4 Using SESTLC: A Simplified AC Induction and Field Calculation Program

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4.1 Introduction

The TLC software package is a **T**ransmission (and distribution) **L**ine **C**alculator for rapid EMF, line parameter, and induced voltage estimates. It can be used to quickly estimate line parameters, electric fields, and magnetic fields associated with arbitrary configurations of parallel transmission and distribution lines. It also estimates induced voltages and currents on other parallel metallic utilities, such as pipelines and railways. TLC has been designed with simplicity in mind, providing much useful information with minimal data entry, when applied to simple system configurations. This can be very helpful for preliminary analyses of more complex systems. Keep in mind that for more complex systems or more detailed studies, the Right-of-Way software package or the HIFREQ engineering module are recommended.

The main functions of TLC are summarized as follows:

(1) Line parameter calculation;

(2) Electric field calculation;

(3) Magnetic field calculation;

(4) Steady-state condition inductive interference calculation;

(5) Fault condition inductive interference calculation.

A typical example is given below to demonstrate how to use SESTLC to compute various quantities mentioned above.

4.2 A Typical Example

Figure 4-1 shows a typical configuration of a transmission system with a pipeline (refered to as the **victim line** in TLC instead of pipeline because it can be a communication line or a rail) parallel to the transmission line. The parallel length of the pipeline with the transmission line is 10 km. Both the left and right continuous lengths are 5 km. The cross section of the transmission line and pipeline configuration is illustrated in Figure 4-2. Each of the phase wires consists of four solid copper conductors bundled together in a rectangular shape. The conductor radius is 0.01 meter, and the size of the rectangle is 1 meter by 1 meter. The cross section and physical dimensions of the transmission line are shown in Figure 4-2.

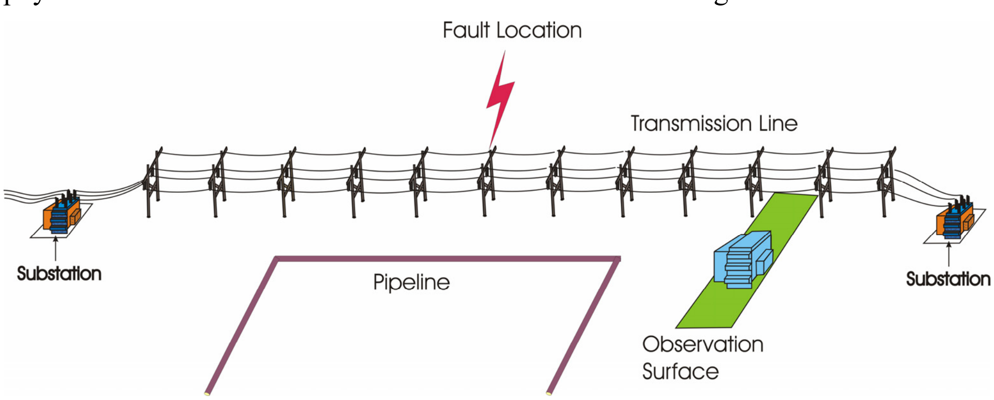


Figure 4-1 A Typical Transmission Line System with Pipeline.

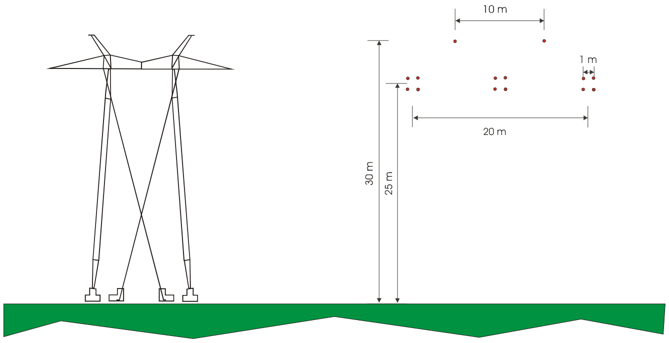


Figure 4-2 The Cross-Section of the Transmission Line Configuration.

4.3 SESTLC Interface Overview

Let's start TLC now. A Start Page screen will appear as shown in Figure 4-3. There are several ways to start a *new project*. Please refer to the SESTLC on-line help for more information. The simplest way is to click on the (New Project) icon on the toolbar. The *New Project Wizard* will be invoked as shown in Figure 4-4.

Let's start with the **Steady State Induction** computation. Now the *New Project Wizard* will walk us through the whole process of data entry. At any time you can interrupt the data entry session on the *New Project Wizard* dialog screen by clicking on the Finish button. This will bring you back to the standard screen, **General** page in this case, as shown in Figure 4-5. We can see that the standard screen offers a menu bar, a toolbar and a status bar. Below the toolbar, there are two panels. The left panel gives quick access to the various computation types that can be selected from the dropdown menu. The data items (pages) corresponding to each computation type is refreshed when you switch from one type to another. The right panel displays the input data pertaining to the page you have selected (by clicking on the Select Page item).

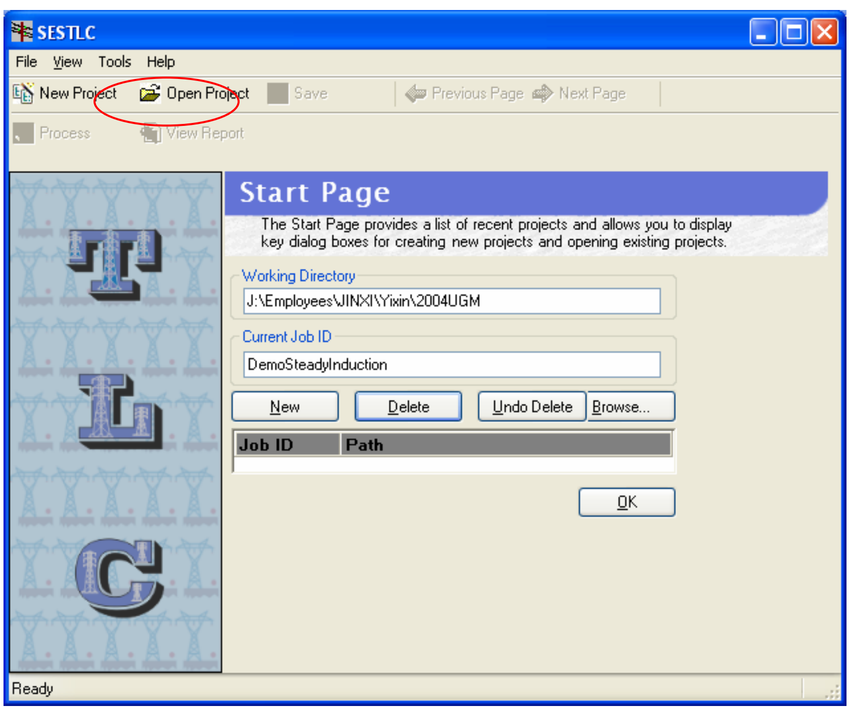


Figure 4-3 The TLC Start Page.

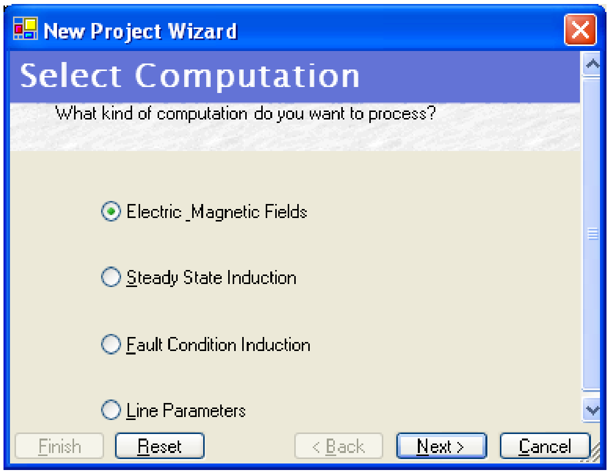


Figure 4-4 The TLC New Project Wizard.

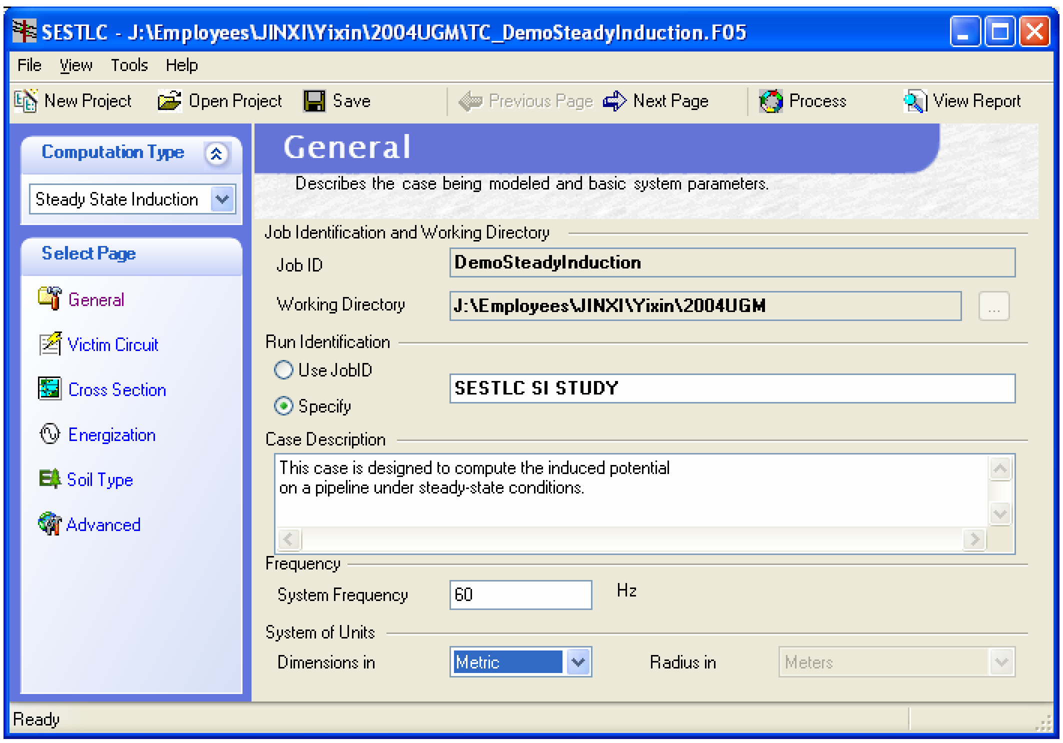


Figure 4-5 TLC Standard Screen: General.

Let's now go through all the standard screens (pages). The General page allows you to define the common general project information such as Case Description, System Frequency and System of Units.

4.4 Steady State Induction Computations

In this section, the steady-state induction computation using TLC is presented. The cross section of the transmission line with the pipeline is shown in Figure 4-2. The 3D view is similar to that shown in Figure 4-1.

The Victim Circuit Page is shown in Figure 4-6. Here we specify the parallel length, left continuous length, and right continuous length of the pipeline as defined in the figure in the screen. The pipe coating resistance, left and right ground impedances of the pipe are also specified here.

The Cross Section Page is shown in Figure 4-7. Cross section of the common corridor of the transmission line and the parallel pipeline is specified here. Line characteristics such as relative resistivity and permeability as well as inner and outer radius of phase conductors, neutral wires, and pipeline are also specified here. The neutral conductor in this case is 1/2 EHS-AG steel conductor. The pipeline radius is 0.127 m (10”) and its thickness is 7 mm. The pipeline is buried at a depth of 1.5 m.

Figure 4-8 shows the Energization Page where the energization currents of the phase conductors are specified.

Figure 4-9 shows the Soil Type Page where the soil resistivity is specified.

The Advanced Page is shown in Figure 4-10. Note that ‘Show Plots’ here requests that the plots be displayed on screen immediately after the computations have been performed rather than be saved in files which can be displayed later. TLC presents computation plots using the Array Visualizer application.

To run TLC, simply click **Process** in any standard screen. In this case, induced pipe potential will be displayed on screen as shown in Figure 4-11. The two peaks in the potential curve correspond to the two locations where the pipe deviates from the transmission line (the two ends of the Parallel Length). The lowest potential in the middle of the curve corresponds to the middle point of the pipeline, which is as expected.

Figure 4-12 shows the induced current flowing in the pipeline. It can be seen that the maximum current appears at the middle point of the pipe, as expected.

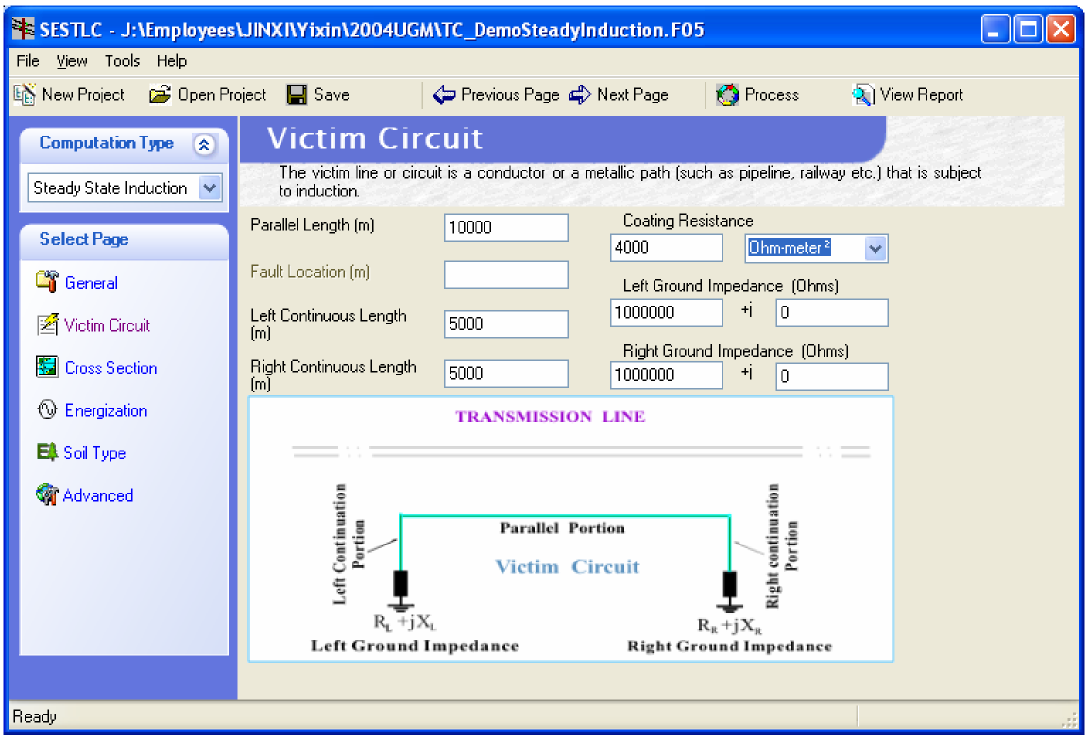


Figure 4-6 TLC Standard Screen: Victim Circuit.

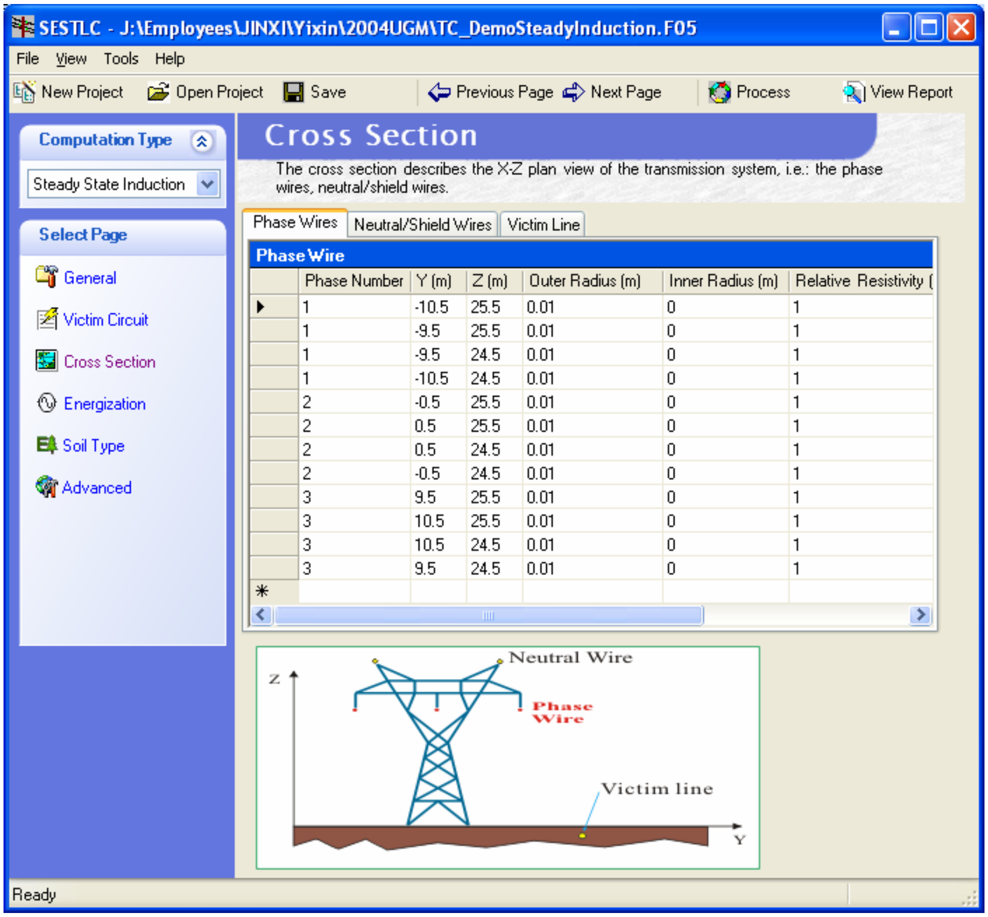


Figure 4-7 TLC Standard Screen: Cross Section.

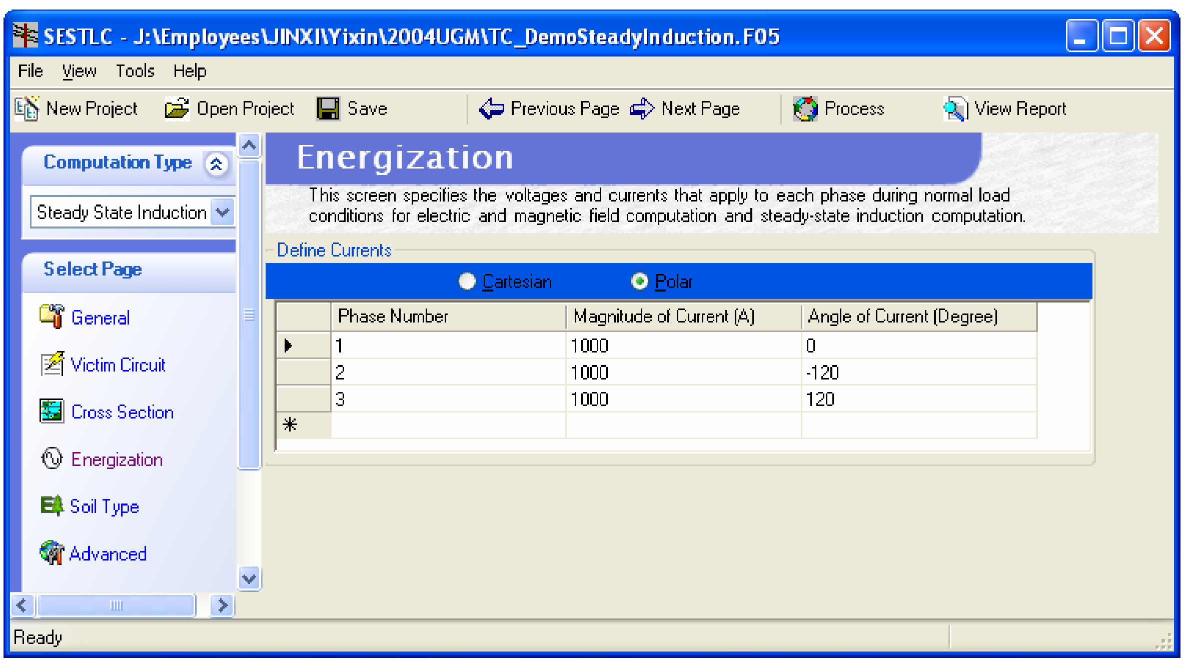


Figure 4-8 TLC Standard Screen: Energization.

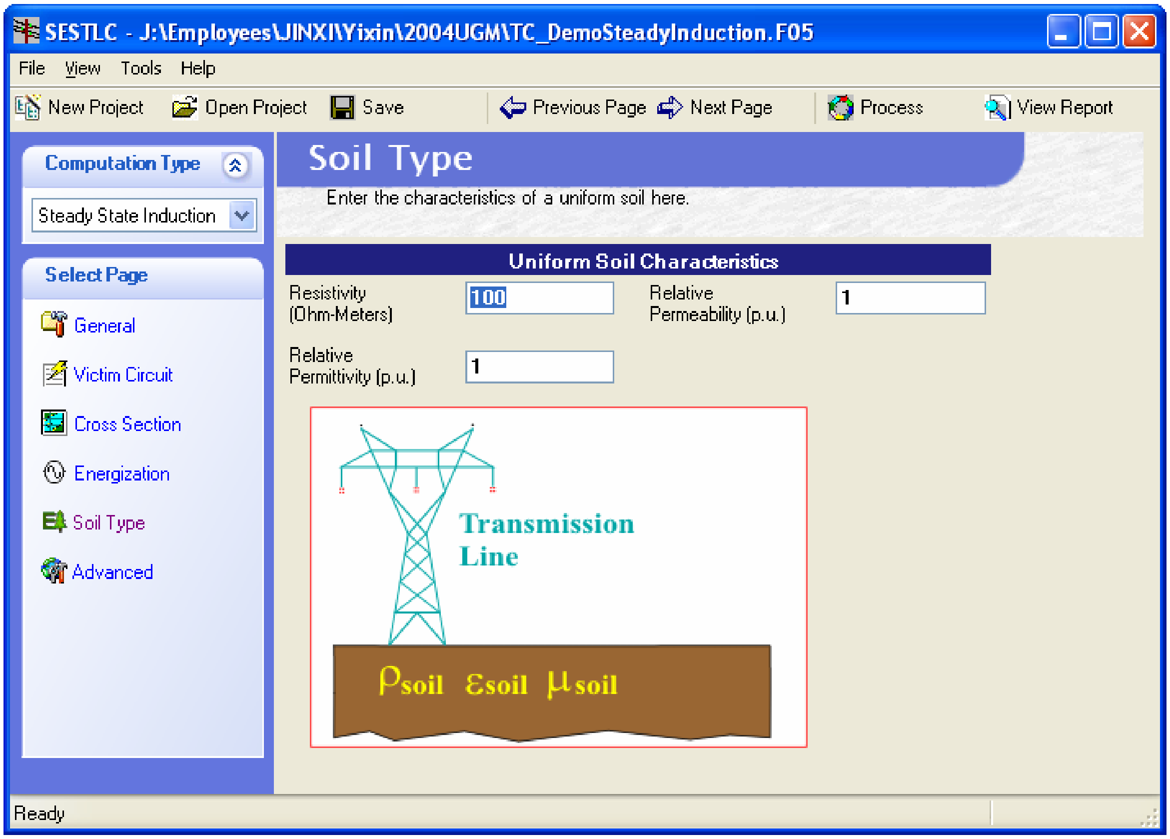


Figure 4-9 TLC Standard Screen: Soil Type.

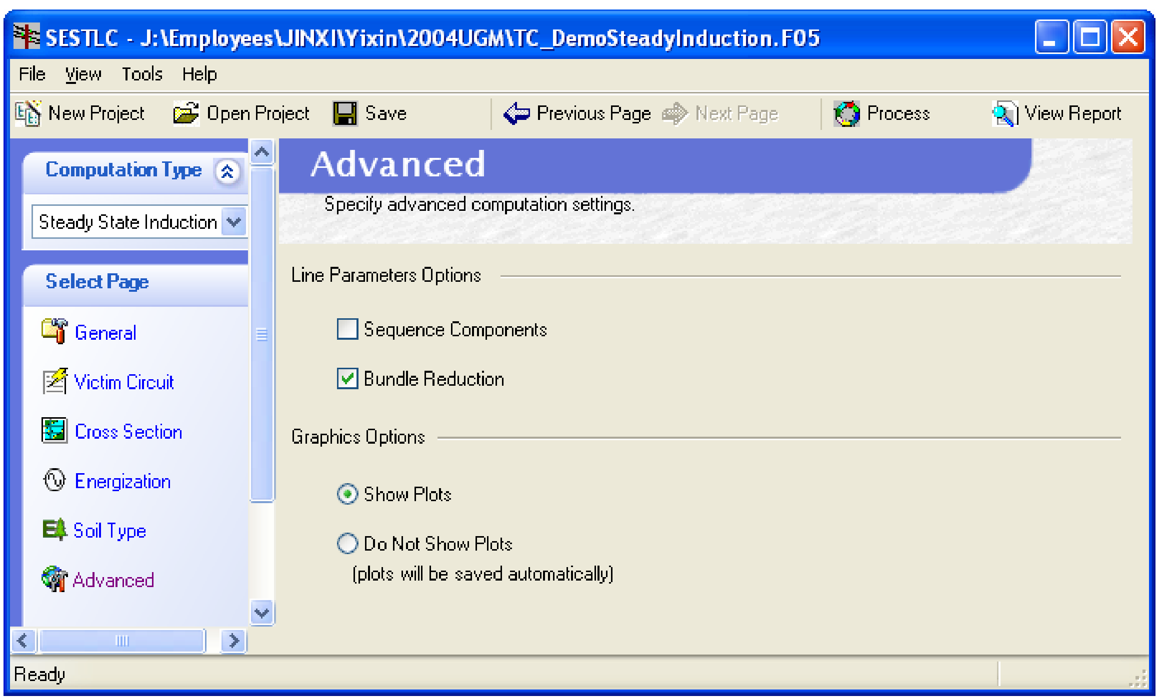


Figure 4-10 TLC Standard Screen: Advanced.

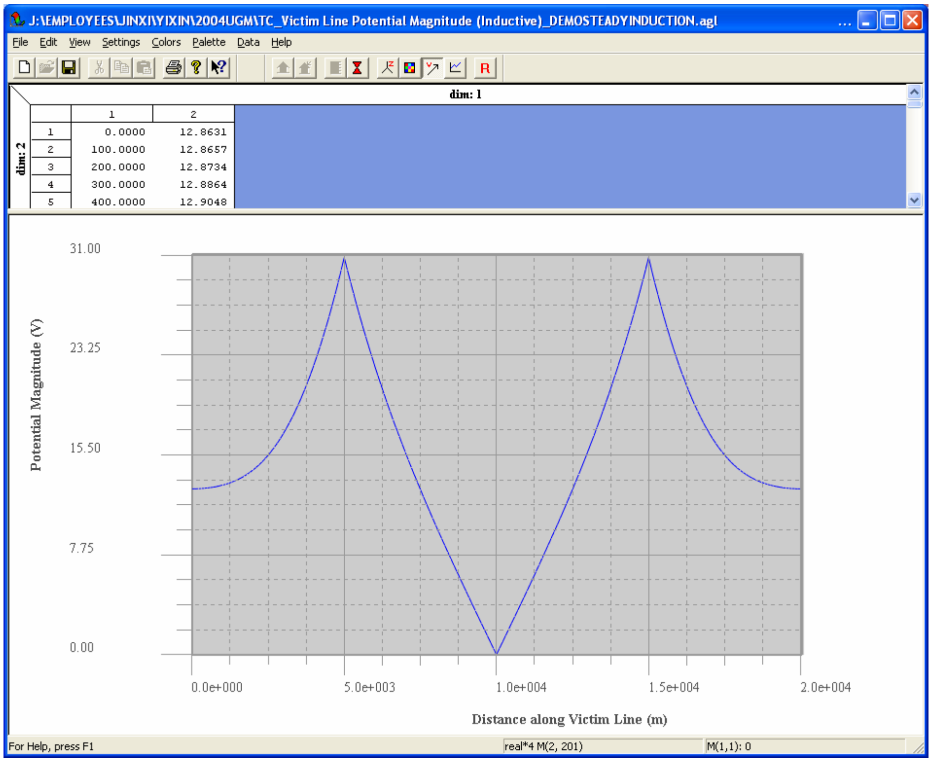


Figure 4-11 Induced Potential on the Pipeline.

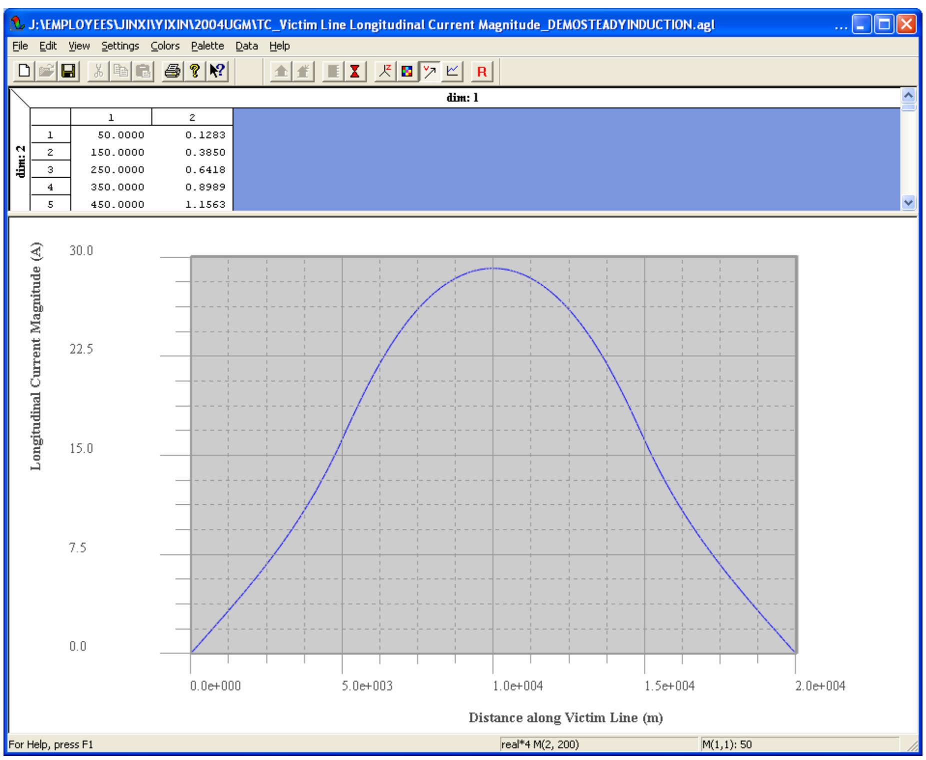


Figure 4-12 Induced Current Flowing in the Pipeline.

4.5 Fault Condition Induction Computations

In this section, the fault condition induction computation option using TLC is presented. The system modeled is exactly the same as in the steady state induction calculation described in the previous section. The fault location is assumed to be at the middle point of the parallel length of the pipeline (as shown in Figure 4-2).

Figure 4-13 shows the Victim Circuit Page for Fault Condition Induction calculations. The difference between this page and that for Steady State Induction (Figure 4-6) is that the field for specifying the Fault Location is now active. The fault location is defined by its distance from the left end of the parallel length to the fault location. It can also be seen that the Data Items (Pages) on the left panel are different, the new ones being Terminal 1, Terminal 2, and Central Site. The Central Site Page is shown in Figure 4-14. The faulted phase and the Grid Impedance are defined here. The Grid Impedance is usually a tower ground resistance for faults at a tower. It can also be the ground impedance of the substation grounding grid for faults at a substation. In this case, it is a 30 Ω tower ground resistance.

The Energization Page for Steady State Induction computations is replaced by the Pages, Terminal 1 and Terminal 2. For Fault Condition Induction, we assume that there are always currents coming from both sides of the fault location. Figure 4-14 shows the Terminal 1 Page. The fault current from Terminal 1 is specified here (4000 A), as well as the number of sections (tower spans), span length, tower ground impedance and ground impedance of Terminal 1. The Terminal 2 Page is exactly the same as the Terminal 1 Page in our case.

Again we run TLC by clicking the Process button on any standard screen. The following plots will be generated. Figures 16 and 17 show the tower shunt potentials and currents. Figure 4-18 shows the induced potential on pipeline. It is at its maximum at the fault location, as expected. Figure 4-19 shows the conductively transferred potential at the pipeline location due to the potential rise of the towers. Note that the title of this plot, victim line potential magnitude, is not very clear. In fact, this is the conductive component of the pipeline coating stress voltage. The total stress voltage, which is the sum of the induced pipeline potential (inductive component) shown in Figure 4-18 and the conductively transferred potential at the pipeline location due to the potential rise of towers (conductive component) shown in Figure 4-19, taking into account their relative phase angles, is shown in Figure 4-20. Figure 4-21 shows the induced current flowing in the pipeline.

It can be seen that the Induction Calculation option offered by TLC requires only the essential input data, while producing the desired results such as induced pipeline potential and coating stress voltage. Note that the Victim Line is used instead of Pipeline because it can be a communication line or a rail. Only one victim line can be analyzed at a time. This limitation will probably remain for some time. Also, a non-parallel victim line cannot be modeled at present. This option will be available in future releases.

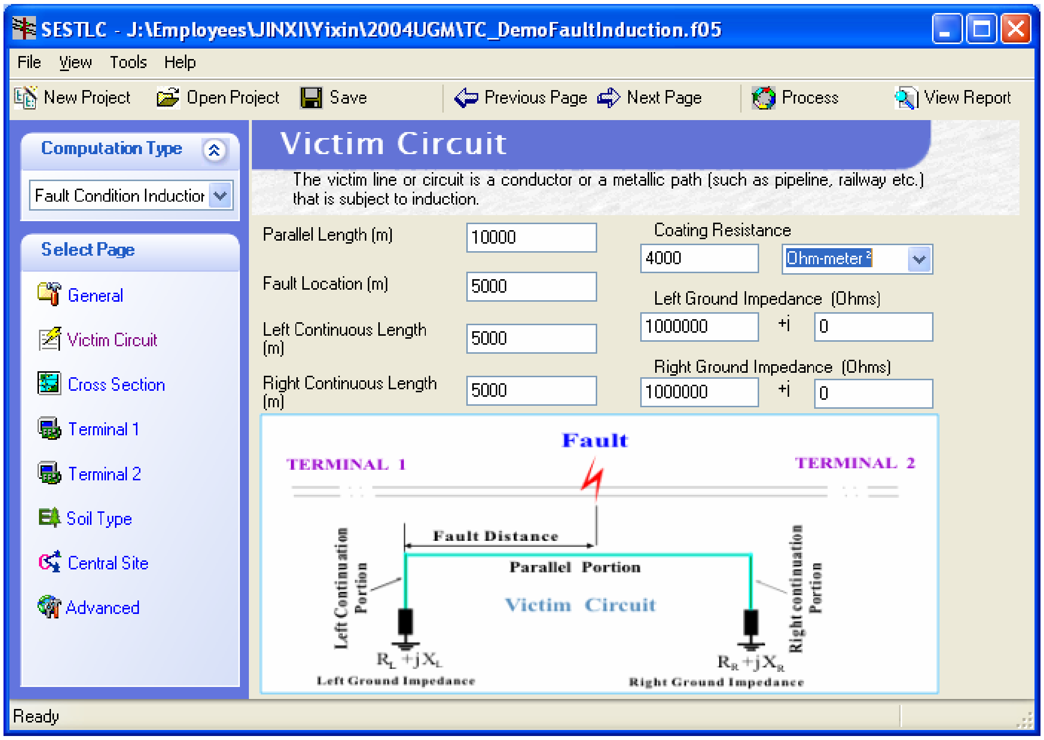


Figure 4-13 The Victim Circuit Page for Fault Condition Induction.

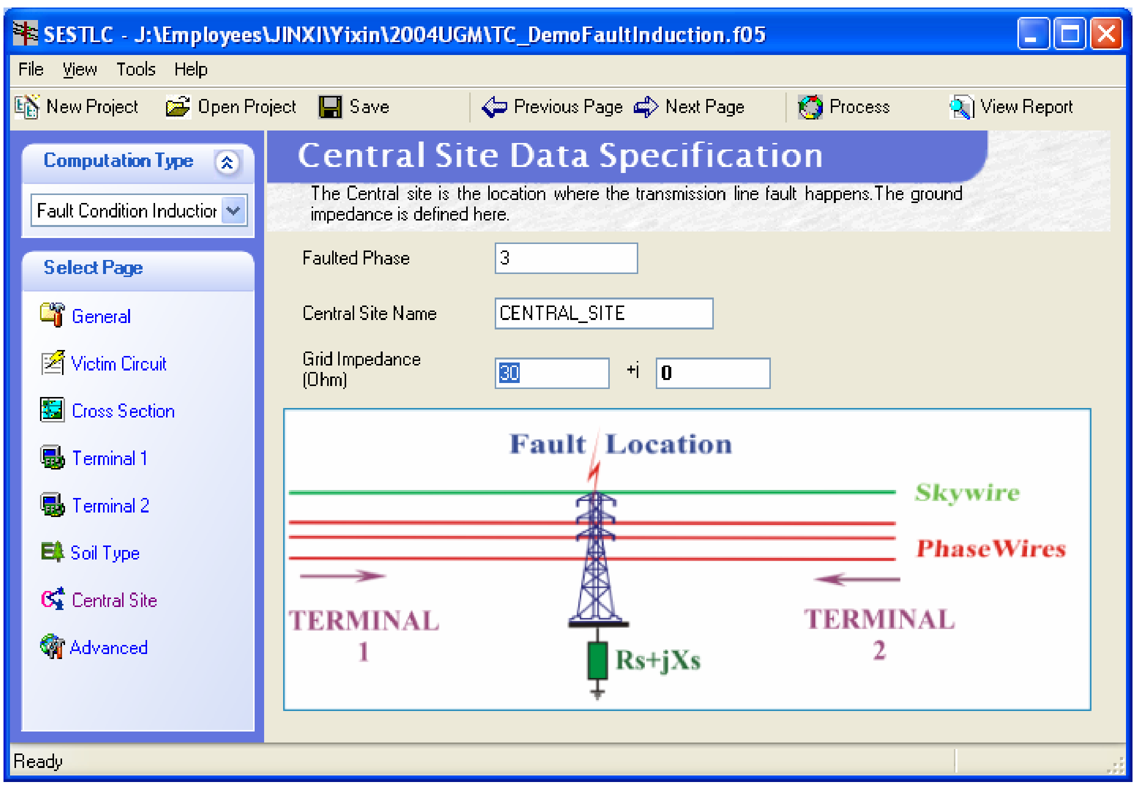


Figure 4-14 The Central Site Page.

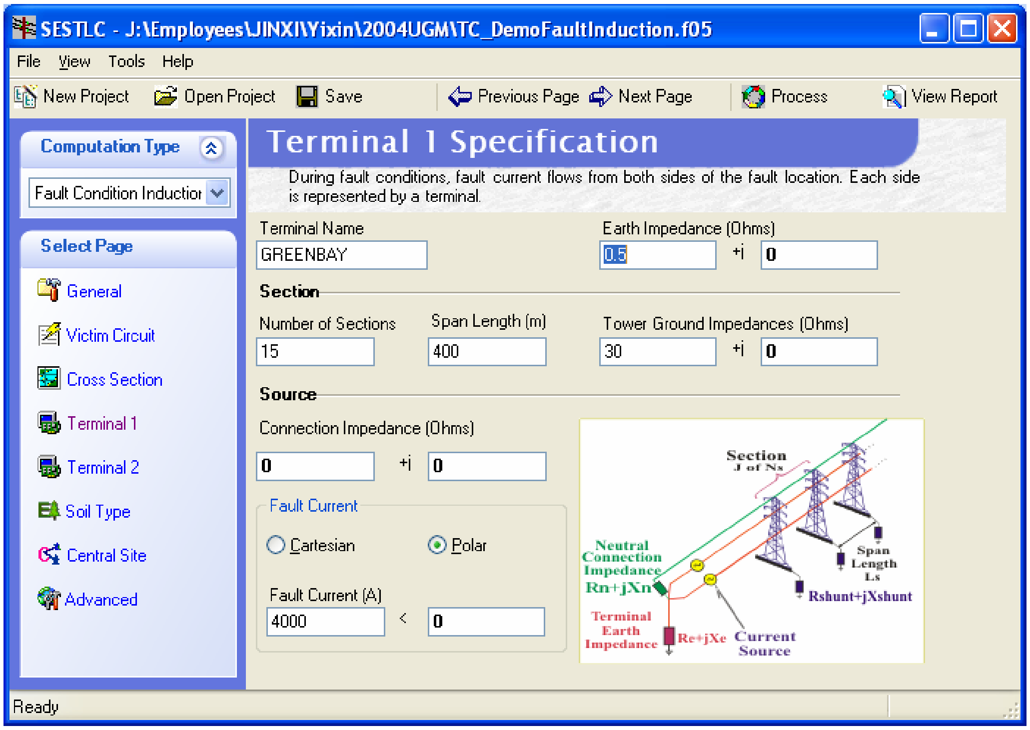


Figure 4-15 The Terminal 1 Page.

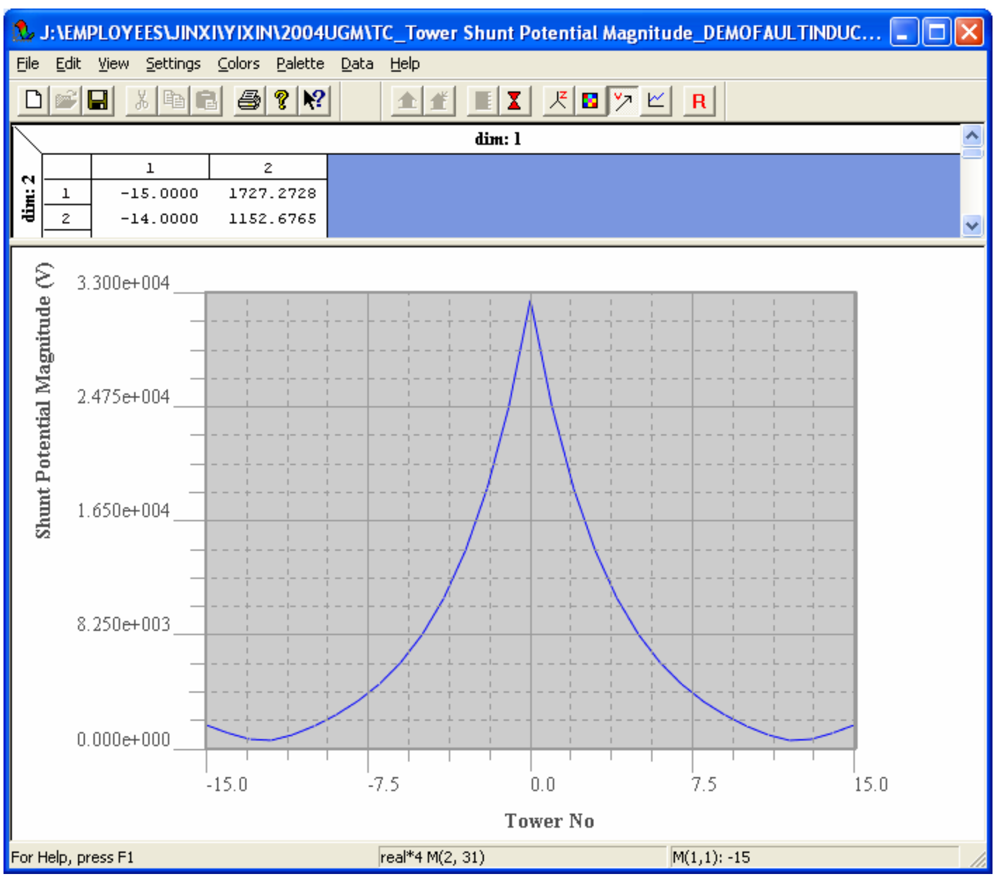


Figure 4-16 Tower Shunt Potential.

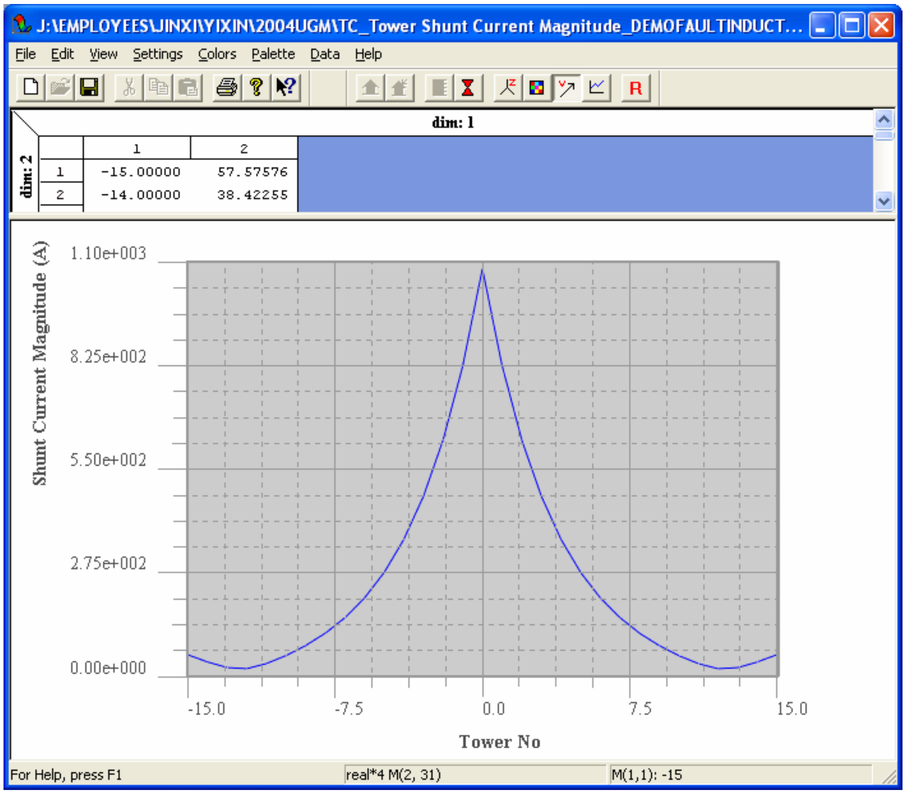


Figure 4-17 Tower Shunt Current.

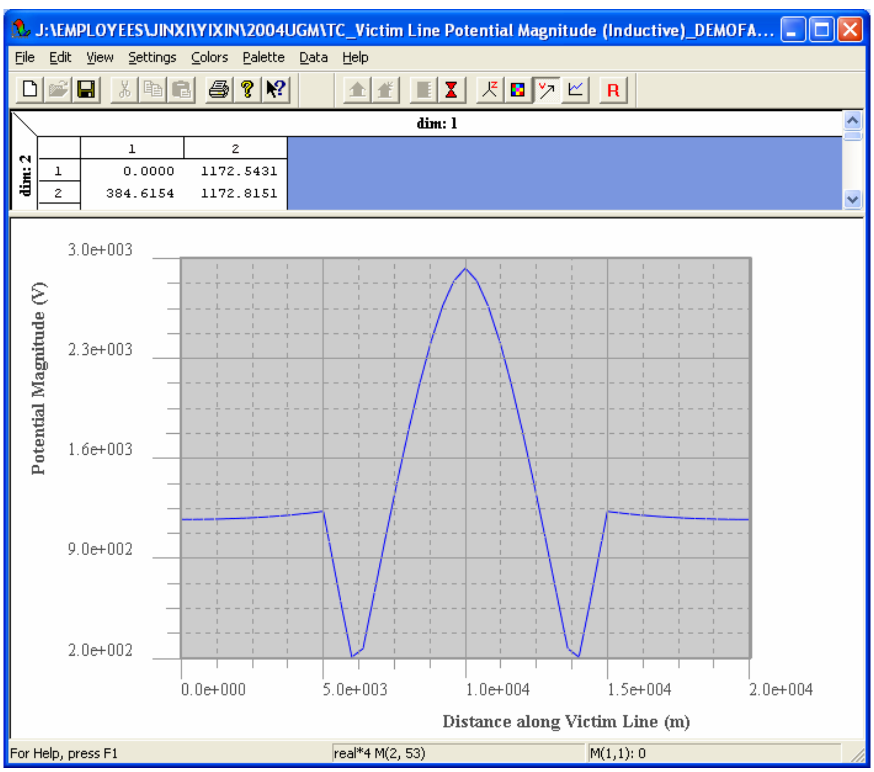


Figure 4-18 Induced Potential on Pipeline.

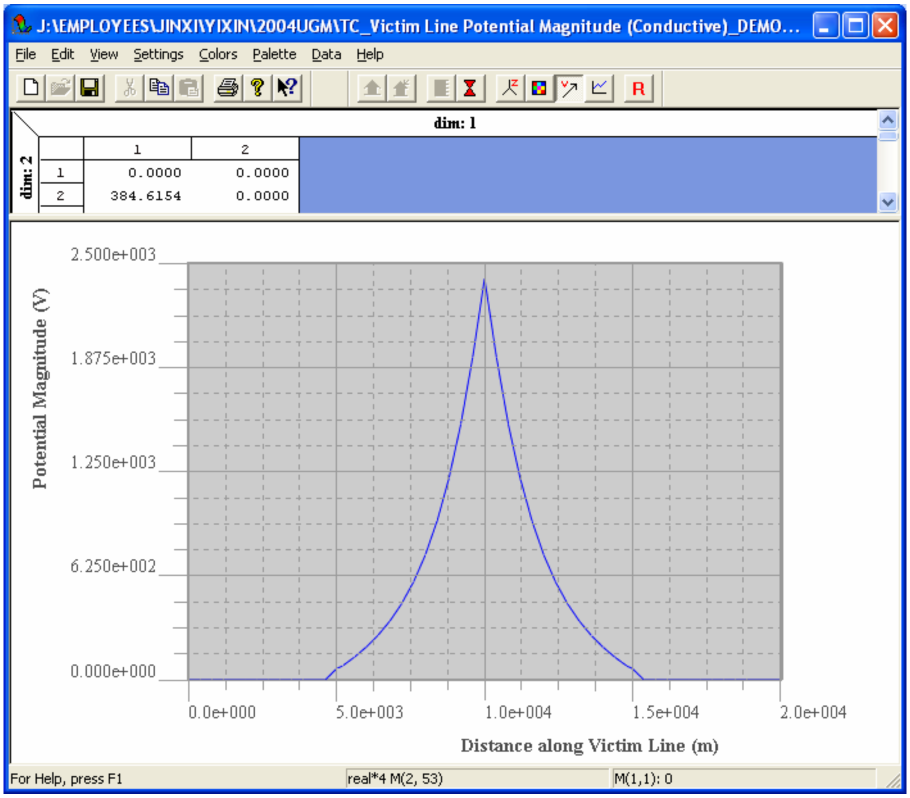


Figure 4-19 Conductively Transferred Potential at Pipeline Location Due to Potential Rise of Towers.

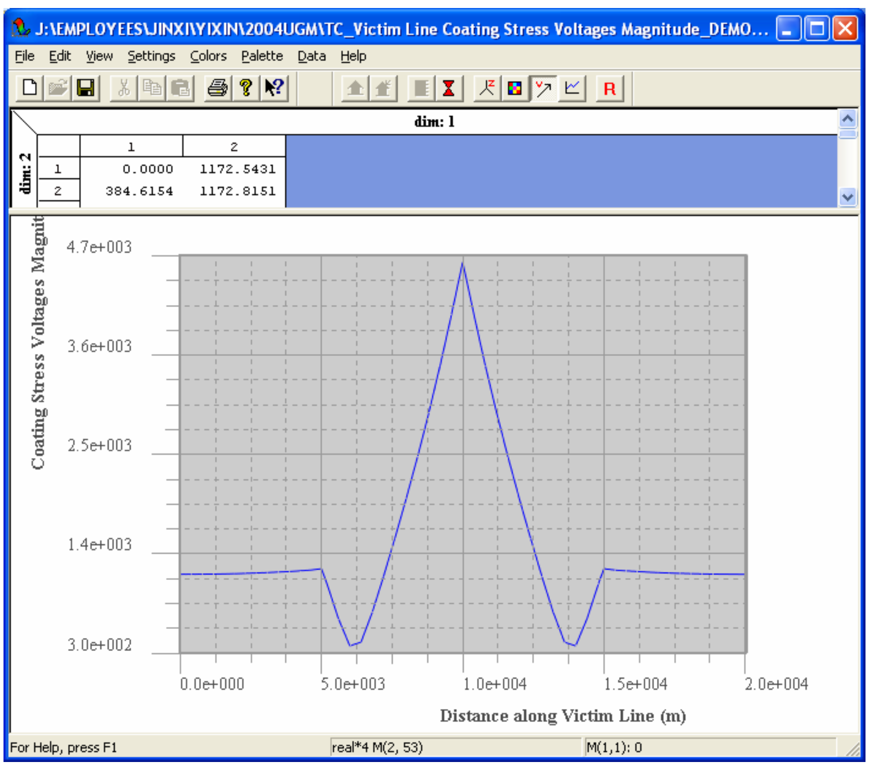


Figure 4-20 Potential Coating Stress Voltage.

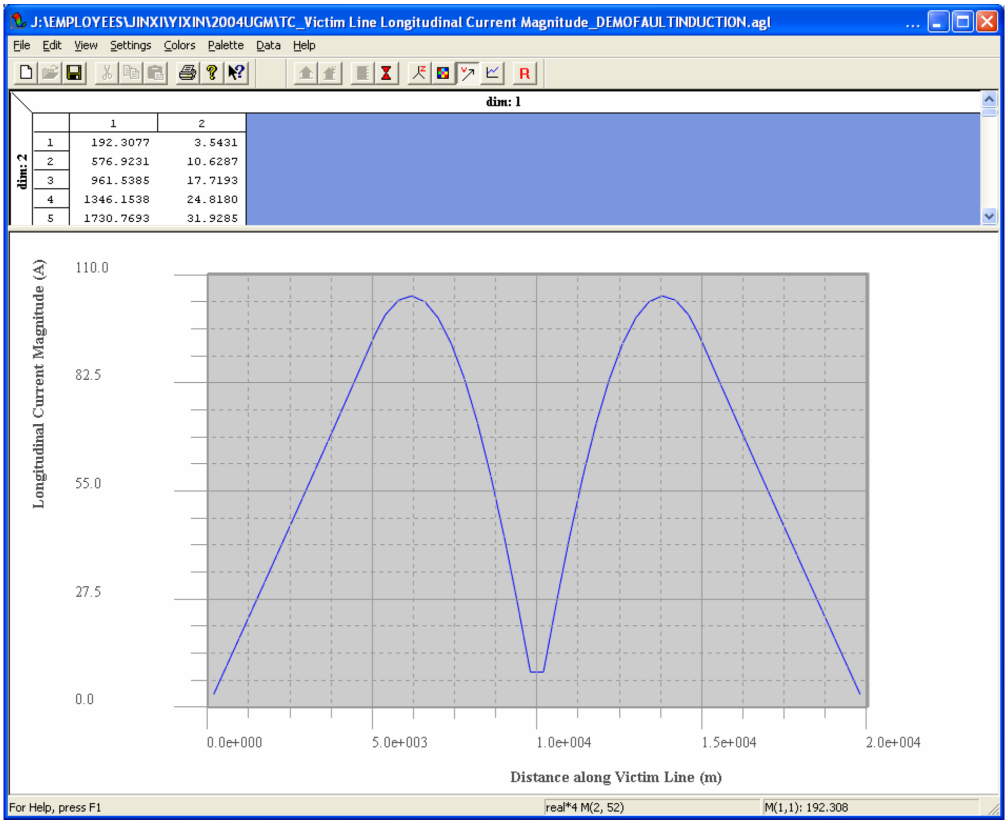


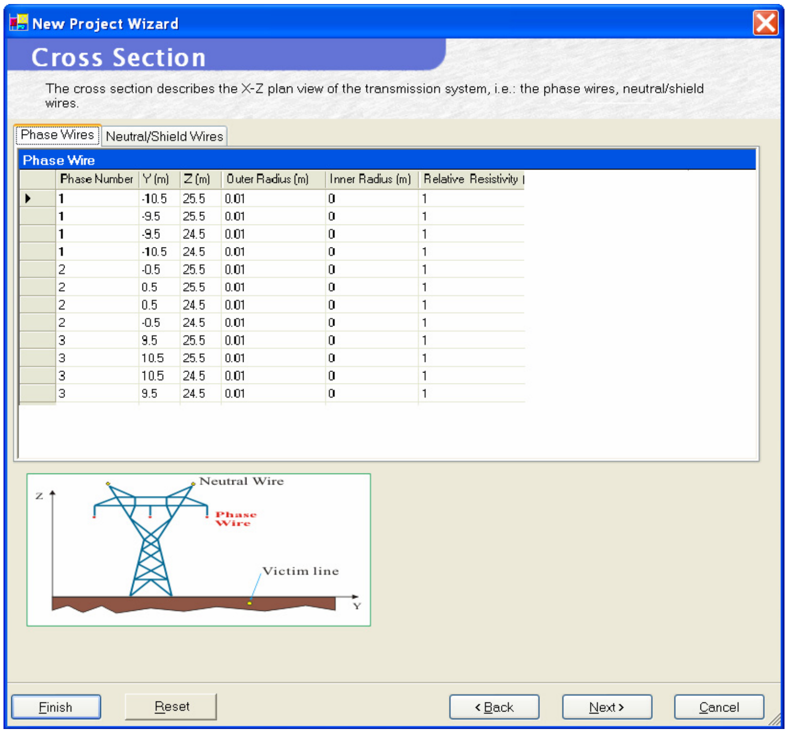
Figure 4-21 Induced Current Flowing in the Pipeline.

4.6 Line Parameters Computations

In this section, the line parameters computations option using TLC is presented. The line parameters, mainly the series (self) and mutual impedance matrices, of the transmission line are essential in this study. The line parameters include conductor-based parameters, and the phase based parameters. In the phase based parameter computation, the conductors in the same phase are treated as one equivalent conductor. This procedure is called bundle reduction.

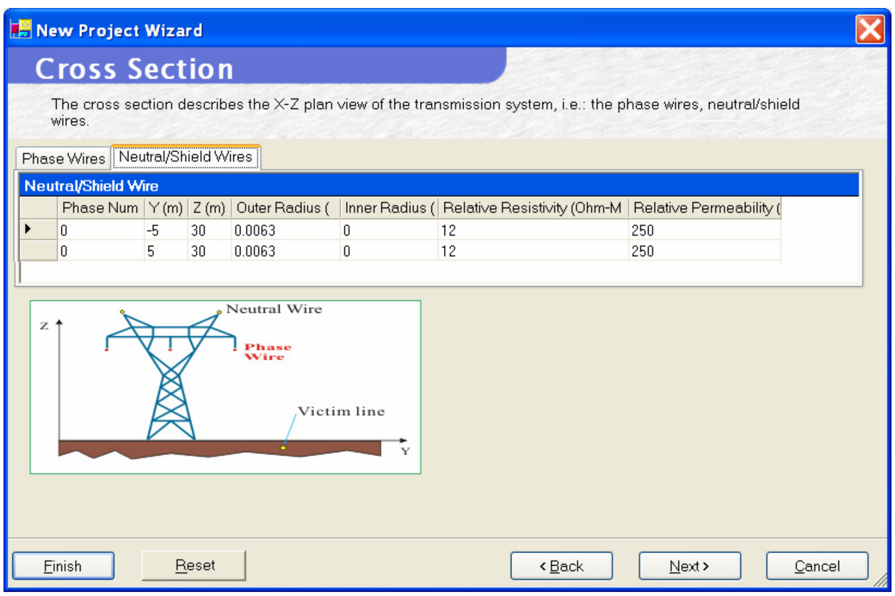
The symmetric sequence components of impedances are used in the unbalanced system operation analysis. In order to compute these parameters, the effect of the overhead ground wires should be included in the phase based parameters. This procedure is called ground wire elimination. After ground wire elimination, the sequence components are computed.

Figure 4-22 and Figure 4-23 show the data entry screen of the phase wires and the overhead ground wires data. Figure 4-24 show the Soil Type page. This screen allows you to specify the characteristics of a uniform soil. A 100 Ω-m soil resistivity value is used in this example.



Phase Number	Y (m)	Z (m)	Outer Radius (m)	Inner Radius (m)	Relative Resistivity (
1	-10.5	25.5	0.01	0	1
1	-9.5	25.5	0.01	0	1
1	-9.5	24.5	0.01	0	1
1	-10.5	24.5	0.01	0	1
2	-0.5	25.5	0.01	0	1
2	0.5	25.5	0.01	0	1
2	0.5	24.5	0.01	0	1
2	-0.5	24.5	0.01	0	1
3	9.5	25.5	0.01	0	1
3	10.5	25.5	0.01	0	1
3	10.5	24.5	0.01	0	1
3	9.5	24.5	0.01	0	1

Figure 4-22 Cross Section Page – Phase Wires Data Entry Screen.



Phase Num	Y (m)	Z (m)	Outer Radius (	Inner Radius (	Relative Resistivity (Ohm-M	Relative Permeability (
0	-5	30	0.0063	0	12	250
0	5	30	0.0063	0	12	250

Figure 4-23 Cross Section Page – Neutral/Shield Wires Data Entry Screen.

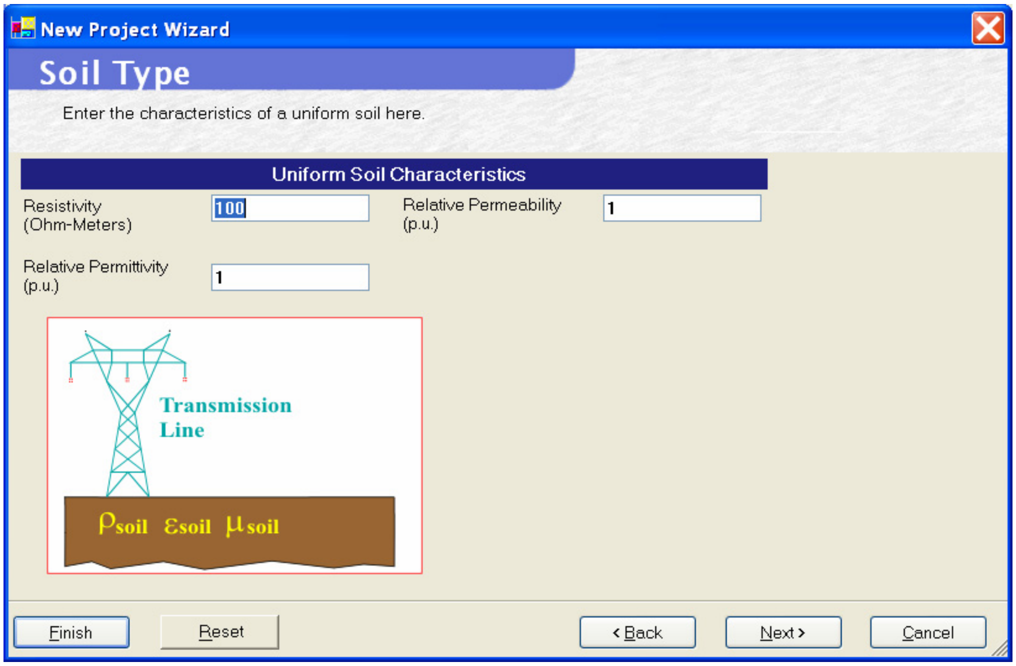


Figure 4-24 Soil Type Page.

The last page in the wizard is the 'Advanced' page (Figure 4-25). The check box 'Sequence Components' is automatically selected by default. This feature will invoke bundle reduction and ground wire elimination. The Graphics option is disabled since the line parameters computation will generate a report only.

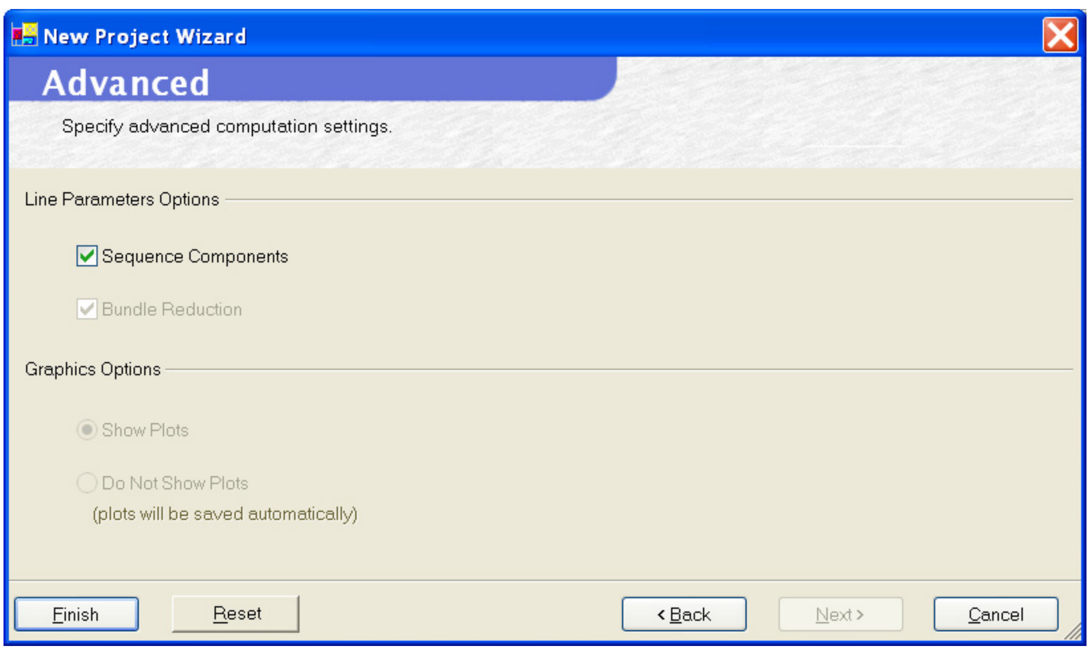


Figure 4-25 The Advanced Page.

Click on the 'Finish' button to complete the *New Project Wizard* dialog, and this will bring you to the main screen. You can click on the 'Process' button to start the computation.

When the computation is completed, the 'View Report' icon on the toolbar is activated. Click on it, the report file (TC_Jobid.f09) will display as shown in Figure 4-26.

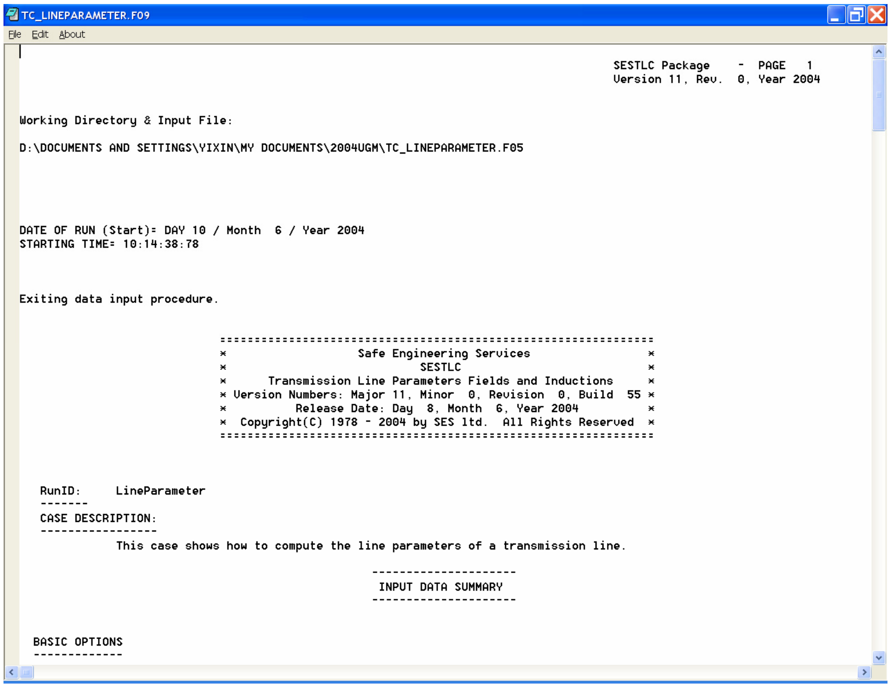


Figure 4-26 The Computation Report Screen.

4.7 Electric and Magnetic Field Computations

In this section, the electric and magnetic field computation option using TLC is presented. First, the Cross Section page is identical to the one shown in Figures 22 and 23. The Energization page is shown in Figure 4-27, where you can specify the voltage and current for all the phases. The phase currents magnitudes are 1000 Amperes and the corresponding phase angles are 0, 120 and 240 degrees respectively. The voltages magnitudes are 100,000 Volts and the corresponding angles are 0, 120 and 240 degrees respectively.

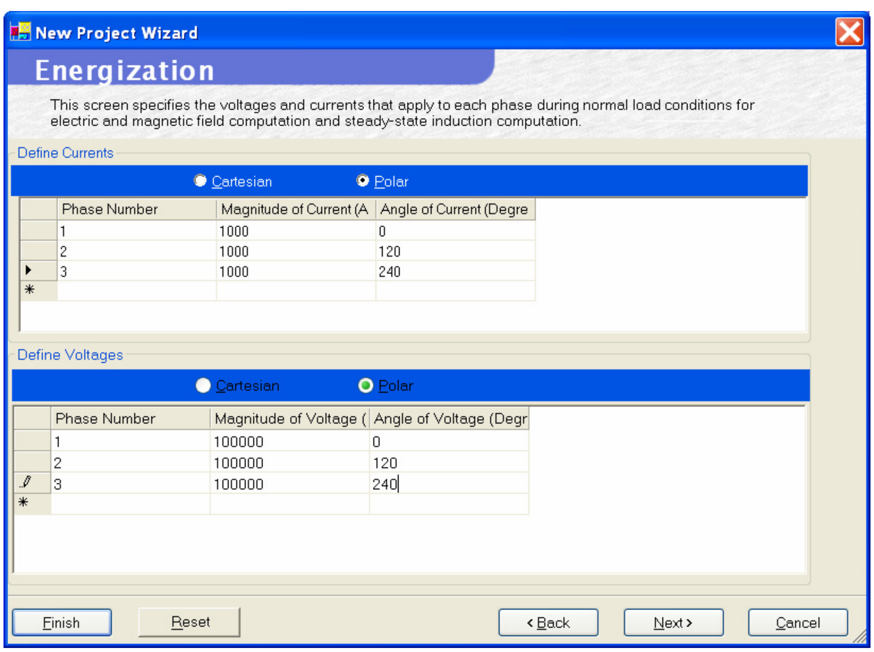


Figure 4-27 The Energization Page.

The presence of the tower conductors will affect the distribution of the electric field. Figure 4-28 shows the Tower Conductors page that allows you to specify the tower conductors coordinates. Typically, the tower conductors at the locations of observation points at which the electric and magnetic fields will be calculated are of interest.

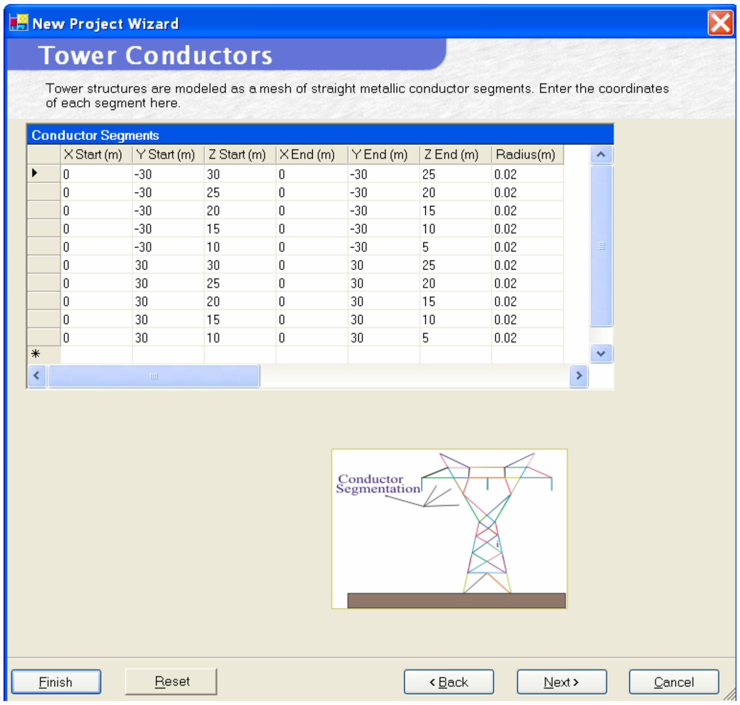


Figure 4-28 The Tower Page – Tower Conductors Data Entry Screen.

Next, you can specify the observation points at which the electric and magnetic field values are to be calculated by defining them in the Computations page as shown in Figure 4-29.

First, let's specify an observation profile. In this case, the profile is composed of 101 observation points and is located in the plane of the cross section of the line (Y-axis). The X-axis is along the direction of the line. The Z-axis represents the height of the profile which is 10 meters above ground. The reason to place the profile at this height is that we want to show a non-zero X and Y components plot of the electric field.

To define a surface profile, click on the **Surface** button as shown in Figure 4-29. The surface profile defines an array of observation profiles contained within a plane by copying and shifting the defined profile 19 times along the X-direction and at intervals of 1 meter as shown in Figure 4-30.

The Advanced Page is shown in Figure 4-31. Note that 'Show Plots' here requests that the plots be displayed on screen immediately after the computations are completed rather than be saved in files which can be displayed later.

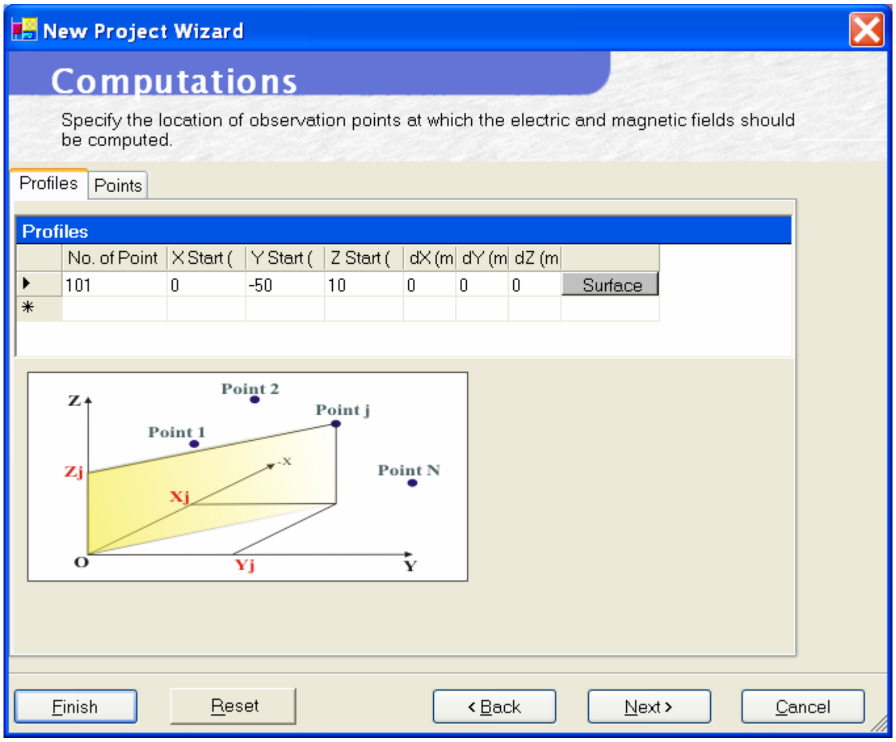


Figure 4-29 The Computations Page – Data Entry Screen for Observation Points & Profiles.

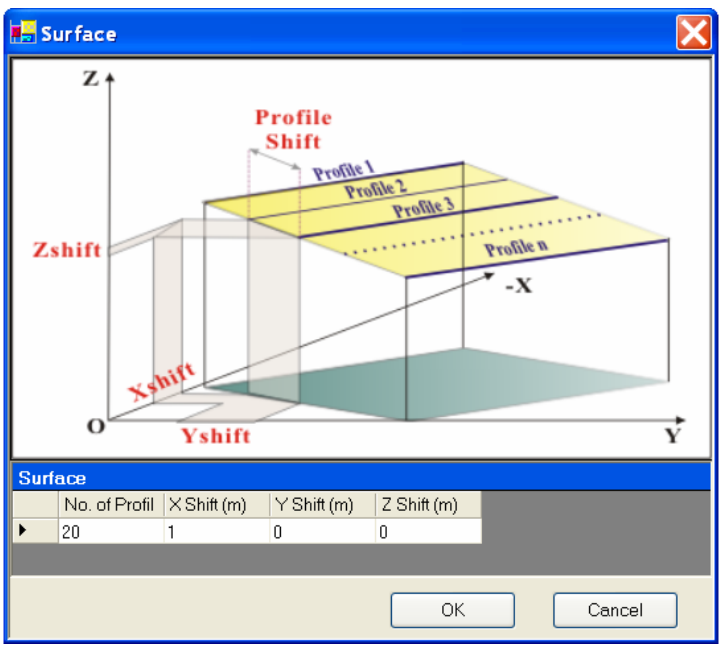


Figure 4-30 Data Entry Screen to Specify a Surface Profile.

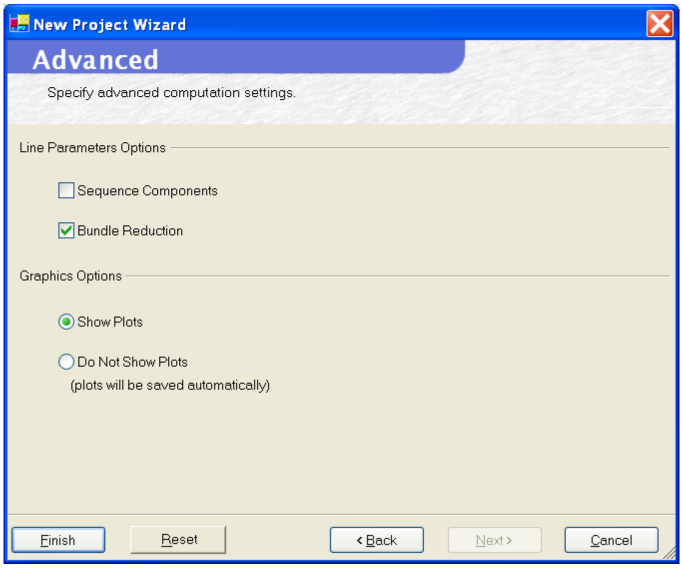


Figure 4-31 The Advanced Page

Simply click the **Process** button in any standard screen. In this case, the first plot shown in Figure 4-32 will be displayed on screen as well as a dialog message box that requires user's confirmations will be displayed as is shown in Figure 4-33. There will be a total of 8 plots generated for the electric and magnetic fields computations. In this example, only 2 plots will be shown, the Y-component of the magnetic field (Figure 4-32) and the X-component of the electric field (Figure 4-34). Note that the X-component of the electric field is zero where there are no tower conductor present. The effects of the tower conductors can be seen clearly in the figure.

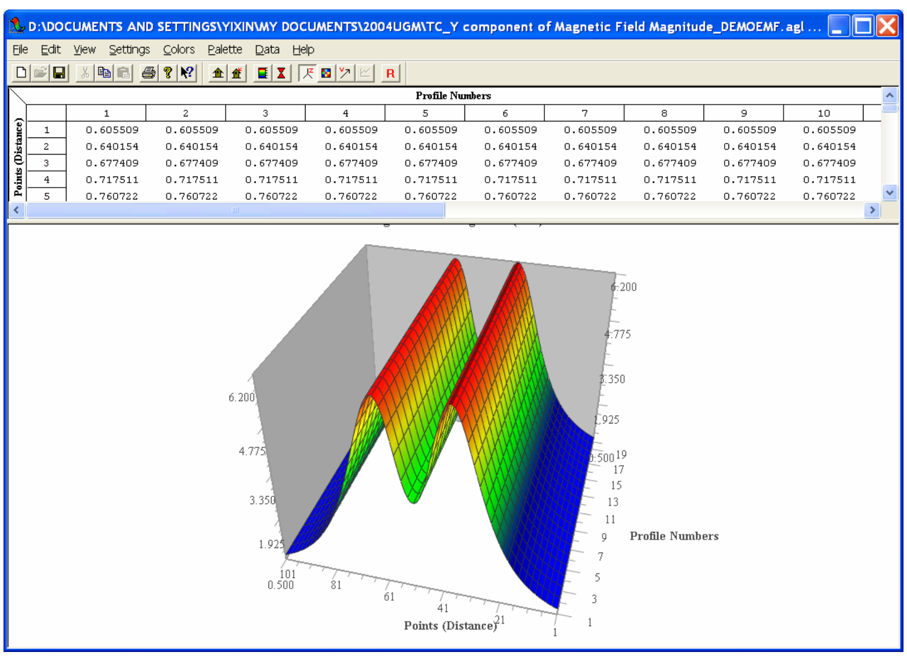


Figure 4-32 Y Component of Magnetic Field at the Specified Observation Surface.

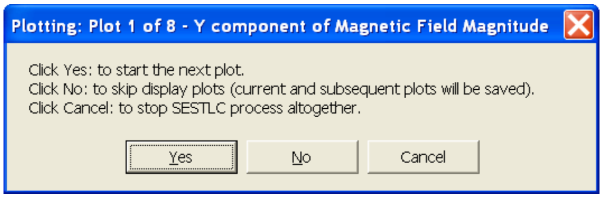
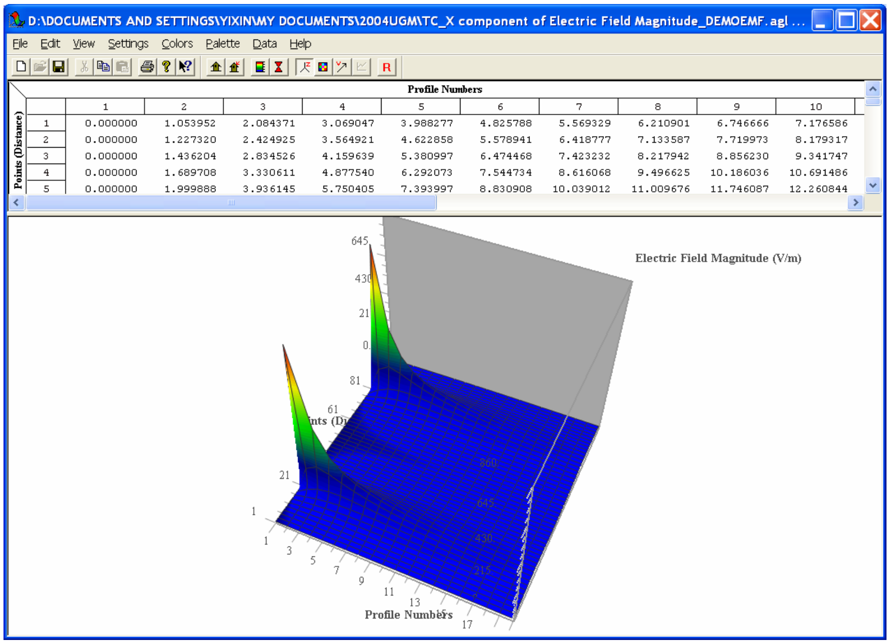


Figure 4-33 Dialog Box that Requires User Confirmation to Proceed with the Plots.



	1	2	3	4	5	6	7	8	9	10
1	0.000000	1.053952	2.084371	3.069047	3.988277	4.825788	5.569329	6.210901	6.746666	7.176586
2	0.000000	1.227320	2.424925	3.564921	4.622858	5.578941	6.418777	7.133587	7.719973	8.179317
3	0.000000	1.436204	2.834526	4.159639	5.380997	6.474468	7.423232	8.217942	8.856230	9.341747
4	0.000000	1.689708	3.330611	4.877540	6.292073	7.544734	8.616068	9.496625	10.186036	10.691486
5	0.000000	1.999888	3.936145	5.750405	7.393997	8.830908	10.039012	11.009676	11.746087	12.260844

Figure 4-34 X Component of Electric Field at the Specified Observation Surface.