 or 2 for DC line and 3 or 6 for AC line.

- Unit type is used to identify the system of unit for various input data. It is interpreted as -
  - 0 : MKS system
  - 1 : FPS system

- Output option identifies the units for the computed quantities in the above system of units. It is interpreted as -
  - 0 : Actual value (Ohm or Mho) per unit length of the line.

  - 1 : Actual value (Ohm or Mho) for entire length of the line.
  - 2 : Value in Per Unit system per unit length of the line.
  - 3 : Value in Per Unit system for entire length of the line.

- Conductor type refers to conductor material type. It is interpreted as -
  - 0 : 100% conductivity copper
  - 1 : 97.3% conductivity copper (hard drawn)
  - 2 : aluminium conductor

- The value given in column 11 is the frequency in Hz, at which the electrical parameters are computed.

- In the computation of line parameters, Carson correction terms are added to the parameters computed.

- This correction is interpreted as -
  - 0 : No correction added.
  - 1 : Single term correction is added.
  - 2 : Two term corrections are added.

- **POWERLPC** is designed to compute the line parameters at different frequencies in single execution. Computation starts with the starting frequency (in Hzs.) specified in column 16. Frequency is incremented in steps by the value specified in column 18. At each frequency the parameters are computed, till the frequency is greater than the value specified in column 17.

Stream 3: Conductor Details

In this stream of data, in each line, the conductor data is given. The number of lines of data is equal to the sum of product of number of phases and number of circuits and number of ground wires. The order in which the data appears is - phase A, B, of circuit 1, then corresponding phases of circuit 2, followed by ground wire information. The data in each column of a line is given in Table 4.3.

Table 4.3 : Conductor/Tower Details				
Col.No.	**Description**	**Type**	**Min**	**Max**
1.	DC resistance	float	1.0e-20	1.0e3
2.	Temperature T1	float	-1.0e3	1.0e4
3.	Temperature T2	float	-1.0e3	1.0e4
4.	Conductor diameter	float	1.0e-10	1.0e10
5.	Conductor height	float	1.0e-2	1.0e4
6.	Conductor width	float	-1.0e3	1.0e3
7.	Sag	float	-1.0e3	1.0e3

Explanation to entries given in table 4.3 is as follows -

- DC resistance is in ohm/unit length at temperature T1. T2 is the temperature at which the line resistance is computed.
- Conductor diameter is in inches if the FPS system of unit is used and is in Cms. if MKS system of unit is used.
- Conductor height is height of the conductor above the ground.
- The unit is in Metres for MKS system and is in Feet for FPS system.
- Conductor width is the distance of the conductor from the center of the tower. Positive sign is to be entered for all the Conductors appearing to the left of center of tower, and negative sign is to be entered for all the conductors appearing to the right of center of tower. Unit is either in Metres or in Feet, depending on MKS or FPS system, respectively.

Stream 4: Communication Line Details

In this stream, communication line details are given. The stream consists of one line of data, containing the information as given in table 2.4.

Table 4.4 : Communication Line Details				
Col.No.	**Description**	**Type**	**Min**	**Max**
1.	Conductor height	float	1.0e-2	1.0e4
2.	Conductor width	float	-1.0e3	1.0e3

Conductor height is height of the communication conductor above the ground. The unit is in Metres for MKS system and is in Feet for FPS system.

Conductor width is the distance of the communication conductor from the center of the tower. Positive sign is to be entered if the communication line appears to the left of center of tower, and negative sign is to be entered for if the communication line appears to the right of center of tower. Unit is either in Metres or in Feet, depending on MKS or FPS system, respectively.

5. CASE STUDY

In this section, a case study is included for 3 phase double circuit overhead transmission line with two ground wires. Two bundle conductors are used in the configuration considered. The line length is 100 Miles, voltage level 220 kV and lines are perfectly transposed. 100 MVA base is used for calculation purposes. Table 5.1 gives names of different input and output files used by **POWERLPC**.

Table 5.1 : Input and Output Files of POWERLPC

Sl.No.	File Name	Mode	Description
1.	**"LPCIN"**	input	Program input file
2.	**"LPCOUT"**	output	Program output (general report) file
3.	"**LPCNORM**"	output	Positive and zero sequence impedance and susceptance
4.	"**LPCHARM**"	output	Phase values of impedance and admittance
5.	**"BINARY FILES"**	output	Variation of line parameters with frequency

"**LPCOUT**" file contains -

- Input data to the program, in the order the data is read. Series phase impedance matrix (R+jX format) for line.
- Series phase impedance matrix (R+jX format) after the elimination of ground wires.
- Series sequence impedance matrix (R+jX format) after the elimination of ground wires.
- Series sequence impedance matrix (R+jX format) for the equivalent circuit.
- Above four matrices for shunt admittance matrix (G+jB format).
- Attenuation constant, Phase constant, Velocity of propagation and surge impedance.

"**LPCNORM**" file contains positive sequence resistance, reactance, and susceptance/2, and zero sequence resistance, reactance, and susceptance/2 in order. The entries are separated by blanks and values are per circuit.

"**LPCHARM**" file contains frequency count, 3x3 series impedance and 3x3 shunt admittance matrices at different frequencies for phase values per circuit. By giving the minimum frequency value and step values same as system frequency, maximum frequency value equal to the maximum harmonic order frequency, line parameters at different harmonic orders can be generated. Shunt admittance value in **LPCHARM** is for half the line.

The files in table 5.1 are the default, when no arguments (parameters) are passed to **POWERLPC**. User defined names can be given to above files

The listing of program input and result files are given in table 5.2 to 5.5 respectively.

Table - 5.2: "LPCCASE1" Input File

```
CASE 1 : 3 PHASE TWO CIRCUITS, TWO GROUND WIRES, 2 CONDUCTORS PER BUNDLE,
LINES ARE TRANSPOSED, 100MVA, 100 kV LINE OF 100 MILES, OUTPUT TYPE OHM/MILE
CARSON CORRECTION SINGLE, FREQUENCY VARIED FROM 0 TO 600 HZS IN STEP OF 60.
3 2 2 2 1 100.0 100.0 1 0 1  60.0 1.5  100.0  100.0 1  0.0 600.0 60.0
0.0424 25.0 75.0 0.144583333 106.0 -26.0 0.0
0.0424 25.0 75.0 0.144583333  74.0 -39.0 0.0
0.0424 25.0 75.0 0.144583333  44.0 -28.0 0.0
0.0424 25.0 75.0 0.144583333 106.0  26.0 0.0
0.0424 25.0 75.0 0.144583333  74.0  39.0 0.0
0.0424 25.0 75.0 0.144583333  44.0  28.0 0.0
1.2071 20.0 20.0 0.007601430 138.0 -26.0 0.0
1.2071 20.0 20.0 0.007601430 138.0  26.0 0.0
30.0 500.0
```

Table - 5.3: "LPCOUT" Output File

```
DATE : 2/7/1994                                             TIME : 07:06:46.53
--------------------------------------------------------------------------------
-----------------------------------------------------------
CASE 1 : 3 PHASE TWO CIRCUITS, TWO GROUND WIRES, 2 CONDUCTORS PER BUNDLE,
LINES ARE TRANSPOSED, 100MVA, 100 kV LINE OF 100 MILES, OUTPUT TYPE OHM/MILE
CARSON CORRECTION SINGLE, FREQUENCY VARIED FROM 0 TO 600 HZS IN STEP OF 60.
--------------------------------------------------------------------------------
--------------------------------------------------------
NUMBER OF PHASES PER CIRCUIT    :    3
NUMBER OF CIRCUITS              :    2
NUMBER OF GROUND WIRES          :    2
NUMBER OF CONDUCTORS PER BUNDLE :    2
LINE TRANSPOSITION STATUS       :    1 (TRANSPOSED)
BASE MVA                                             :  100.000
BASE kV                                                 :  100.000
UNIT TYPE                                             :    1 (FPS SYSTEM)
```

```
OUT TYPE                                              :    0  - Ohm(Mho)/mile
CONDUCTOR MATERIAL TYPE       :    1  - HARD DRAWN 97.3% CONDUCTIVITY COPPER
FREQUENCY                                         :   60.000 hertz
BUNDLE SPACE                                   :  1.50000 feet
EARTH RESISTIVITY                          :  100.000 ohm-metre
LINE LENGTH                                       :  100.000 mile
CARSON CORRECTION OPTION     :    1  - SINGLE TERM CORRECTION
FREQUENCY STARTING VALUE     :     0.00 Hzs
FREQUENCY ENDING VALUE          :   600.00 Hz
FREQUENCY STEP VALUE               :    60.00 Hz
--------------------------------------------------------------------------------
---
NOTATION USED FOR CONDUCTOR INFORMATION
RDC : DC resistance of conductor in ohms at T1 degree Celsius.
T1  : Temperature in degree Celsius at which RDC value is provided.
T2 : Temperature in degree Celsius at which resistance is to be computed.
CD  : Diameter of the conductor in the given units.
CH  : Height of the conductor above ground in given units.
CW  : Distance between the conductor and the centre of the tower in given
units.
--------------------------------------------------------------------------------
---
COND.         RDC          T1          T2          CD          CH          CW    Sag
(no.)*      (ohm) (degree-c) (degree-c)      (feet)      (feet)      (feet) (feet)
--------------------------------------------------------------------------------
---
     1    0.04240   25.00000   75.00000    0.14458  106.00000  -26.00000  0.000
     2    0.04240   25.00000   75.00000    0.14458   74.00000  -39.00000  0.000
     3    0.04240   25.00000   75.00000    0.14458   44.00000  -28.00000  0.000
     4    0.04240   25.00000   75.00000    0.14458  106.00000   26.00000  0.000
     5    0.04240   25.00000   75.00000    0.14458   74.00000   39.00000  0.000
     6    0.04240   25.00000   75.00000    0.14458   44.00000   28.00000  0.000
     7    1.20710   20.00000   20.00000    0.00760  138.00000  -26.00000  0.000
     8    1.20710   20.00000   20.00000    0.00760  138.00000   26.00000  0.000
--------------------------------------------------------------------------------
---
COMMUNICATION LINE HEIGHT FROM GROUND         :   30.00000 feet
COMMUNICATION LINE WIDTH FROM CENTRE OF TOWER :  500.00000 feet
--------------------------------------------------------------------------------
---
SERIES PHASE IMPEDANCE MATRIX FOR ALL THE CONDUCTORS IN SELECTED UNIT
CONVENTION (A1 B1 C1),(A2 B2 C2),...,(G1 G2..)

 1.22824e-01+j1.11281e+00   9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01

 9.53040e-02+j4.62158e-01   1.22824e-01+j1.11281e+00    9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01    9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01
```

```
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01   1.22824e-01+j1.11281e+00
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01

 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01    9.53040e-02+j4.62158e-01
 1.22824e-01+j1.11281e+00   9.53040e-02+j4.62158e-01    9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01

 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01    9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   1.22824e-01+j1.11281e+00    9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01

 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01    9.53040e-02+j4.62158e-01

 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01    1.22824e-01+j1.11281e+00
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01

 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01    9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01    9.53040e-02+j4.62158e-01
 1.30240e+00+j1.66942e+00   9.53040e-02+j4.62158e-01

 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01    9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   9.53040e-02+j4.62158e-01    9.53040e-02+j4.62158e-01
 9.53040e-02+j4.62158e-01   1.30240e+00+j1.66942e+00

-----------------------------------------------------------------------------
---
SERIES PHASE IMPEDANCE MATRIX AFTER GROUND WIRE ELIMINATION IN SELECTED UNIT
CONVENTION (A1 B1 C1),(A2 B2 C2),...

 1.53011e-01+j9.40725e-01   1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01
 1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01

 1.25492e-01+j2.90069e-01   1.53011e-01+j9.40725e-01   1.25492e-01+j2.90069e-01
 1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01

 1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01   1.53011e-01+j9.40725e-01
 1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01

 1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01
 1.53011e-01+j9.40725e-01   1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01

 1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01
 1.25492e-01+j2.90069e-01   1.53011e-01+j9.40725e-01   1.25492e-01+j2.90069e-01

 1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01
 1.25492e-01+j2.90069e-01   1.25492e-01+j2.90069e-01   1.53011e-01+j9.40725e-01
```

```
--------------------------------------------------------------------------------
---
SERIES SEQUENCE IMPEDANCE MATRIX AFTER GROUND WIRE ELIMINATION IN SELECTED UNIT
CONVENTION (0 1 2),(0 1 2),...

 4.03995e-01+j1.52086e+00   0.00000e+00-j1.49012e-08   2.98023e-08-j2.98023e-08
 3.76475e-01+j8.70208e-01   0.00000e+00-j1.11759e-08  -1.49012e-08-j0.00000e+00

-1.49012e-08-j2.98023e-08    2.75195e-02+j6.50656e-01    0.00000e+00-j2.98023e-08
 0.00000e+00-j2.23517e-08    0.00000e+00-j0.00000e+00    0.00000e+00-j0.00000e+00

-1.49012e-08-j1.49012e-08    1.49012e-08-j1.49012e-08    2.75195e-02+j6.50656e-01
 0.00000e+00-j5.58794e-09    0.00000e+00-j0.00000e+00    0.00000e+00-j0.00000e+00

 3.76475e-01+j8.70208e-01    0.00000e+00-j1.11759e-08   -1.49012e-08-j0.00000e+00
 4.03995e-01+j1.52086e+00    0.00000e+00-j1.49012e-08    2.98023e-08-j2.98023e-08

 0.00000e+00-j2.23517e-08    0.00000e+00-j0.00000e+00    0.00000e+00-j0.00000e+00
-1.49012e-08-j2.98023e-08    2.75195e-02+j6.50656e-01    0.00000e+00-j2.98023e-08

 0.00000e+00-j5.58794e-09    0.00000e+00-j0.00000e+00    0.00000e+00-j0.00000e+00
-1.49012e-08-j1.49012e-08    1.49012e-08-j1.49012e-08    2.75195e-02+j6.50656e-01

--------------------------------------------------------------------------------
---
SERIES SEQUENCE IMPEDANCE MATRIX - EQUIVALENT CIRCUIT (0 1 2) IN SELECTED UNIT
CONVENTION (0 1 2)

 3.90235e-01+j1.19554e+00   7.45058e-09+j3.72529e-09   7.45058e-09+j1.11759e-08

 2.98023e-08-j2.98023e-08   1.37598e-02+j3.25328e-01   0.00000e+00-j7.45058e-09

-5.96046e-08-j0.00000e+00   7.45058e-09-j0.00000e+00   1.37597e-02+j3.25328e-01

--------------------------------------------------------------------------------
---
SHUNT PHASE ADMITTANCE MATRIX FOR ALL THE CONDUCTORS IN SELECTED UNIT
CONVENTION (A1 B1 C1),(A2 B2 C2),...,(G1 G2..)

-0.00000e+00+j6.91566e-06   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07

 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07
  0.00000e+00-j6.48939e-07    0.00000e+00-j6.48939e-07

  0.00000e+00-j6.13073e-07    0.00000e+00+j6.91566e-06    0.00000e+00-j6.13073e-07
 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07    0.00000e+00-j6.13073e-07
 0.00000e+00-j6.48939e-07  -0.00000e+00-j6.48939e-07

  0.00000e+00-j6.13073e-07    0.00000e+00-j6.13073e-07   -0.00000e+00+j6.91566e-06
  0.00000e+00-j6.13073e-07    0.00000e+00-j6.13073e-07    0.00000e+00-j6.13073e-07
```

```
 0.00000e+00-j6.48939e-07   0.00000e+00-j6.48939e-07

 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07
 0.00000e+00+j6.91566e-06   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07
 0.00000e+00-j6.48939e-07  -0.00000e+00-j6.48939e-07

  0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07
 0.00000e+00-j6.13073e-07  -0.00000e+00+j6.91566e-06    0.00000e+00-j6.13073e-07
 0.00000e+00-j6.48939e-07   0.00000e+00-j6.48939e-07

  0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07
 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00+j6.91566e-06
 0.00000e+00-j6.48939e-07  -0.00000e+00-j6.48939e-07

  0.00000e+00-j6.48939e-07   0.00000e+00-j6.48939e-07   0.00000e+00-j6.48939e-07
  0.00000e+00-j6.48939e-07   0.00000e+00-j6.48939e-07   0.00000e+00-

j6.48939e-07
-0.00000e+00+j7.28228e-06   0.00000e+00-j6.86904e-07

  0.00000e+00-j6.48939e-07   0.00000e+00-j6.48939e-07   0.00000e+00-j6.48939e-07
 0.00000e+00-j6.48939e-07   0.00000e+00-j6.48939e-07   0.00000e+00-j6.48939e-07
 0.00000e+00-j6.86904e-07   0.00000e+00+j7.28228e-06
-------------------------------------------------------------------------------
---
SHUNT PHASE ADMITTANCE MATRIX AFTER GROUND WIRE ELIMINATION IN SELECTED UNIT
CONVENTION (A1 B1 C1),(A2 B2 C2),...

-0.00000e+00+j6.91566e-06   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07
 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07

 0.00000e+00-j6.13073e-07   0.00000e+00+j6.91566e-06   0.00000e+00-j6.13073e-07
 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07  -0.00000e+00-j6.13073e-07

 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07  -0.00000e+00+j6.91566e-06
 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07

 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07
 0.00000e+00+j6.91566e-06   0.00000e+00-j6.13073e-07  -0.00000e+00-j6.13073e-07

 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07
 0.00000e+00-j6.13073e-07  -0.00000e+00+j6.91566e-06    0.00000e+00-j6.13073e-07

 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07
 0.00000e+00-j6.13073e-07   0.00000e+00-j6.13073e-07   0.00000e+00+j6.91566e-06

-------------------------------------------------------------------------------
---
SHUNT SEQUENCE ADMITTANCE MATRIX AFTER GROUND WIRE ELIMINATION IN SELECTED UNIT
CONVENTION (0 1 2),(0 1 2),...
```

```
-7.66628e-14+j5.68951e-06    1.13687e-13+j2.27374e-13  -1.13687e-13+j3.41061e-13
 2.47824e-14-j1.83922e-06    0.00000e+00-j0.00000e+00   0.00000e+00-j0.00000e+00

 0.00000e+00-j1.13687e-13    9.84768e-14+j7.52873e-06    0.00000e+00-j1.13687e-13
 0.00000e+00-j4.97380e-14   -9.00021e-15+j2.65269e-14   -3.36324e-14+j1.89478e-15

 0.00000e+00-j0.00000e+00    0.00000e+00+j2.27374e-13   -5.68434e-14+j7.52873e-06
 0.00000e+00-j4.97380e-14    3.36324e-14+j1.89478e-15    9.00021e-15+j2.65269e-14

 2.47824e-14-j1.83922e-06    0.00000e+00-j5.68434e-14    0.00000e+00-j5.68434e-14
-7.66628e-14+j5.68951e-06    1.13687e-13+j2.27374e-13   -1.13687e-13+j3.41061e-13

 1.42109e-14-j6.39488e-14   -7.10543e-15+j3.36324e-14   -7.10543e-15+j9.00021e-15
 0.00000e+00-j1.13687e-13    9.84768e-14+j7.52873e-06    0.00000e+00-j1.13687e-13

-1.42109e-14-j7.10543e-14    7.10543e-15+j1.89478e-15    7.10543e-15+j2.65269e-14
 0.00000e+00-j0.00000e+00    0.00000e+00+j2.27374e-13   -5.68434e-14+j7.52873e-06

-------------------------------------------------------------------------
------
---
SHUNT SEQUENCE ADMITTANCE MATRIX - EQUIVALENT CIRCUIT (0 1 2) IN SELECTED
UNIT CONVENTION (0 1 2)

-1.03761e-13+j7.70059e-06   0.00000e+00+j2.27374e-13
                            0.00000e+00+j4.54747e-13

-2.27374e-13-j0.00000e+00   6.32827e-14+j1.50575e-05  -4.54747e-13-

 j2.27374e-13 2.27374e-13+j1.13687e-13    4.54747e-13+j2.27374e-13  -

 4.88498e-15+j1.50575e-05
-------------------------------------------------------------------------
------
---
ATTENUATION CONSTANT (Line-to-Line mode)       :    0.00005 neper
/ mile PHASE CONSTANT (Line-to-Line mode)       :   0.00221
rad/mile CHARACTERISTIC WAVELENGTH (Line-to-Line mode)
                                               : 2838.22113 mile
PROPAGATION VELOCITY (Line-to-Line mode)        : 170293.26796
mile
SURGE IMPEDANCE (REAL, including losses)        :  294.04379
Ohms SURGE IMPEDANCE (IMAGINARY, including losses)       :
                                               -6.21551 Ohms
```

```
ATTENUATION CONSTANT (Line-to-Ground mode)      :    0.00049
neper/mile PHASE CONSTANT (Line-to-Ground mode) :    0.00307
rad/mile CHARACTERISTIC WAVELENGTH (Line-to-Ground mode) :
2044.42449 mile PROROGATION VELOCITY (Line-to-Ground mode)
                                                 : 122665.46940
mile
```

```
MUTUAL INDUCTANCE IN SELECTED UNIT
BETWEEN  PHASE  LINE  1  &  COMMUNICATION  LINE
0.20130 BETWEEN PHASE LINE 2 & COMMUNICATION
LINE   0.19919   BETWEEN   PHASE   LINE   3   &
COMMUNICATION LINE 0.20205 BETWEEN PHASE LINE
4 & COMMUNICATION LINE    0.21364

BETWEEN PHASE LINE 5 & COMMUNICATION LINE

0.21801 BETWEEN PHASE LINE 6 & COMMUNICATION
LINE

0.21564
-------------------------------------------------------------------------
------
---
TIME TAKEN BY THE PROGRAM :     3.03
Seconds
DATE : 2/7/1994                                             TIME :
07:06:49.56
```

Table - 5.4 : "LPCHARM" harmonic libraries -compatible to miharm.txt

```
LH  0    11
   1
 2.27271e-02  2.50082e-03   1.62122e-04  1.41640e-03   1.62122e-04  1.41640e-03
 1.62122e-04  1.41640e-03   2.27271e-02  2.50082e-03   1.62122e-04  1.41640e-03
 1.62122e-04  1.41640e-03   1.62122e-04  1.41640e-03   2.27271e-02  2.50082e-03
-0.00000e+00  5.76305e-09   0.00000e+00  5.10894e-10   0.00000e+00  5.10894e-10
  0.00000e+00  5.10894e-10   0.00000e+00  5.76305e-09   0.00000e+00  5.10894e-10
  0.00000e+00  5.10894e-10   0.00000e+00  5.10894e-10  -0.00000e+00   5.76305e-09
2
  1.53011e-01  9.40725e-01   1.25492e-01  2.90069e-01   1.25492e-01  2.90069e-01
  1.25492e-01  2.90069e-01   1.53011e-01  9.40725e-01   1.25492e-01  2.90069e-01
  1.25492e-01  2.90069e-01   1.25492e-01  2.90069e-01   1.53011e-01  9.40725e-01
-0.00000e+00  3.45783e-06   0.00000e+00  3.06536e-07   0.00000e+00  3.06536e-07

  0.00000e+00  3.06536e-07   0.00000e+00  3.45783e-06   0.00000e+00  3.06536e-07
  0.00000e+00  3.06536e-07   0.00000e+00  3.06536e-07  -0.00000e+00   3.45783e-06
3
```

```
  1.98116e-01  1.80450e+00   1.64891e-01  5.03185e-01   1.64891e-01  5.03185e-01
  1.64891e-01  5.03185e-01   1.98116e-01  1.80450e+00   1.64891e-01  5.03185e-01
  1.64891e-01  5.03185e-01   1.64891e-01  5.03185e-01   1.98116e-01  1.80450e+00
 -0.00000e+00  6.91566e-06   0.00000e+00  6.13073e-07   0.00000e+00  6.13073e-07
  0.00000e+00  6.13073e-07   0.00000e+00  6.91566e-06   0.00000e+00  6.13073e-07
  0.00000e+00  6.13073e-07   0.00000e+00  6.13073e-07  -0.00000e+00  6.91566e-06
4
  2.37980e-01  2.67014e+00   1.98532e-01  7.18173e-01   1.98532e-01  7.18173e-01
  1.98532e-01  7.18173e-01   2.37980e-01  2.67014e+00   1.98532e-01  7.18173e-01
  1.98532e-01  7.18173e-01   1.98532e-01  7.18173e-01   2.37980e-01  2.67014e+00
 -0.00000e+00  1.03735e-05   0.00000e+00  9.19609e-07   0.00000e+00  9.19609e-07
  0.00000e+00  9.19609e-07   0.00000e+00  1.03735e-05   0.00000e+00  9.19609e-07
  0.00000e+00  9.19609e-07   0.00000e+00  9.19609e-07  -0.00000e+00  1.03735e-05
5
  2.78625e-01  3.53246e+00   2.33646e-01  9.29837e-01   2.33646e-01  9.29837e-01
  2.33646e-01  9.29837e-01   2.78625e-01  3.53246e+00   2.33646e-01  9.29837e-01
  2.33646e-01  9.29837e-01   2.33646e-01  9.29837e-01   2.78625e-01  3.53246e+00

 -0.00000e+00  1.38313e-05   0.00000e+00  1.22615e-06   0.00000e+00  1.22615e-06
  0.00000e+00  1.22615e-06   0.00000e+00  1.38313e-05   0.00000e+00  1.22615e-06
  0.00000e+00  1.22615e-06   0.00000e+00  1.22615e-06  -0.00000e+00  1.38313e-05
6
  3.20444e-01  4.39058e+00   2.70588e-01  1.13730e+00   2.70588e-01  1.13730e+00
  2.70588e-01  1.13730e+00   3.20444e-01  4.39058e+00   2.70588e-01  1.13730e+00

  2.70588e-01  1.13730e+00   2.70588e-01  1.13730e+00   3.20444e-01  4.39058e+00
 -0.00000e+00  1.72891e-05   0.00000e+00  1.53268e-06   0.00000e+00  1.53268e-06
  0.00000e+00  1.53268e-06   0.00000e+00  1.72891e-05   0.00000e+00  1.53268e-06
  0.00000e+00  1.53268e-06   0.00000e+00  1.53268e-06  -0.00000e+00  1.72891e-05
7
  3.63391e-01  5.24462e+00   3.09128e-01  1.34068e+00   3.09128e-01  1.34068e+00
  3.09128e-01  1.34068e+00   3.63391e-01  5.24462e+00   3.09128e-01  1.34068e+00
  3.09128e-01  1.34068e+00   3.09128e-01  1.34068e+00   3.63391e-01  5.24462e+00
 -0.00000e+00  2.07470e-05   0.00000e+00  1.83922e-06   0.00000e+00  1.83922e-06
  0.00000e+00  1.83922e-06   0.00000e+00  2.07470e-05   0.00000e+00  1.83922e-06
  0.00000e+00  1.83922e-06   0.00000e+00  1.83922e-06  -0.00000e+00  2.07470e-05
8
  4.07339e-01  6.09487e+00   3.49021e-01  1.54028e+00   3.49021e-01  1.54028e+00
  3.49021e-01  1.54028e+00   4.07339e-01  6.09487e+00   3.49021e-01  1.54028e+00
  3.49021e-01  1.54028e+00   3.49021e-01  1.54028e+00   4.07339e-01  6.09487e+00
 -0.00000e+00  2.42048e-05   0.00000e+00  2.14575e-06   0.00000e+00  2.14575e-06
  0.00000e+00  2.14575e-06   0.00000e+00  2.42048e-05   0.00000e+00  2.14575e-06
  0.00000e+00  2.14575e-06   0.00000e+00  2.14575e-06  -0.00000e+00  2.42048e-05
9
  4.52166e-01  6.94168e+00   3.90075e-01  1.73643e+00   3.90075e-01  1.73643e+00
  3.90075e-01  1.73643e+00   4.52166e-01  6.94168e+00   3.90075e-01  1.73643e+00
```

```
 3.90075e-01  1.73643e+00   3.90075e-01  1.73643e+00   4.52166e-01  6.94168e+00
-0.00000e+00  2.76626e-05   0.00000e+00  2.45229e-06   0.00000e+00  2.45229e-06
 0.00000e+00  2.45229e-06   0.00000e+00  2.76626e-05   0.00000e+00  2.45229e-06
 0.00000e+00  2.45229e-06   0.00000e+00  2.45229e-06  -0.00000e+00  2.76626e-05
10
 4.97774e-01  7.78533e+00   4.32139e-01  1.92942e+00   4.32139e-01  1.92942e+00
 4.32139e-01  1.92942e+00   4.97774e-01  7.78533e+00   4.32139e-01  1.92942e+00
 4.32139e-01  1.92942e+00   4.32139e-01  1.92942e+00   4.97774e-01  7.78533e+00
-0.00000e+00  3.11205e-05   0.00000e+00  2.75883e-06   0.00000e+00  2.75883e-06
 0.00000e+00  2.75883e-06   0.00000e+00  3.11205e-05   0.00000e+00  2.75883e-06
 0.00000e+00  2.75883e-06   0.00000e+00  2.75883e-06  -0.00000e+00  3.11205e-05
11
 5.44085e-01  8.62607e+00   4.75098e-01  2.11950e+00   4.75098e-01  2.11950e+00

 4.75098e-01  2.11950e+00   5.44085e-01  8.62607e+00   4.75098e-01  2.11950e+00
 4.75098e-01  2.11950e+00   4.75098e-01  2.11950e+00   5.44085e-01  8.62607e+00
-0.00000e+00  3.45783e-05   0.00000e+00  3.06536e-06   0.00000e+00  3.06536e-06
 0.00000e+00  3.06536e-06   0.00000e+00  3.45783e-05   0.00000e+00  3.06536e-06
 0.00000e+00  3.06536e-06   0.00000e+00  3.06536e-06  -0.00000e+00  3.45783e-05
```

Table - 5.5 : "LPCNORM" line library - compatible to miline.txt

CS	Ref.No.	Manf Name	PosSeqR ZerSeqR	PosSeqX ZerSeqX	PosSeqS ZerSeqS	Thermal Rating	LnHarNo
Ln	1	Ln1	0.13 0.325	0.0952 0.238	5.34e-5 3.74e-7	7.335	0

Table of Contents

1. INTRODUCTION

POWERCPC is designed to compute the cable electrical parameters from the design data. The cable construction details is described in section 2.How to compute cable parameters using MiP-PSCT is explained in Section-3.The program input data is through an ASCII file, the format of which is described in Section-4. In Section-5, case study is given. When **POWERCPC** is executed from integrated environment, the input data file is automatically generated from the centralized database.

Cables are most useful for low voltage distribution in thickly populated areas. Cables have also been designed for high voltage transmission but their use is limited due to their high cost.

Cables as compared to overhead lines have the following advantages:

- They are not subjected to supply interruptions caused by lightning or thunderstorms, birds & other severe weather conditions.

- Accidents caused by breaking of conductors are reduced.

1.1 Cable Conductors

The conductors of cables are usually stranded i.e., it consists of a number of strands of wire of circular c/s area so that it may be flexible and carry more current. The number of strands in cables is usually 7, 19, 37, 61, 91, 127 or 169 as these numbers give the conductors a cylindrical formation.

1.2 Geometry of Cables

The space relationship of sheaths and conductors in a cable circuit is a major factor in determining reactance, capacitance and insulation resistance. The symbols used for various cable dimensions, both for single conductor and three conductor types are given figures 1.1 to 1.3.

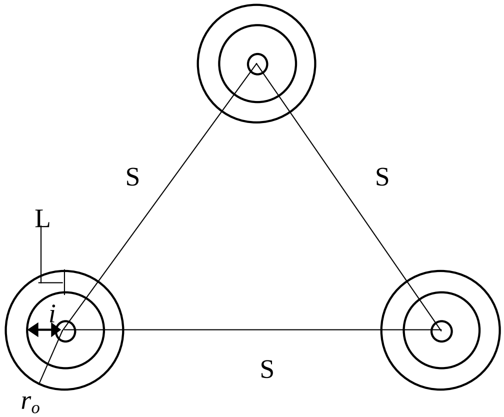


Figure 1.1: Single Conductor Cable, Equilaterally Spaced

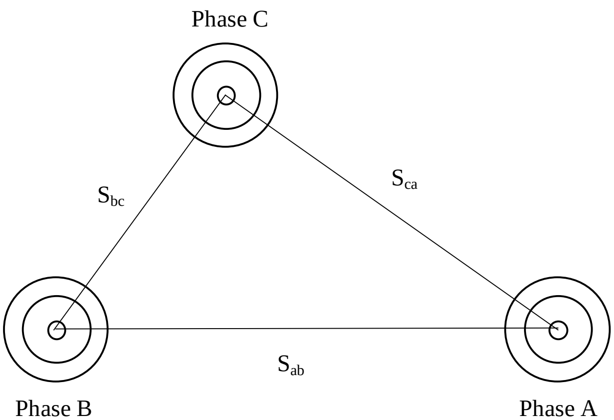


Figure 1.2: Single conductor cable, unsymmetrically spaced but perfectly transposed

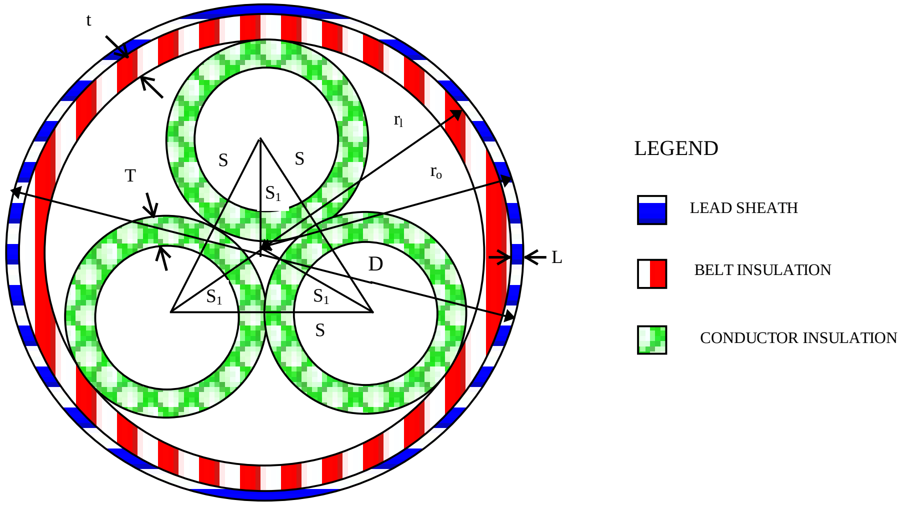


Figure 1.3: Three Conductor Cable

Where,

r_o	=	outer radius of sheath
r_i	=	inner radius of sheath
t	=	belt insulation thickness
S	=	spacing between conductor centers
L	=	lead sheath thickness
T	=	conductor insulation thickness
S_1	=	distance between conductor center and sheath center for 3 conductor cables

2. CABLE CONSTRUCTION

In this section cable construction is described.

2.1 Core

All cables have one central core or a number of cores of stranded copper or aluminium conductors having highest conductivity. Generally there are one, two, three or four cores.

2.2 Insulation

The different insulations used to insulate the conductors are paper, varnished cambric and vulcanized bitumen for low voltages. Usually impregnated paper is used which is an excellent insulating material.

2.3 Metallic Sheath

A metallic sheath is provided over the insulation so as to prevent the entry of moisture into the insulating material. It is usually made of lead or lead alloy in case of copper conductors.

2.4 Bedding

Bedding is a layer of paper tape over the metallic sheath, to provide the metallic sheath from mechanical injury from armouring.

2.5 Armouring

Armouring is provided to avoid mechanical injury to the cable and is made of two layers of steel tape.

2.6 Serving

Over and above armouring, a layer of fibrous material is again provided which is similar to that of bedding but is called serving.

2.7 Mathematical Equations

Electrical parameters like resistance of the conductor, reactance and capacitance (positive, negative and zero) for both single conductor and three conductor cables are calculated using the relations described below:

Resistances Expressions for conductor and insulation resistances are given below.

2.7.1. Cable Conductor Resistance

The resistance of any cable conductor will depend on several factors like temperature, increase in length due to spiralling in a multi-strand conductor, actual physical c/s area which may be less than the nominal size etc.

The dc resistance of the cable conductor is calculated as :

$$R_{dc(t1)} = \frac{R_{dc(t0)} (M + t_1)}{M} \ \Omega \qquad (2.1)$$

Where,

$R_{dc(t1)}$: the resistance to be calculated at the required temperature t_1.

$R_{dc(t0)}$: the resistance of the conductor at zero degree centigrade
$R_{dc(t0)}$ is calculated as

$$R_{dc(t0)} = \frac{res_0}{A} \ \Omega \qquad (2.2)$$

Where,
res_0 : resistivity of the material of the conductor
A : area of the conductor given by –

$$A = \frac{\pi D1^2}{4} \quad \text{sq. inches} \qquad (2.3)$$

Where,
D1: diameter of the conductor given by

$$D1=(1+2n)d \quad \text{inches} \qquad (2.4)$$

Where,
n : number of layers of strands
d : diameter of each strand in inches
M : is a factor depending on the material used for the conductor
M = 234.5 for 100% conductivity copper
M = 241.5 for 97.3% conductivity copper(hard drawn)
M = 228.1 for aluminium
The ac resistance is calculated by accounting for the skin effect.

$$R_{ac(t1)} = R_{dc(t1)}\, k \qquad (2.5)$$

Where, k depends upon the value of X obtained from table 2.1 :

Table 2.1 : Skin Effect Table							
X	**k**	**X**	**K**	**X**	**k**	**X**	**k**
0.0	1.00000	1.0	1.00519	2.0	1.07816	3.0	1.31809
0.1	1.00000	1.1	1.00758	2.1	1.09375	3.1	1.35102
0.2	1.00001	1.2	1.01071	2.2	1.11126	3.2	1.38504
0.3	1.00004	1.3	1.01470	2.3	1.13069	3.3	1.41999
0.4	1.00013	1.4	1.01969	2.4	1.15207	3.4	1.45570
0.5	1.00032	1.5	1.02582	2.5	1.17538	3.5	1.49202
0.6	1.00067	1.6	1.03323	2.6	1.20056	3.6	1.52879
0.7	1.00124	1.7	1.04205	2.7	1.22753	3.7	1.56587
0.8	1.00212	1.8	1.05240	2.8	1.25260	3.8	1.60314
0.9	1.00340	1.9	1.06440	2.9	1.28644	3.9	1.64051

Where, ***X*** is given by

$$\mathrm{X} = 0.062598 \sqrt{\frac{\mu f}{\mathrm{R}_{dc(t1)}}} \qquad (2.6)$$

Where,
μ: permeability = 1
f : frequency in hertz

The total resistance to positive and negative sequence current flow accounting for the effect of sheath currents, in a single conductor cable is given by

$$r1 = \mathrm{r}_2\,\mathrm{R}_a\mathrm{c} + \frac{x_m^2\,(\mathrm{r_s})}{x_m^2 + \mathrm{r_s^2}}\ \Omega/\text{phase/mile} \qquad (2.7)$$

Where,

$$x_m = 0.1795\, f \log \frac{2\mathrm{S}(\mathrm{r}_0 + \mathrm{r_i})}{60}\ \Omega\,/\,\text{phase}\,/\,\text{mile} \qquad (2.8)$$

Where,
S : axial spacing between the conductors in inches
r_o : outer radius of sheath = D1/2
r_i : inner radius of sheath = r_o - lt

lt : lead sheath insulation thickness in inches

$$r_s = \frac{0.2}{r_o^2 - r_i^2} \ \Omega / \text{phase} / \text{mile} \qquad (2.9)$$

The total resistance to positive and negative sequence current flow in a three conductor cable is calculated as

$$r1 = r2 = R_{ac} + \frac{0.044160(Sl^2)}{r_s r_0 + r_i^2} \ \Omega / \text{phase} / \text{mile} \qquad (2.10)$$

where, $$Sl = \frac{(D + 2T)}{1.732} \ \text{inches} \qquad (2.11)$$

Where, T : thickness of sheath in inches

The zero sequence resistance of the cable r_{oc} is given by

$$r_{oc} = R_{ac} + 0.286 \ \Omega / \text{phase} / \text{mile} \qquad (2.12)$$

Zero sequence resistance of the sheath r_{os} is given by

$$r_{os} = \frac{0.2}{r_o^2 - r_i^2} \ \Omega / \text{phase} / \text{mile} \qquad (2.13)$$

The mutual resistance between the conductor and sheath is $r_{om} = 0.286$

Insulation resistance: Insulation resistance is given by

$$Ri = \frac{res_i \ \ln(D1/D)}{2\pi} \ \Omega / \text{phase} / \text{mile} \qquad (2.14)$$

Where,

res_i : resistivity of the insulation

l : length of the conductor in miles

D1 : overall diameter of the cable in inches(i.e., diameter over insulation)

D : conductor diameter in inches.

2.7.2 Reactance

Equations for positive, negative and zero sequence reactances are given below:

2.7.2.1 Positive and Negative Sequence Reactance

The reactance of a single conductor cable to positive and negative sequence currents taking into account the effect of sheath currents is calculated as

$$x1 = x2 = \frac{0.2794 f \log\left(\frac{GMD_{3c}}{GMR_{lc}}\right)}{60} - \frac{x_m^3}{x_m^2 + r_s^2} \quad \Omega / \text{phase} / \text{mile} \qquad (2.15)$$

Where,

GMR_{3c} : geometric mean distance between 3 conductors

$$GMD_{3C} = (d_{ab})(d_{bc})(d_{ca})^{1/3} \qquad (2.16)$$

GMR_{1c} : geometric mean radius of one conductor

$$GMR_{1c} = \frac{0.779}{D}$$

The reactance to positive and negative sequence current flow of a 3 conductor non-shielded cable is calculated as

$$x1 = x2 = \frac{0.2794\, f \log\left(\frac{GMD_{3c}}{GMR_{1c}}\right)}{60}\ \Omega / \text{phase} / \text{mile} \qquad (2.17)$$

The same equation holds good for a 3 conductor shielded cable as the effect of circulating currents in the shielding cable is negligible.

2.7.2.2 Zero Sequence Reactances

The zero sequence reactance of a single conductor cable is given by

$$x_{oc} = \frac{0.8382\, f \log\left(\frac{D_e}{GMR_{3c}}\right)}{60}\ \Omega / \text{phase} / \text{mile} \qquad (2.18)$$

Where,
De : distance to equivalent earth return path, value of which depends on earth resistivity

Table 2.2 gives the De value for different earth resistivity (P)

Table 2.2 : Equivalent Depth of Earth Return (De)

P	De	P	De
0.0	0.00000	100.0	3.36×10^4
1.0	3.36×10^3	500.0	7.44×10^4
5.0	7.44×10^3	1000.0	1.06×10^5
10.0	1.06×10^4	5000.0	2.4×10^5
50.0	2.4×10^4	10000.0	3.36×10^5

GMR_{3c}: geometric mean radius of conducting path made up of 3 actual conductors taken in a group

$$GMR_{3c} = (GMR_{1c})\,(GMD_{3c}^{2})^{1/3} \qquad (2.19)$$

Zero sequence reactance of sheath

$$x_{0s} = \frac{0.8382\, f \log\left(\frac{D_e}{GMR_{3s}}\right)}{60}\ \Omega / \text{phase} / \text{mile} \qquad (2.20)$$

Where,
GMR_{3s} : geometric mean radius of conducting path

$$GMR_{3s} = \frac{(r_o + r_i)\,(GMD_{3c}^{2})^{1/3}}{2} \qquad (2.21)$$

Mutual reactance between sheath and conductor

$$x_m = \frac{0.8382\ f\ \log\left(\frac{D_e}{GMD_{3c3s}}\right)}{60}\ \Omega/\text{phase}/\text{mile} \qquad (2.22)$$

Where,
GMD_{3c3s}: geometric mean of all separation between sheath and conductor

$$GMD_{3c3s} = \frac{(r_0 + r_i)\,(GMD_{3c}^{2})^{1/3}}{2} \qquad (2.23)$$

Zero sequence reactance of a 3 conductor cable is given by

$$x_{oc} = \frac{0.8382\ f\ log\left(\frac{D_e}{GMR_{3c}}\right)}{60}\ \Omega/phase/mile \quad (2.24)$$

Where, $GMR_{3c} = \left[\left(GMR_{1c}\right)\left(Sl^2\right)\right]^{(1/3)}$ (2.25)

Where, S1 = D + 2T inches

Zero sequence of sheath

$$x_{os} = \frac{0.8382\ f \log\left(\frac{D_e}{(r_o + r_i)}\right)}{60}\ \Omega / phase / mile \quad (2.26)$$

Mutual reactance between sheath and conductor $x_{om} = x_{os}$.

The zero sequence impedance of the conductor $z_{oc} = r_{oc} + j(x_{oc})$ and that of the sheath is $z_{os} = r_{os} + j(x_{os})$

Mutual impedance between the sheath and conductor is given by

$$z_{om} = r_{om} + j(x_{om})$$

The total zero sequence impedance between the conductor and sheath is given by the following equations depending on the earth return path.

1. When the earth return path is through both the ground and sheath

$$z_{om} = z_{oc} - \frac{z_{om}^2}{z_{os}}$$

2. When the earth return path is through the sheath only

$$z0 = z_{oc} + z_{os} - 2z_{om}$$

3. When the earth return path is through the ground only

$$z0 = z_{oc}$$

2.7.3 Capacitances

The positive, negative and zero sequence shunt capacitances for single conductor metallic sheathed cables and 3 conductor shielded cable are all equal.

$$Co : c1 = c2 = \frac{0.0892(k)}{G} \mu F/phase/mile \qquad (2.27)$$

where, k : dielectric constant

$$G = 2.303 \log \frac{2r_i}{D}$$

The positive, negative and zero sequence capacitances of 3 conductor belted cable with no shield is

$$c1 = c2 = \frac{0.267(k)}{G1} \mu F / phase / mile \qquad (2.28)$$

The zero sequence capacitance of a 3 conductor cable is

$$c0 = \frac{0.892(k)}{G0} \mu F / phase / mile \qquad (2.29)$$

Values of G0 and G1 are obtained from tables 2.3 & 2.4 respectively.

Table 2.3 : Values for G0						
t/T (T+t)/D	**0.00**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.58	0.61	0.64	0.67	0.70	0.72
0.20	0.85	0.87	0.90	0.93	0.97	1.00
0.30	1.07	1.07	1.08	1.08	1.09	1.09
0.40	1.23	1.26	1.27	1.28	1.29	1.30
0.50	1.39	1.40	1.41	1.43	1.44	1.45
0.60	1.50	1.52	1.55	1.57	1.59	1.60
0.70	1.62	1.64	1.67	1.70	1.72	1.74
0.80	1.70	1.75	1.79	1.80	1.84	1.86
0.90	1.80	1.84	1.88	1.92	1.95	1.98
1.00	1.88	1.92	1.97	2.00	2.05	2.07
1.10	1.95	2.00	2.05	2.09	2.12	2.15
1.20	2.02	2.08	2.12	2.17	2.20	2.23
1.30	2.09	2.14	2.19	2.24	2.28	2.30
1.40	2.14	2.20	2.25	2.30	2.34	2.38
1.50	2.20	2.27	2.30	2.36	2.40	2.42
1.60	2.25	2.30	2.37	2.42	2.45	2.50
1.70	2.30	2.37	2.42	2.47	2.50	2.54
1.80	2.35	2.40	2.46	2.52	2.57	2.60
1.90	2.40	2.45	2.52	2.58	2.62	2.65
2.00	2.44	2.50	2.56	2.62	2.70	2.71
2.10	2.49	2.55	2.60	2.68	2.72	2.75
2.20	2.53	2.59	2.65	2.71	2.76	2.80
2.30	2.56	2.63	2.70	2.75	2.80	2.85
2.40	2.60	2.67	2.80	2.80	2.85	2.90
2.50	2.63	2.70	2.83	2.83	2.90	2.93

Table 2.4 : Values for G1						
t/T (T+t)/D	**0.00**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.90	0.87	0.84	0.82	0.80	0.78
0.20	1.40	1.35	1.30	1.25	1.25	1.18

0.30	1.90	1.80	1.73	1.68	1.60	1.53
0.40	2.30	2.15	2.05	1.99	1.90	1.83
0.50	2.60	2.48	2.35	2.17	2.15	2.09
0.60	2.90	2.75	2.60	2.50	2.40	2.31
0.70	3.20	3.00	2.85	2.73	2.60	2.53
0.80	3.45	3.24	3.09	2.95	2.84	2.75
0.90	3.68	3.48	3.30	3.15	3.05	2.95
1.00	3.88	3.68	3.40	3.35	3.22	3.12
1.10	4.80	3.86	3.69	3.52	3.40	3.30
1.20	4.25	4.05	3.85	3.70	3.57	3.45
1.30	4.43	4.20	4.00	3.85	3.72	3.60
1.40	4.60	4.39	4.18	4.00	3.88	3.78
1.50	4.75	4.53	4.32	4.15	4.00	3.90
1.60	4.90	4.68	4.48	4.28	4.14	4.02
1.70	5.03	4.80	4.60	4.40	4.28	4.16
1.80	5.18	4.95	4.72	4.55	4.40	4.29
1.90	5.30	5.08	4.85	4.68	4.52	4.40
2.00	5.40	5.19	4.98	4.78	4.64	4.52
2.10	5.53	5.30	5.10	4.90	4.75	4.63
2.20	5.63	5.40	5.20	5.00	4.87	4.74
2.30	5.75	5.52	5.32	5.12	4.97	4.84
2.40	5.85	5.68	5.42	5.22	5.07	4.94
2.50	5.96	5.74	5.52	5.32	5.17	5.01

2.8 Assumptions and Limitations

Approximations are made in the calculation of the correction factor added to the ***ac resistance*** while computing the positive and negative sequence resistances. The correction factor accounts for the effect of sheath currents and the results are sufficiently accurate for most practical purposes.

In the calculation of shunt capacitive reactance of 3 conductor shielded cables with sector shaped conductors the geometric factor ***G*** is approximated to be equal to that for round conductors.

3. How to do Cable Parameter Calculation?

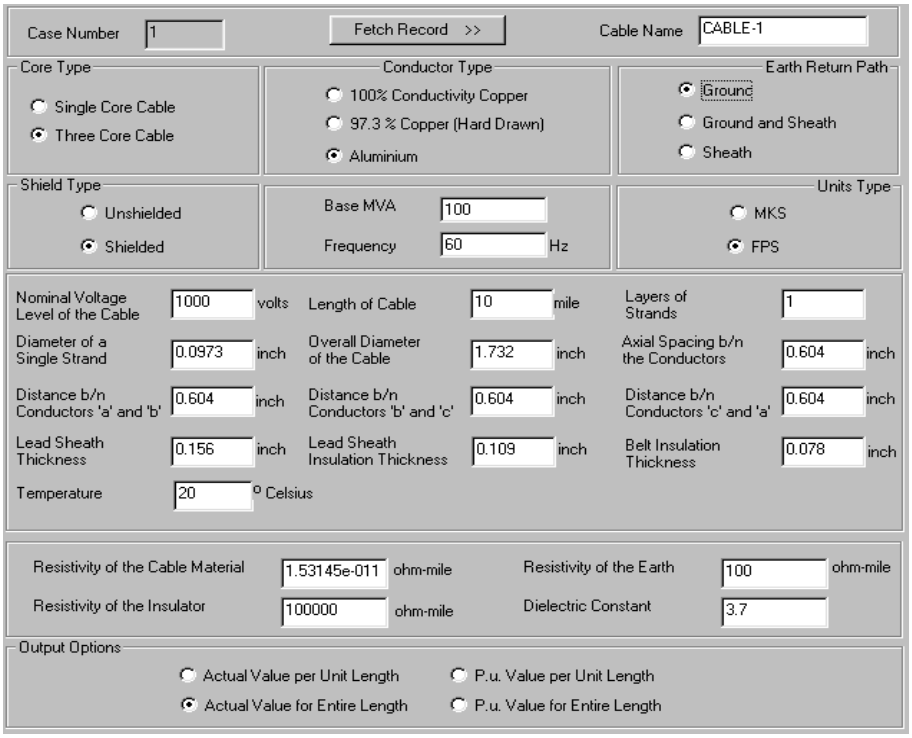
For a case study, a 3 conductor shielded cable with one layer of stranded conductors made of hard-wired copper is considered. The data required for the cable parameter calculation is given in table 3.1. The earth return path is through ground only.

Table 1: Input Data

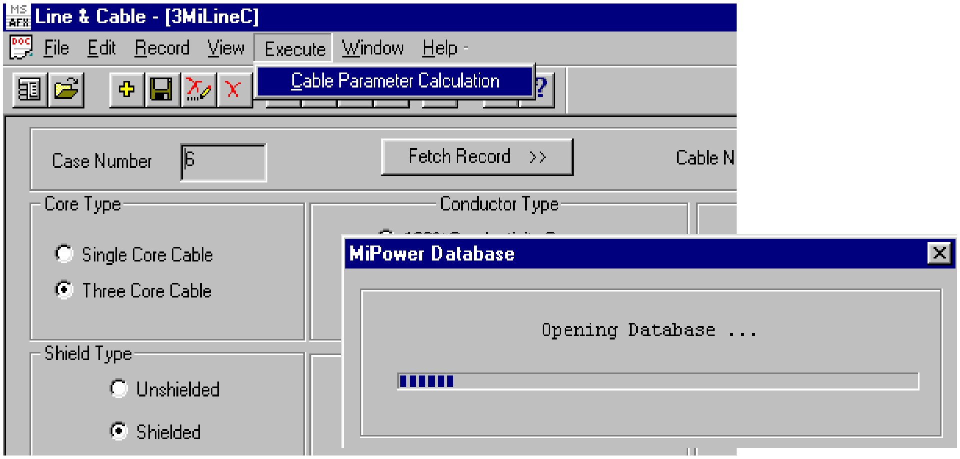
Parameter	Typical Value	Unit
System description 1	Case Study	
Temperature	20	Degree Celsius
System of Units	1	(FPS)
Diameter of strand	0.0973	Inches
No. of layers of strands	1	
Length of the conductor	10	Miles
Resistively of the material of the conductor at 273K	1.53145e-011	Ohm-mile
Lead sheath insulation thickness	0.109	Inches
Axial spacing between conductors	0.604	Inches
Frequency	60	Hertz
Type of core	3 core cable	
Resistivity of the insulation	100000	Ohm-mile
Diameter over insulation	1.732	Inches
Thickness of sheath	0.156	Inches
Earth return path	Through Ground	
Conductor type	2	Aluminium
Distance between conductors A and B	0.604	Inches
Distance between conductors B and C	0.604	Inches
Distance between conductors C and A	0.604	Inches
Voltage	1000	Volts
Earth Resistivity	100	Ohm-meter
Dielectric constant	3.7	
Shielded/unshielded cable	Shielded	
Belt insulation	0.078	Inches
Output unit		Ohm (Mho)/Miles
Base MVA	100	MVA

Procedure

Open **Line & Cable Parameter Calculation** module from the MiP-PSCT main screen. A window appears as shown below. Select **Cable** from the **View** menu. **Add** a new record to enter the data .Enter all the data as given in the table 3.1. Four output options are given here. Check the relevant option, which specifies the type of output required.



After entering all the data in the corresponding field **Execute** the program to get the parameters.



After the execution the program will give a report as given below.

Report:

CABLE PARAMETER CALCULATION

CASE NO : 1 SCHEDULE NO : 0

Temperature at which the R is calculated : 20.0 degree celsius
Units : 1 (FPS system)
Diameter of the strand : 0.0973 inch
Number of layers of stranded conductors : 1
Length of the conductor : 10.000 mile
Resistivity at zero degree Celsius : 1.53145e-011 ohm-mile
Lead sheath insulation : 0.1090 inch
Axial spacing between conductors : 0.6040 inch
Frequency : 60.0 hertz
Number of cores : 3

Resistivity of the insulation : 100000.0 ohm-mile
Diameter over insulation : 1.7320 inch
Conductor Insulation Thickness : 0.1560 inch
Return path : Through ground
Conductor type : 2
(Material used for the conductor - Aluminium)
Distance among conductor centers (a-b) : 0.6040 inch
Distance among conductor centers (b-c) : 0.6040 inch
Distance among conductor centers (c-a) : 0.6040 inch
System voltage : 1000 volts
Earth resistivity : 100.0 ohm-m
Dielectric constant : 3.7
Shield : 1
(3 core, shielded cable)
Belt insulation : 0.0780 inch
Output option : 1 - Ohms(Mhos) FOR ENTIRE LINE LENGTH
Base MVA : 100.000

POSITIVE SEQUENCE IMPEDANCE : 9.89613+j2.02648
POSITIVE SEQUENCE SUSCEPTANCE : 0.00076
NEGATIVE SEQUENCE IMPEDANCE : 9.89613+j2.02648
NEGATIVE SEQUENCE SUSCEPTANCE : 0.00076
ZERO SEQUENCE IMPEDANCE : 12.73810+j41.80200
ZERO SEQUENCE SUSCEPTANCE : 0.00076

----

4. INPUT FILE FORMAT

The program requires two input data files viz., "**CABLE.INP**" and "**CPCIN**" in the working directory.

"**CABLE.INP**" file comes along with the cable parameter calculation program. It contains the correction factors for ***G0*** and ***G1***. Contents of this file should never be tampered.

"**CPCIN**" file contains the user defined data for the study considered. This file is to be created by the use of **POWERCPC**. If the cable parameter computation is invoked from integrated environment, then "**CPCIN**" file in the required format is automatically created from the centralized data base. Data format for "**CPCIN**" file is given in table 4.1.

In table 4.1 -

- System description refers to 3 lines of information pertaining to the study to be done. These lines should be left blank, whenever the data is not available. The total number of characters including the blanks in a line should not exceed 80.
- System of units entry is 0 for MKS system and 1 for FPS system.
- For the type of core the entry is 1 or 3 for single conductor cable or 3-conductor cable respectively.

Table 4.1 : "CPCIN" File Format		
Line No.	**Parameter**	**Type**
1-3	System Description	char
4	Temperature	float
5	System of Units	int
6	Diameter of strand	float
7	No. of layers of strands	int
8	Length of the conductor	float
9	the conductor at 273K	float
10	Lead sheath insulation thickness	float
11	Axial spacing between conductors	float
12	Frequency	float
13	Number of cores	int
14	Resistivity of the insulation	float
15	Diameter over insulation	float
16	Thickness of sheath	float
17	Earth return path	int
18	Conductor type	int
19	Distance between conductors A and B	float
20	Distance between conductors B and C	float
21	Distance between conductors C and A	float
22	Voltage	float
23	Earth resistivity	float
24	Dielectric constant	float
25	Shielded/unshielded cable	int
26	Belt insulation	float
27	Output unit	int
28	Base MVA	float

- Earth return path entry is 0 for ground, 1 for ground & sheath and 2 for sheath.
- Conductor type entry is 1 for 100% conductivity copper, 2 for 97.3% conductivity copper (hard drawn) and 3 for aluminium.
- Entry for unshielded cable is 0 and shielded is 1.
- Output unit is interpreted as -
  - 1 : Actual value per unit length of cable.
  - 2 : Actual value for entire length of cable.

  - 3 : p.u. value per unit length of cable.
  - 4 : p.u. value for entire length of cable.
- Base MVA is used to compute the cable parameters in pu.

5. CASE STUDY

POWERCPC writes the results of cable parameter calculation into **CPCOUT** file. The listing of "**CPCIN**" data is given in Table 5.1 and table 5.2 and 5.3 gives the input and output files.

As a case study, a 3 conductor shielded cable with one layer of stranded conductors made of hard-wired copper is taken. The earth return path is through ground only. Table 5.1 gives the input data for the case study considered.

Table 5.1 : Input Data

Parameter	Typical Value	Unit
System description 1	Case Study	
System description 2		
System description 3		
Temperature	20	degree celsius
System of Units	1	(FPS)
Diameter of strand	0.09730	inches
No. of layers of strands	1	
Length of the conductor	10	miles
Resistivity of the material of the conductor at 273K	1.531450e-011	ohm-mile
Lead sheath insulation thickness	0.156	inches
Axial spacing between conductors	1.15032	inches
Frequency	60	hertz
Type of core	3 core cable	
Resistivity of the insulation	100000.0	ohm-mile
Diameter over insulation	1.732	inches
Thickness of sheath	0.109	Inches
Earth return path	Through Sheath	
Conductor type	Aluminium	

Table 5.2 : Input Data

Parameter	Typical Value	Unit
Distance between conductors A and B	0.604	inches
Distance between conductors B and C	0.604	inches
Distance between conductors C and A	0.604	inches
Voltage	1000.0	volts
Earth resistivity	100.0	ohm-meter
Dielectric constant	3.7	

Shielded/unshielded cable	shielded	
Belt insulation	0.078	inches
Output unit	Ohm/Mho per mile	
Base MVA	100.0	

CABLE PARAMETER CALCULATION
Electrical Transmission & Distribution Reference Book-Westinghouse
(Chapter 4, Electrical Characteristics of Cables, Example 2)

% Temperature at which R is calculated
20.000
% Units
1
% Diameter of the Strand in Inches
0.09730
% Number of layers of stranded conductors
1
% Length of the Conductor (in miles)
10.0000
% Resistivity at Zero degree celsius (ohm-mile)
1.531450e-011
% Lead Sheath Insulation (inches)
0.10900
% Axial Spacing between Conductors (inches)
0.60400
% Frequency (Htz)
60.00000
% Number of Cores
3
% Resistivity of Insulation (ohm-mile)
100000.00000
% Overall Diameter of cable (inches)
1.73200
% Conductor Insulation Thickness (inches)
0.15600
% Return Path
2
% Conductor Type
2
% Distance Between centers of Conductors 'a' and 'b' (inches)
0.60400
% Distance Between centers of Conductors 'b' and 'c' (inches)
0.60400
% Distance Between centers of Conductors 'c' and 'a' (inches)

0.60400
% System Voltage (volts)
1000.000
% Earth Resistivity (ohm-m)
100.000
% Dielectric Constant
3.700
% Shield
1
% Belt Insulation (inches)
0.0780
% Output Option
0
% Base MVA
100.00

Table - 5.3 : "**CPCOUT**" output file

```
--------------------------------------------------------------------------------
        CABLE PARAMETER CALCULATION
                Electrical Transmission & Distribution Reference Book-Westinghouse (
Chapter 4, Electrical Characteristics of Cables, Example 2 )
--------------------------------------------------------------------------------
Temperature at which the R is calculated   :     20.0 degree celsius
Units                              :        1 (FPS system)
Diameter of the strand                :    0.0973 inch
Number of layers of stranded conductors   :        1
Length of the conductor               :   10.000 mile
Resistivity at zero degree celsius       : 1.53145e-011 ohm-mile
Lead sheath insulation                :   0.1090 inch
Axial spacing between conductors        :   0.6040 inch
Frequency                           :     60.0 hertz
Number of cores                      :        3
Resistivity of the insulation           : 100000.0 ohm-mile
Diameter over insulation               :   1.7320 inch
Conductor Insulation Thickness          :   0.1560 inch
Return path                         : Through  sheath
Conductor type                       :        2
(Material used for the conductor  - Aluminium)
Distance among conductor centers  (a-b)   :   0.6040 inch
Distance among conductor centers  (b-c)   :   0.6040 inch
Distance among conductor centers  (c-a)   :   0.6040 inch
System voltage                       :     1000 volts
Earth resistivity                    :    100.0 ohm-m
Dielectric constant                   :      3.7
Shield                             :       1
```

(3 core ,shielded cable)
Belt insulation : 0.0780 inch
Output option : 0 - Ohm(Mho)/mile
Base MVA : 100.000

POSITIVE SEQUENCE IMPEDANCE : 0.98961+j0.20265
POSITIVE SEQUENCE SUSCEPTANCE : 0.00008
NEGATIVE SEQUENCE IMPEDANCE : 0.98961+j0.20265
NEGATIVE SEQUENCE SUSCEPTANCE : 0.00008
ZERO SEQUENCE IMPEDANCE : 4.37942+j0.31019
ZERO SEQUENCE SUSCEPTANCE : 0.00008

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