We are IntechOpen,
the world's leading publisher of
Open Access books
Built by scientists, for scientists

6,900
Open access books available

186,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

A student friendly toolbox for power system analysis using MATLAB

A. B. M. Nasiruzzaman
Department of Electrical & Electronic Engineering,
Rajshahi University of Engineering & Technology
Bangladesh

1. Introduction

There are various premier software packages available in the market, either for free use or found at a high price, to analyse the century old electrical power system. Universities in the developed countries expend thousands of dollars per year to bring these commercial applications to the desktops of students, teachers and researchers. For teachers and researchers this is regarded as a good long-term investment. As well, for the postgraduate students these packages are very important to validate the model developed during course of study. For simulating different test cases and/or standard systems, which are readily available with these widely used commercial software packages, such enriched software plays an important role. But in case of underdeveloped and developing countries the high amount of money needed to be expended per year to purchase commercial software is a far-fetched idea. In addition, undergraduate students who are learning power system for the very first time find these packages incongruous for them since they are not familiar with the detailed input required to run the program. Even if it is a simple load flow program to find the steady-state behaviour of the system, or an elementary symmetrical fault analysis test case these packages require numerous inputs since they mimic a practical power system rather than considering simple test cases. In effect, undergraduate students tend to stay away from these packages. So rather than aiding the study in power system, these create a bad impression on students' mind about the very much interesting course.

Many researchers have tried a lot to solve this overarching problem. With the advent of personal computers (PCs) the solution to this issue has been very easy. Then came MATLAB, a flagship software for scientific and engineering computation. A revolution occurred in the field of science. Teaching and learning became very much easier than ever with the powerful graphical tools of MATLAB. Many researchers have developed various attractive software packages to aid to the power system analysis and design. A few have focused on the power engineering education field. This chapter discusses an excellent software package based on MATLAB developed mainly to aid in power system study. Although the program is developed using MATLAB, it is compiled such that it can be used outside MATLAB environment.

2. Overview of Software Packages for Power Engineering

To facilitate power engineering analysis and design various companies have developed diverse software. Among them some are used widely and some are built to meet specific purpose of a company. There are PSS®E, ETAP, NEPLAN and much more commercial programs. PSAT, Power World Simulator, and POWERHU basically developed to facilitate power engineering education and sometimes available with textbooks. Among these programs some are code based and some are model based. Some written in C, and Java, others depend on MATLAB.

PSS®E (Siemens, 2009) developed by Siemens Power Technologies International (Siemens PTI) has various modules like power flow, short circuit, dynamic simulation, contingency analysis, optimal power flow, linear network, reliability assessment, and small signal analysis. These modules requires a solid idea about the whole generation, transmission, and distribution system, various control devices used at different points to improve power system quality. This software is a benchmark against which other newly developed software is tested.

ETAP (Operation Technology, 2009) offers a group of fully integrated power engineering software solutions including arc flash, load flow, short circuit, transient stability, relay coordination, optimal power flow, and more. Its modular functionality can be customized to fit the needs of any company, from small to large power systems. ETAP is a comprehensive analysis platform for the design, simulation, operation, and automation of generation, distribution, and industrial power systems. As a fully integrated enterprise solution, ETAP extends to a real-time intelligent power management system to monitor, control, automate, simulate, and optimize the operation of power systems.

BCP (i.e., Busarello + Cott + Partner AG) was founded 1988 in Zurich, Switzerland and is specialized in the field of power systems engineering. BCP is the developer and owner of the power system analysis tool NEPLAN (BCP, 2010). Small and large utilities, industrial organizations, engineering companies and universities in more than 80 countries around the world use this product. NEPLAN is the planning, optimization and simulation tool for transmission, distribution, generation and industrial networks. It covers all aspects of modern power system planning and analysis. NEPLAN offers several starter packages. These starter packages are extendable with many useful modules. All these modules may be added to a starter package at any time. It is available in 9 languages.

The Power System Analysis Toolbox (PSAT) is a MATLAB toolbox for electric power system analysis and simulation (Milano, 2005). All operations can be assessed by means of graphical user interfaces (GUIs) and a SIMULINK based library provides a tool for network design. The main features of PSAT are: power flow, optimal power flow, small signal stability analysis, time domain simulation, FACTS models, wind turbine models, conversion of data files from several formats; Export results to MS Excel and LaTeX files.

PowerWorld Simulator (PowerWorld Corporation, 2009) is an interactive power systems simulation package designed to simulate high voltage power systems operation on a time frame ranging from several minutes to several days. The software contains a highly effective power flow analysis package capable of efficiently solving systems with up to 100,000 buses.

PowerWorld Simulator is ideally suited for teaching power systems operations and analysis and for performing research. In fact, the original version of the simulator software was built as a tool for teaching power systems and presenting power systems analysis results to technical and non-technical audiences alike. Since that time, simulator has evolved into the highly powerful power systems analysis and visualization platform that it is today. Simulator has been, and continues to be, used effectively in undergraduate and graduate level classes in power systems operation, control, and analysis. Concepts are presented simply, yet the software has sufficient detail to challenge advanced engineering students.

MATLAB 4.0 was used to develop a software package named POWERHU (Songur & Ercan, 1997) keeping in mind power engineering students. It has the excellent feature of solving problems in a way that most widely used power system analysis textbooks use. It is capable of performing load flow study, impedance calculation, fault calculation, and transient stability analysis.

PSS®E, ETAP, and NEPLAN are mainly used in industries and for research purposes. They are not suitable for first time learners of power system. PSAT and PowerWorld Simulators are excellent tools that can be used to teach and learn power system. But the problem here is that these packages are mainly model based and does not give the chance to see the inner structure of the program. It just takes inputs and provides outputs after some processing. The students may not see the inner structure of the program which is required very much to develop insight into the behaviour of various components of power system. POWERHU takes into account the problems of PSAT and PowerWorld Simulator. It provides a step by step solution so that the confidence can be built up towards solving more complex problems. But this program is not MATLAB independent. One has to start MATLAB first to run this program, and the size and cost of MATLAB license is increasing day by day. This is why; it may not be possible for students in some developing countries to use this program in the laboratories since they may not have the high performance computers. Also, the program may not run in the recent versions of MATLAB since many old commands of MATLAB have been obsolete. The POWERHU is neither standalone nor it is made version independent. It was developed and tested in MATLAB 4.0 and no improvement was reported after that.

3. Structure of Student Friendly Power System Analysis Toolbox

Power system analysis courses taught in undergraduate levels cover mainly basic concepts of power system like single-line diagram, per unit system, modelling of generators, transformers, transmission lines and loads, load flow analysis, fault analysis, stability studies etc. The purpose of such courses is to develop a fundamental idea about the power system among the undergrads so that they can develop their own skills and aptitudes for solving real world power engineering problems. The huge computations required for these courses are handled by computers and now-a-days MATLAB is used extensively for scientific and engineering computation. In this chapter, a student friendly toolbox developed to assist students during their course of study in basic power system courses is presented. The toolbox takes into account the fresh students having no idea about the course and can alone be used as a textbook. The help menu in the toolbox provides details of problems solved with sufficient background materials so that each and every module can be

grasped and mastered with ease. One can easily see the inner structure of the program to understand how to code a power engineering problem. The main advantage of the toolbox is that apart from using the software within MATLAB it is made version compatible and can be used without MATLAB. So it can be regarded as a standalone software package for power system analysis. The software was developed in MATLAB 6.5 and now successfully tested in the recent version of MATLAB 2010a. The toolbox is divided into different modules to focus different areas of power system as follows:

a) Fault analysis of a motor-generator set
b) Demonstration of symmetrical components
c) Fault analysis of unloaded alternator
d) Synchronous machine transients (balanced)
e) Synchronous machine transients (unbalanced)
f) Fault analysis of interconnected buses
g) Single machine stability analysis (classical)
h) Single machine stability analysis (modern)
i) Load flow

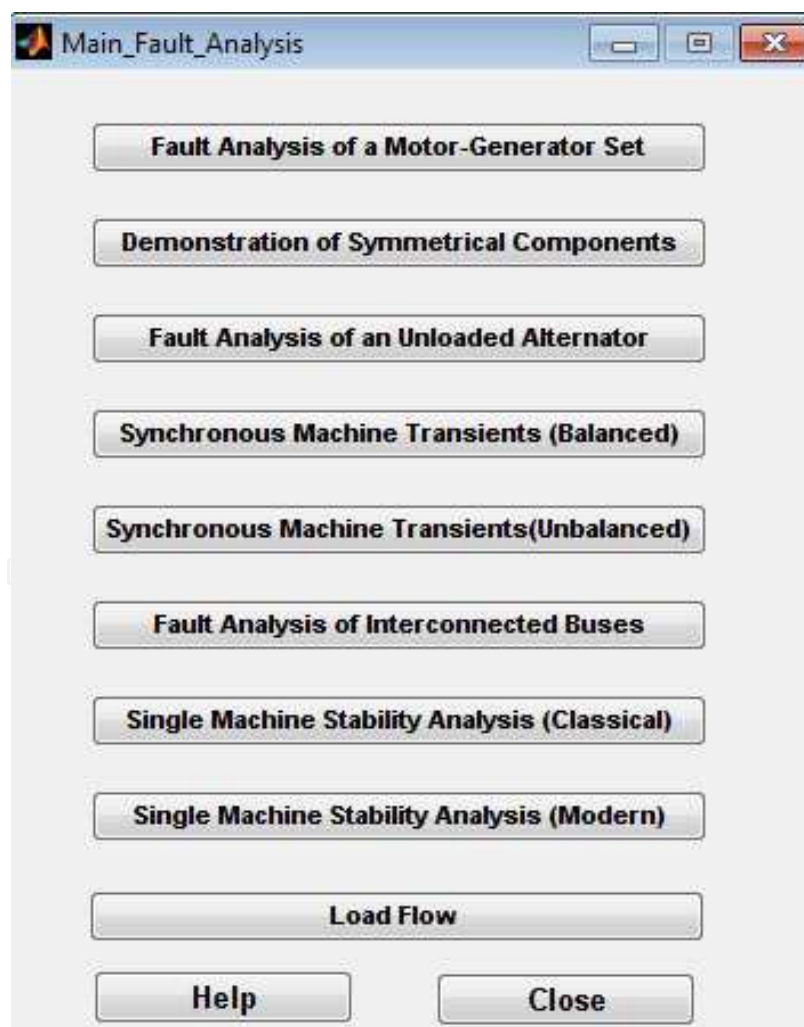When the program is run the main window appears as in Fig. 1.

Fig. 1. Main window of student friendly power system analysis toolbox

4. Fault Analysis of a Motor-Generator Set

This toolbox can be used to study various types of faults encountered in power system and was reported on (Rabbani et al., 2006) which is again presented here in a slight different format.

The effect of a fault in the line connected in between the motor and generator can be visualised using this module which is shown in Fig. 2. The effect of change of various parameters is visualised using this module. This example is taken from a classical textbook of power system (Stevenson, 1982).
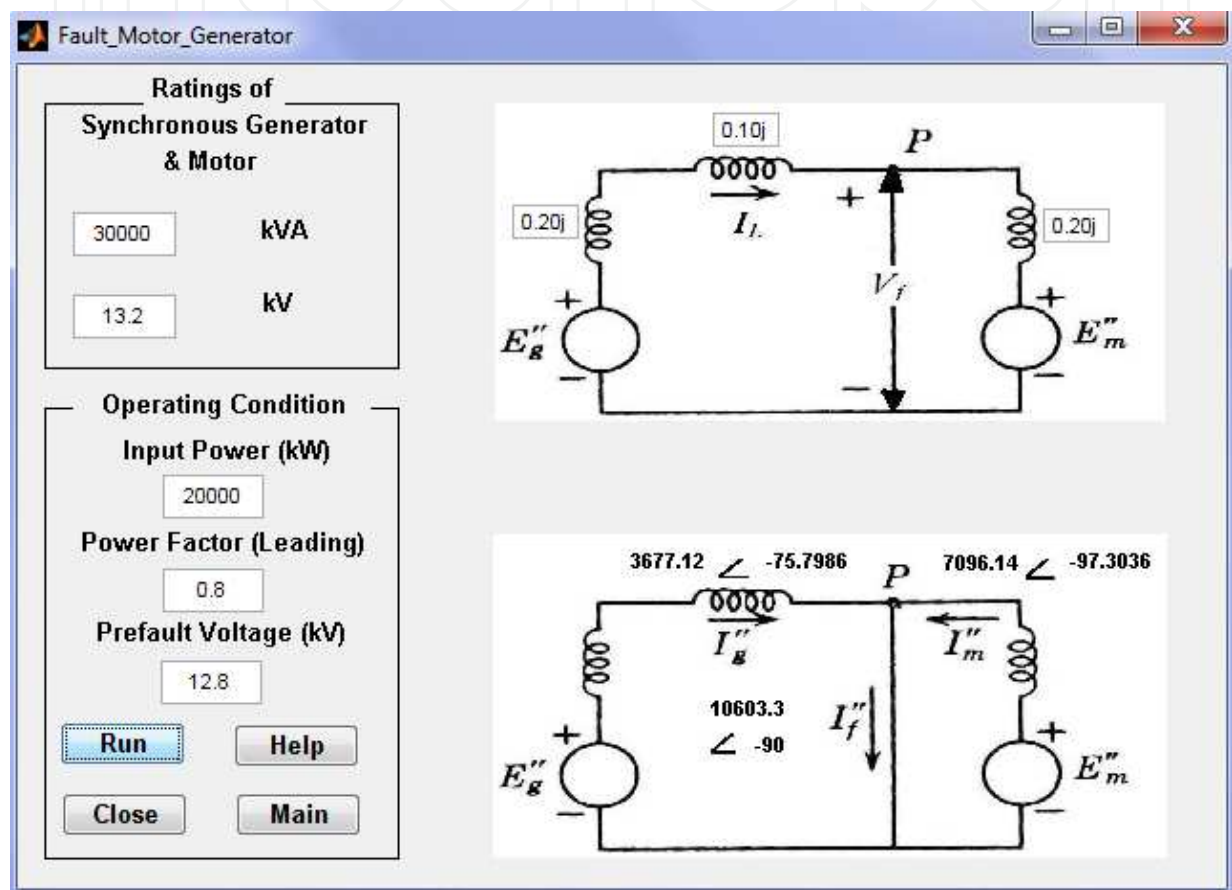
Fig. 2. Symmetrical fault analysis of a motor-generator set

The idea behind the example is to consider a case when a symmetrical three phase fault occurs in the connecting line of a motor-generator set when the system was running full load. The fault current is the contribution from both generator and motor. The magnitude and angle of the fault, generator and motor currents are found by simulating the program. The effect of the pre-fault operating conditions like input power, power factor, and pre-fault voltages on the fault currents can be observed. The impedances of motor, generator, and transmission lines can be changes individually and their impact on fault current can be noticed. The power and voltage ratings of the motor and generator can be modified to see its influence on fault currents. This problem is analysed here with a very attractive user friendly Graphical User Interface (GUI) (MathWorks, 2009) developed using MATLAB GUIDE (GUI Design Environment).

One need not go to the main program each time, save this and run again and need not be worried about unintentionally changing the program and generate an unexpected error. It also provides a help menu for an easy understanding of the problem for the first time user and a step by step procedure of developing program to solve the problem using PC. It provides a complete formulation and solution of the problem. A glimpse of the help file for this module is given in Fig. 3. The help file first describes the problem then the inputs required for running the program are clarified. The next step is to provide a step by step solution procedure for the problem which is given in the textbooks. The last step describes a complete methodology to develop MATLAB program for solving the problem.

After analysing this module a student develops the very basic idea of a fault encountered in power system. By varying various parameters he can verify hand calculation which builds a confidence within him. This hands-on, user friendly interactive module excites the learners to pursue their study of power system. The preliminary objective of providing such a basic problem first is to reinforce students' decision to take power system analysis course, immediately upon starting the course, and help them feel included.
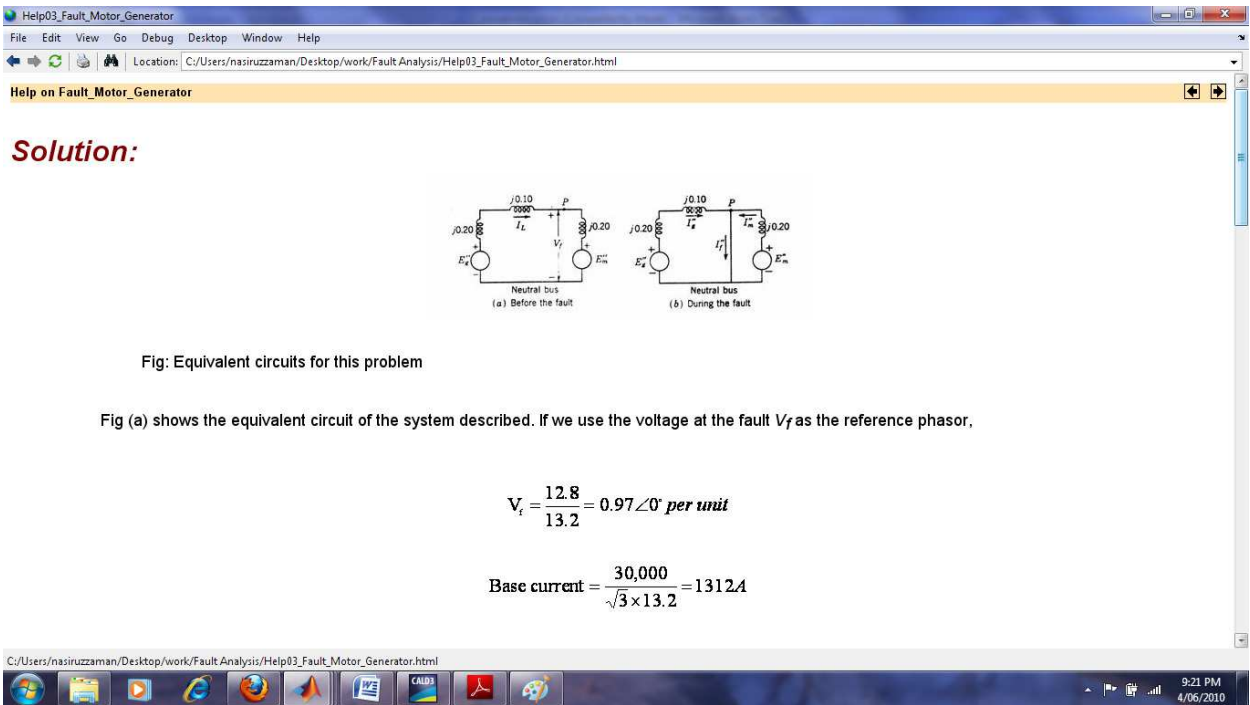

Fig. 3. A portion of help file for symmetrical fault analysis of a motor-generator set

5. Demonstration of Symmetrical Components

Symmetrical components allow unbalanced phase quantities such as currents and voltages to be replaced by three separate balanced symmetrical components. The concept of symmetrical components is an indispensible tool for investigating unbalanced systems. The idea of symmetrical components is found in the paper (Fortescue, 1918). According to Fortescue's theorem, three balanced system of phasors can be constructed from three unbalanced phasor quantities. The balanced components of phasors have the following properties:

a) The *positive sequence components* have three phasors equal in magnitude. Each are displaced 120^0 with each other in phase. It has the phase sequence of the original phasor.

b) The *negative sequence components* also have three phasors equal in magnitude, displaced 120^0 with each other in phase. The difference with the positive sequence component is that the negative sequence components have the opposite phase sequence than that of the positive one.

c) The *zero sequence components* are equal in magnitude and zero phase difference from each other.

In this module as shown in Fig. 4 unbalanced phasors are converted to balanced set of positive, negative, and zero sequence components.
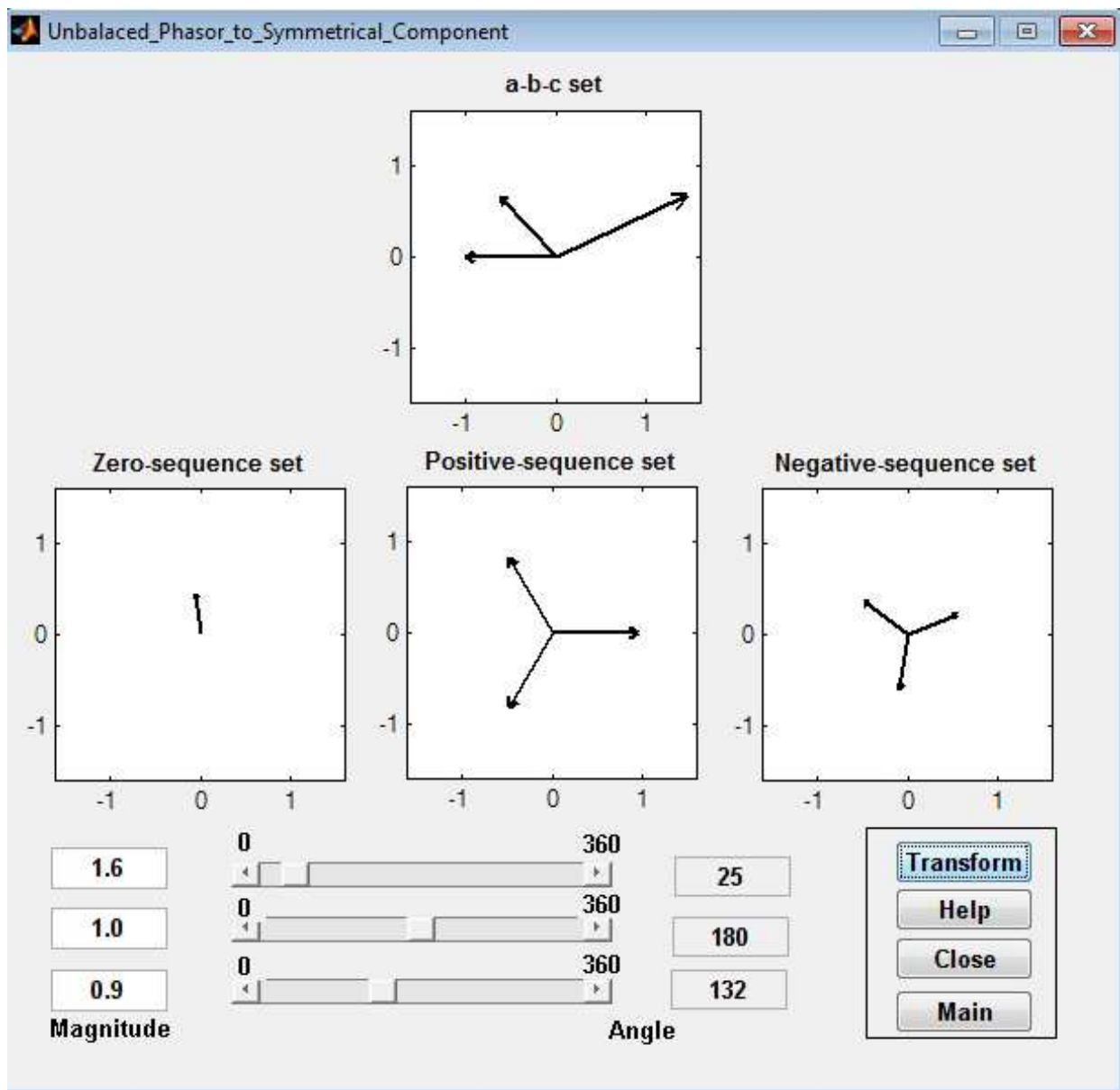

Fig. 4. Conversion of unbalanced phasor to symmetrical components

The a-b-c set in the figure is the unbalanced set of phasors which can be entered in the system using the editable text boxes named as *Magnitude* and *Angle*. In this particular example the magnitudes of three phasors are 1.6, 1.0, and 0.9, while the angles are 25^0, 180^0, and 132^0 respectively. The GUI also has the provision to change the angles using the slider whose range varies from 0 to 360 degrees. After setting all these parameters the user needs to press the *Transform* button and the results are displayed in the three figures titled *Zero, Positive, and Negative-sequence set*. Like other modules of this toolbox the *Help* button provides a detail description of the symmetrical components and some worked out examples to facilitate plumbing the concept. *Close* button terminates the program. By pressing the pushbutton *Main* the main window of the toolbox as in Fig. 1 is returned.

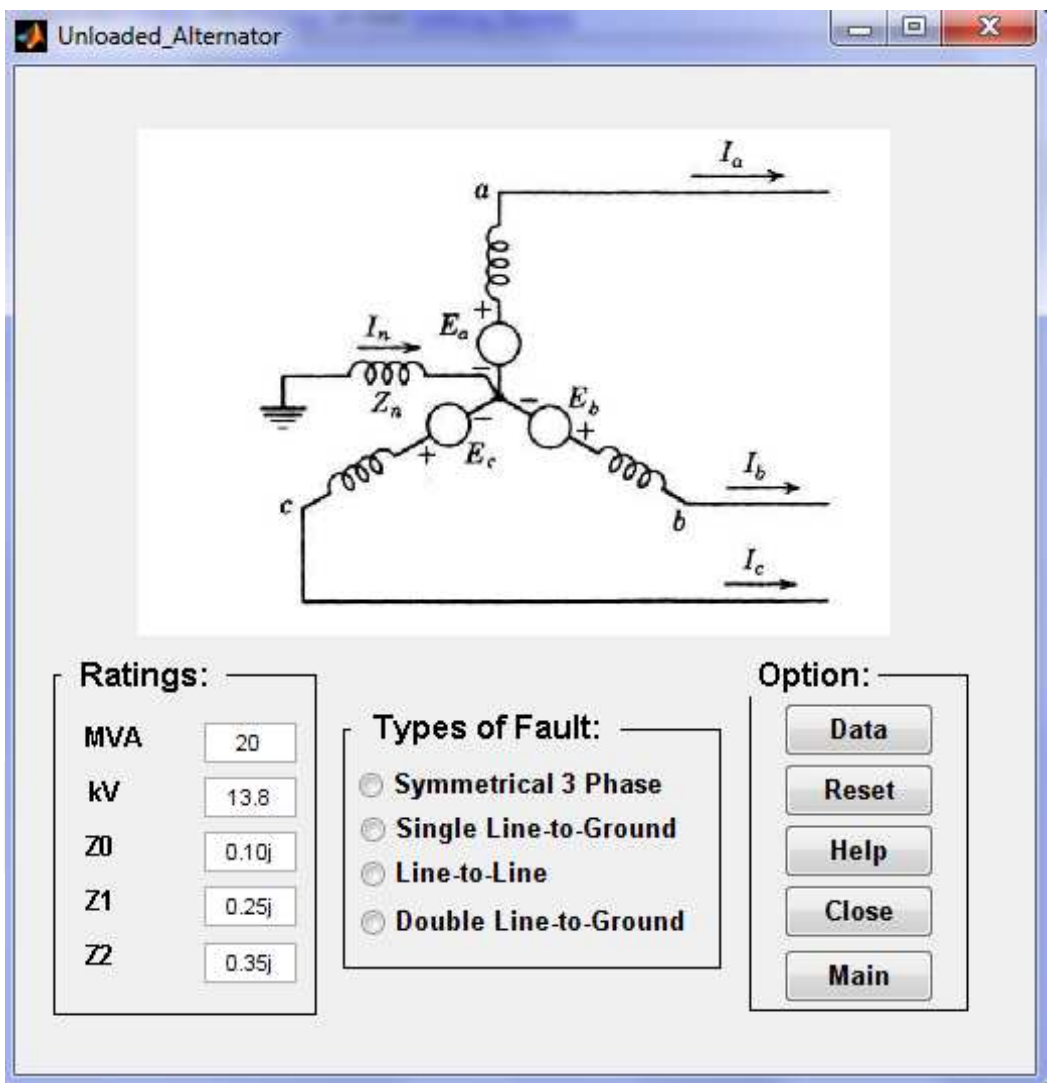## 6. Fault Analysis of an Unloaded Alternator

Fig. 5. Module for different types of fault analysis of an unloaded alternator

This module of the toolbox shown in Fig. 5 is used to study the effect of symmetrical three phase, single line-to-ground, line-to-line, and double line-to-ground faults at the terminal of a previously unloaded alternator which has a rating 20MVA and 13.8kV in this default

example taken from (Stevenson, 1982). The ratings of the alternator (*MVA* and *kV*) can be changed as well as the sequence reactance (*Z0, Z1*, and *Z2*) of the machine can be modified to see the effect of various types of faults on fault currents and voltages. If *Data* button is pressed fault currents and voltages are displayed in a separate window. Initially there is no fault selected as reflected by Fig. 5. If *Line-to-Line* fault is selected then GUI is modified as in Fig. 6 and the result on the analysis is presented in Fig. 7 respectively.
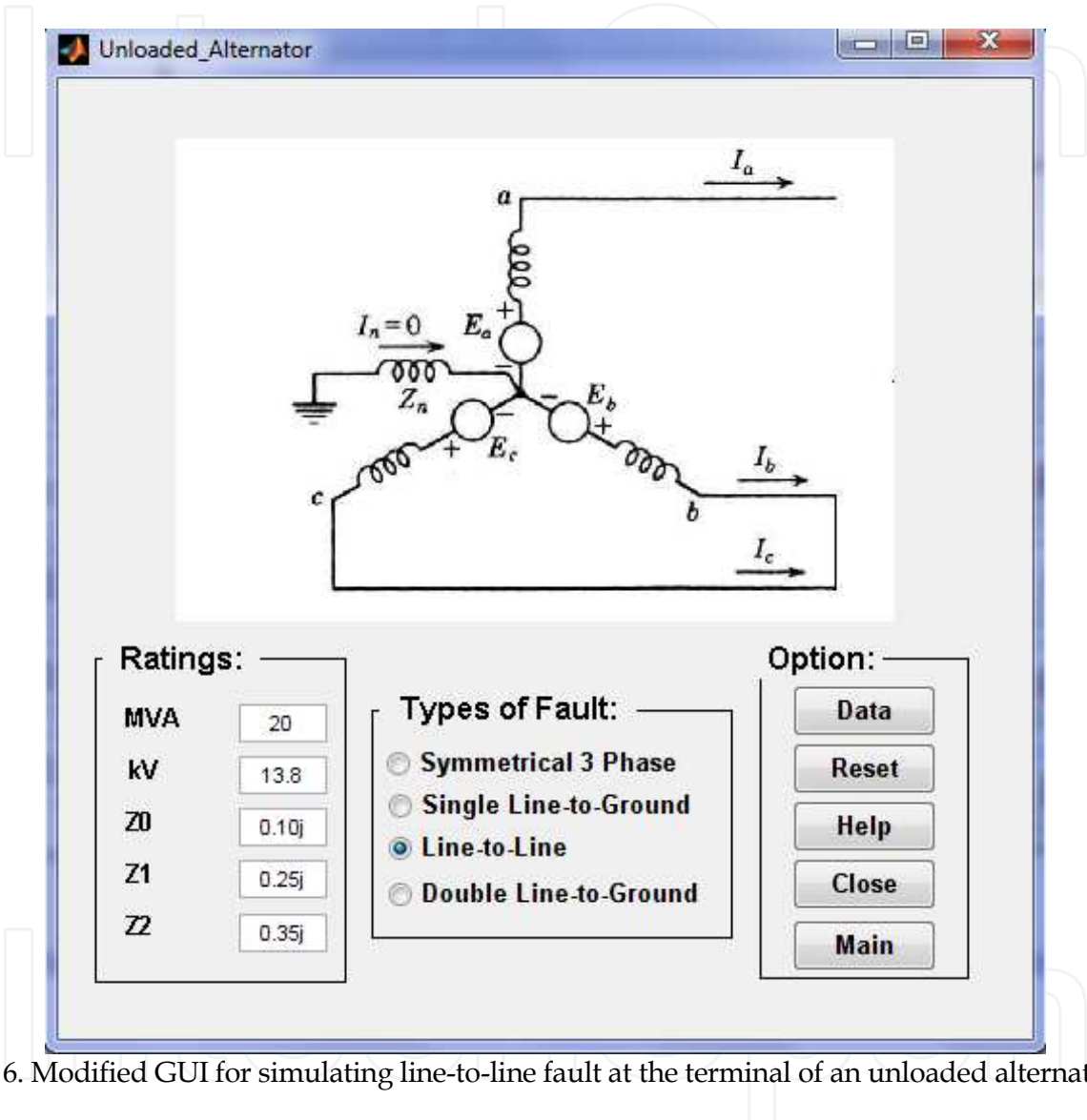

Fig. 6. Modified GUI for simulating line-to-line fault at the terminal of an unloaded alternator

The voltage and current data as shown in Fig. 7 validates some general concept of power system. The first one is the phase a current is zero since the machine was previously unloaded and the line-to-line fault is simulated in phases b and c. Also the voltage difference between phases b and c is zero since these two phases are short-circuited together. The b and c phase currents are same in magnitude but are of opposite phases since they are directly opposing each other as viewed in Fig. 6. This statement is also valid for V_{ab} and V_{ca}. The *Help, Close,* and *Main* buttons perform functions as described earlier and the *Reset* button initializes the module. Table 1 provides voltage and current data by running the program using the ratings as it is shown in Fig. 5 for different types of faults.
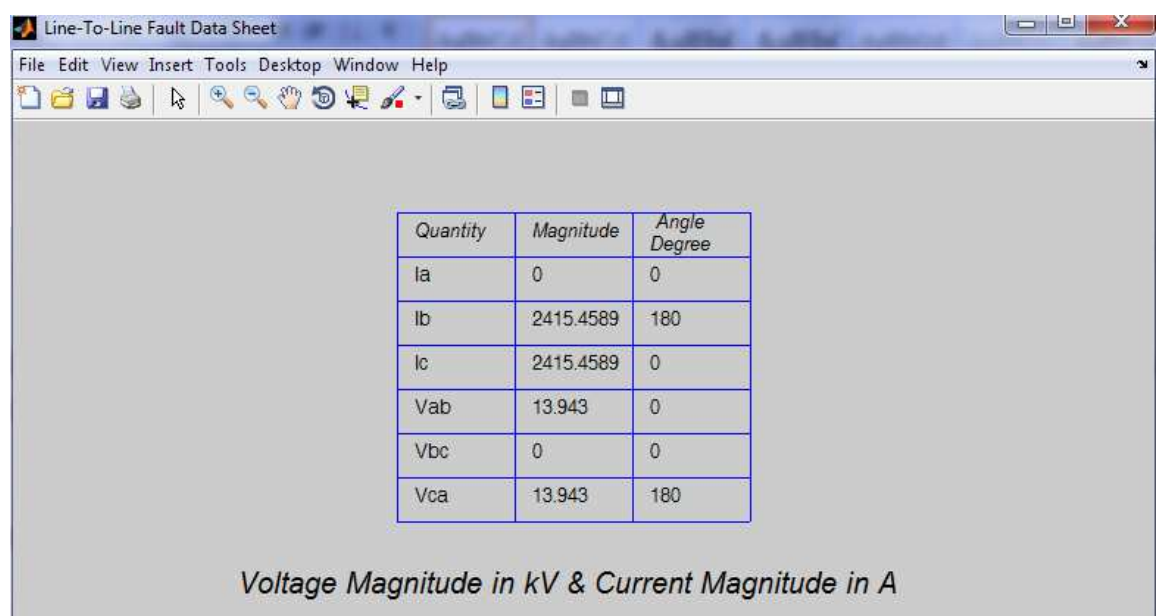
Fig. 7. Voltages and currents after fault

Fault	Symmetrical 3 Phase		Single Line-to-Ground		Line-to-Line		Double-Line-to-Ground	
Quantity	Magnitude	Angle degree	Magnitude	Angle degree	Magnitude	Angle degree	Magnitude	Angle degree
I_a	3346.9981	-90	3586.0265	-90	0	0	0	0
I_b	3346.9981	30	0	0	2415.4589	180	4021.2983	132.2
I_c	3346.9981	150	0	0	2415.4589	0	4021.2983	47.78
V_{ab}	0	0	8.0684	77.78	13.943	0	5.6717	0
V_{bc}	0	0	15.7714	-90	0	0	0	0
V_{ca}	0	0	8.0684	102.2	13.943	180	5.6717	180

Table 1. Currents and Voltages of various types of faults after simulating the system in Fig. 5

7. Balanced and Unbalanced Synchronous Machine Transients

Under steady state condition the rotor m.m.f. and the resultant stator m.m.f. are stationary with respect to each other. So the flux linkages with the rotor circuit do not change with time and no voltage is induced in the rotor circuit. When a balanced or unbalanced fault occurs flux linkages with the rotor circuit changes with time. This causes transient currents in the rotor circuit which in turn creates effect on armatures. This transient analysis is visualised in this module as depicted in Fig. 8 for balanced 3 phase short circuit and in Fig. 9 for unbalanced fault (line-to-line) at the terminal of an alternator.

The field voltage, self and mutual inductances, resistances, frequency, initial torque angle, and time span are the inputs for the module. Two standard frequencies (50 and 60Hz) can be chosen from the drop-down menu in the GUI. The time span can be varied according to the region of interest of the simulation. In case of unbalanced fault analysis there is an extra provision to select between line-to-line and line-to-ground fault. These two modules can be switched using the *Unbalanced* and *Balanced* buttons in the balanced and unbalanced modules respectively. By pressing the *Simulate* button the transient curves can be obtained which takes some time depending upon the time span since it is required to solve differential equations.
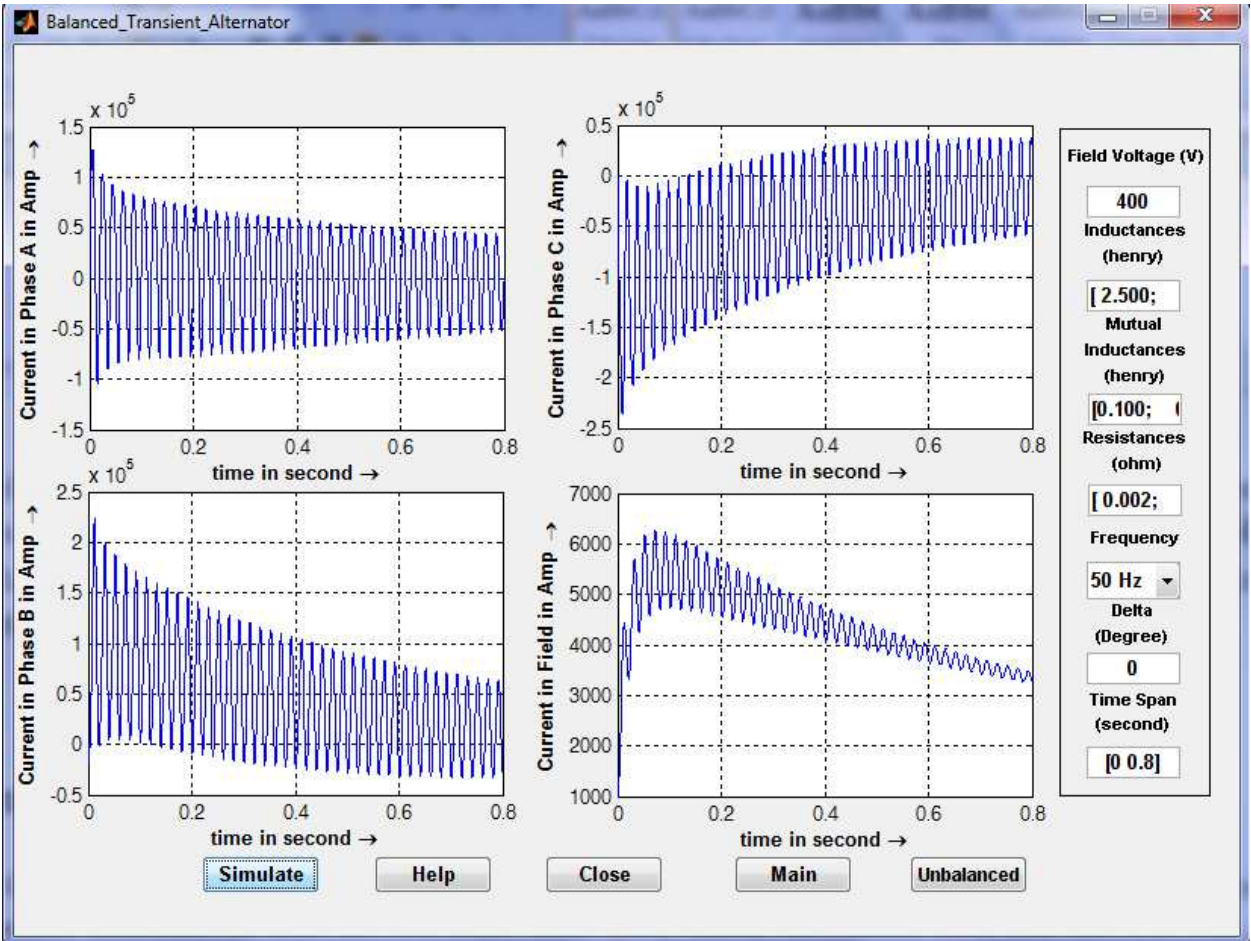
Fig. 8. Currents in various phases of an alternator after a three phase short circuit occurs at its terminal

8. Fault Analysis of Interconnected Buses

In this module a very much challenging problem of power system analysis course is described. The generalised case of finding voltages and currents after the occurrence of symmetrical three phase fault at any bus of a power system is either solidly grounded or shorted with some impedance is the most interesting problem in this toolbox. For example, a simple 11 bus test case is considered as shown in Fig. 10. The pre-fault voltages at various buses can be found by load flow study. Generally, if such accuracy is not important the pre-fault bus voltages are assumed to be unity. The transient impedance of the generators are on a 100MVA base are given in Table 2.

Generator	Ra	X_d'
1	0	0.20
10	0	0.15
11	0	0.25

Table 2. Generator resistance and reactance for simple 11 bus system in Fig. 10
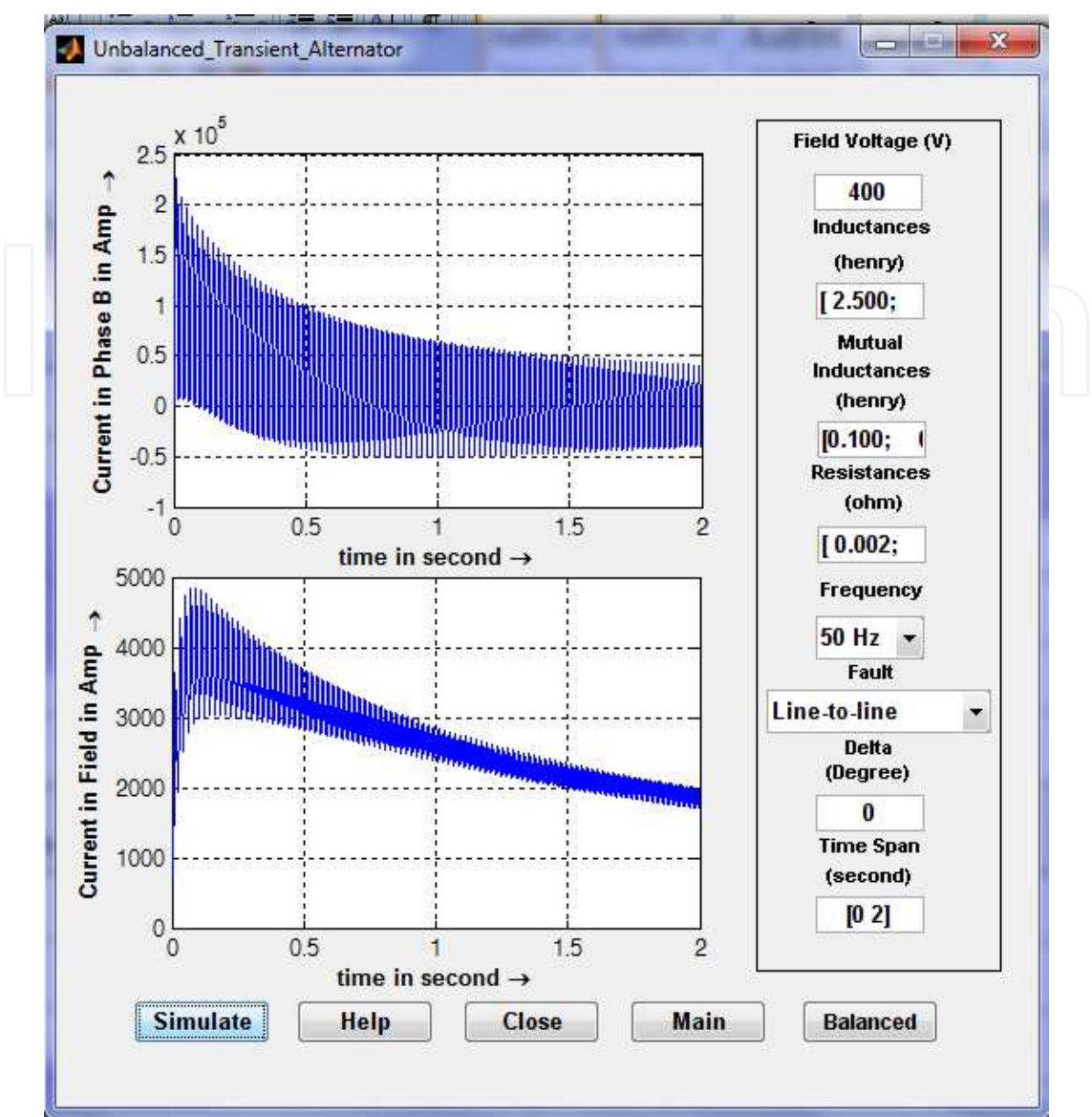
Fig. 9. Simulation of line-to-line fault at the terminal of a 50Hz alternator for 2 seconds
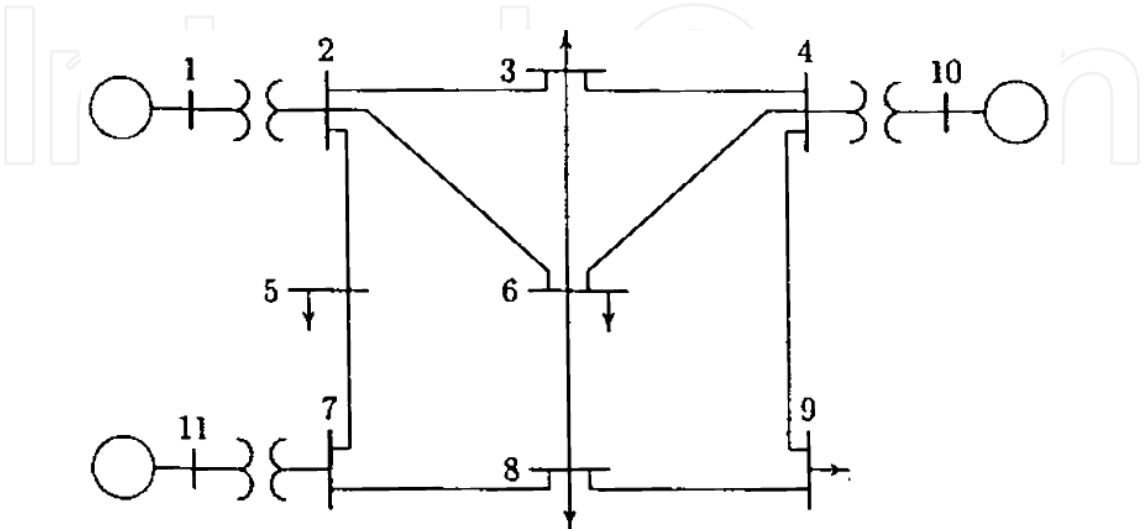

Fig. 10. Simple 11-bus power system for fault studies (Saadat, 2009)

The line and transformer data along with the half of susceptance value is given in Table 3 in per unit. These data are incorporated in the program and the pre-fault bus voltages are assumed to be 1 and a solid 3 phase symmetrical fault is simulated at bus 8. The resulting GUI looks like Fig. 11. The *Voltage Data* corresponds to the various bus voltages after the fault and the *Current Data* represents various currents flowing in various lines in the system after the fault has occurred. The voltage and current data after the fault are given in Fig. 12 and Fig. 13 respectively. If any bus was faulted with some impedance this can be done by entering *Fault Impedance* as r+jx format.

Fro m Bus	To Bus	R pu	X pu	½ B pu
1	2	0.00	0.06	0.0000
2	3	0.08	0.30	0.0004
2	5	0.04	0.15	0.0002
2	6	0.12	0.45	0.0005
3	4	0.10	0.40	0.0005
3	6	0.04	0.40	0.0005
4	6	0.15	0.60	0.0008
4	9	0.18	0.70	0.0009
4	10	0.00	0.08	0.0000
5	7	0.05	0.43	0.0003
6	8	0.06	0.48	0.0000
7	8	0.06	0.35	0.0004
7	11	0.00	0.10	0.0000
8	9	0.052	0.48	0.0000

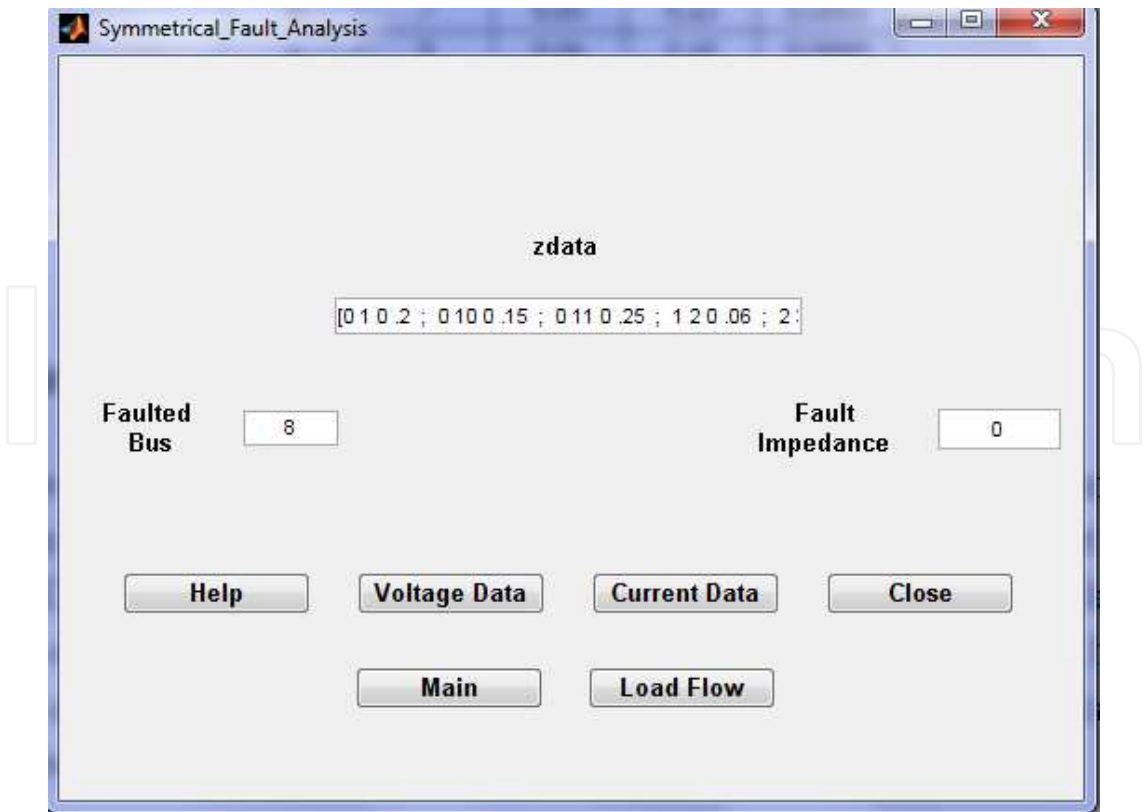Table 3. Line and transformer data for simple 11 bus system in Fig. 10

Fig. 11. GUI for analysing solid fault at bus 8 of 11 bus system

Bus No.	Voltage Magnitude	Angle Degree
1	0.80817	-1.818
2	0.75083	-2.5443
3	0.68819	-1.5987
4	0.74914	-2.4902
5	0.70073	-2.3762
6	0.54537	-1.0194
7	0.56179	-3.8128
8	0	0
9	0.30076	2.4499
10	0.83621	-1.4547
11	0.68663	-2.2272

Fig. 12. Voltage at various buses after a 3 phase symmetrical fault at bus 8 of Fig. 10

From Bus	To Bus	Current Magnitude	Angle Degree
0	1	0.96972	-82.4034
0	10	1.1029	-82.6275
0	11	1.2601	-85.141
1	2	0.96972	-82.4034
2	3	0.20532	-87.8751
2	5	0.323	-79.9626
2	6	0.44267	-81.6497
4	3	0.1503	-88.4042
3	6	0.35561	-88.0987
4	6	0.33055	-82.3804
4	9	0.62294	-81.3672
10	4	1.1029	-82.6275
5	7	0.323	-79.9626
6	8	1.1274	-83.8944
7	8	1.582	-84.0852
11	7	1.2601	-85.141
9	8	0.62294	-81.3672
8	8	3.3319	-83.5126

Fig. 13. Currents at various lines after a 3 phase symmetrical fault at bus 8 of Fig. 10

9. Stability Analysis

Power system stability is defined as 'Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subject to a physical disturbance, with most system variables bounded so that practically the entire system remains intact by (Kundur et. Al., 2004). Broadly, the power system stability is classified as:

a) Rotor angle stability
b) Voltage stability
c) Frequency stability

In this module mainly the rotor angle stability is considered. When a 3 phase short circuit occurs in a line very close to a generator bus of an interconnected power system, the voltage of the bus essentially becomes zero. So the electrical output power also becomes zero. But the mechanical power input to the turbine-generator system remains constant. Hence the generator accelerates. This acceleration means that the rotor angle of the generator will keep increasing. Now, in order to clear the fault the circuit breakers are tripped to remove the faulted line out of the system. Depending upon the time of tripping the rotor angle of the generator of the faulted bus will then wither settle down to a new equilibrium, or keep on increasing resulting in instability. This is an example of rotor angle stability which occurs mainly due to the mismatch of electrical output and mechanical input power of the alternator. Rotor angle stability can be analysed for either for small or large disturbances and generally this type of stability analysis if performed for 2 to 10 seconds i.e., this is an example of short term stability.
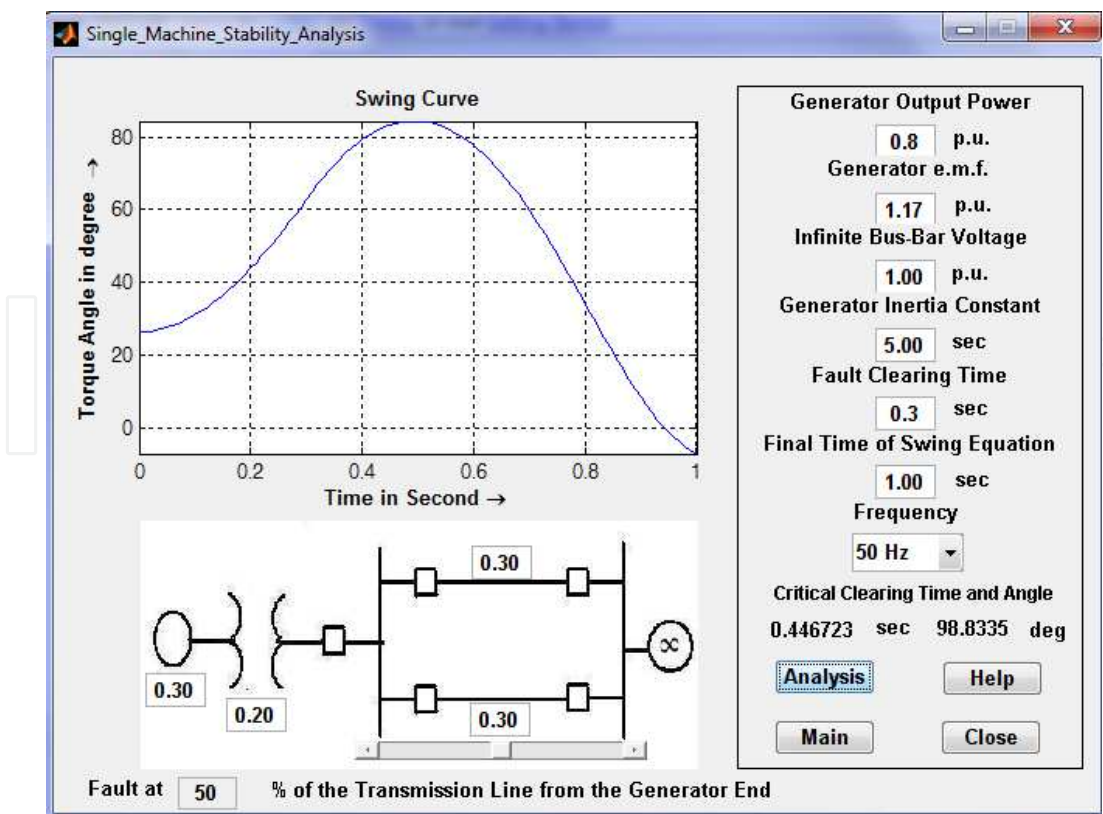

Fig. 14. Stability analysis module

The example that have considered here is a single machine system connected to an infinite bus via two parallel transmission lines as demonstrated in Fig. 14. In this case the stability of the single machine is considered subjected to a symmetrical 3 phase fault in one of the two parallel lines. The position of the fault along the line can be changed and its effect on stability can be visualised. The example shown in Fig. 14 simulates a fault at the middle (50%) of the transmission line. The fault location can be varied either by using the slider control of the GUI or by entering the fault position as a percentage (0% for a fault at the transformer terminal and 100% for the fault at the infinite bus). The generator, transformer, and transmission line reactances can be varied. Various ratings can be changed such as *Generator output power*, *Generator e.m.f.*, *Infinite bus-bar voltage*, *Generator inertia constant*. *Fault clearing time* is very essential for this type of stability and system may become stable or unstable for a same fault with different fault clearing time. The final time that needs to be visualised the rotor angle change due to the application of the fault is entered in the textbox *Final time of swing equation*. The frequency of the system can be set to either 50Hz or 60Hz. The program plots angular swing of the generator with respect to time and gives the *critical clearing time* and *critical clearing angle* of fault which is very important in stability studies.
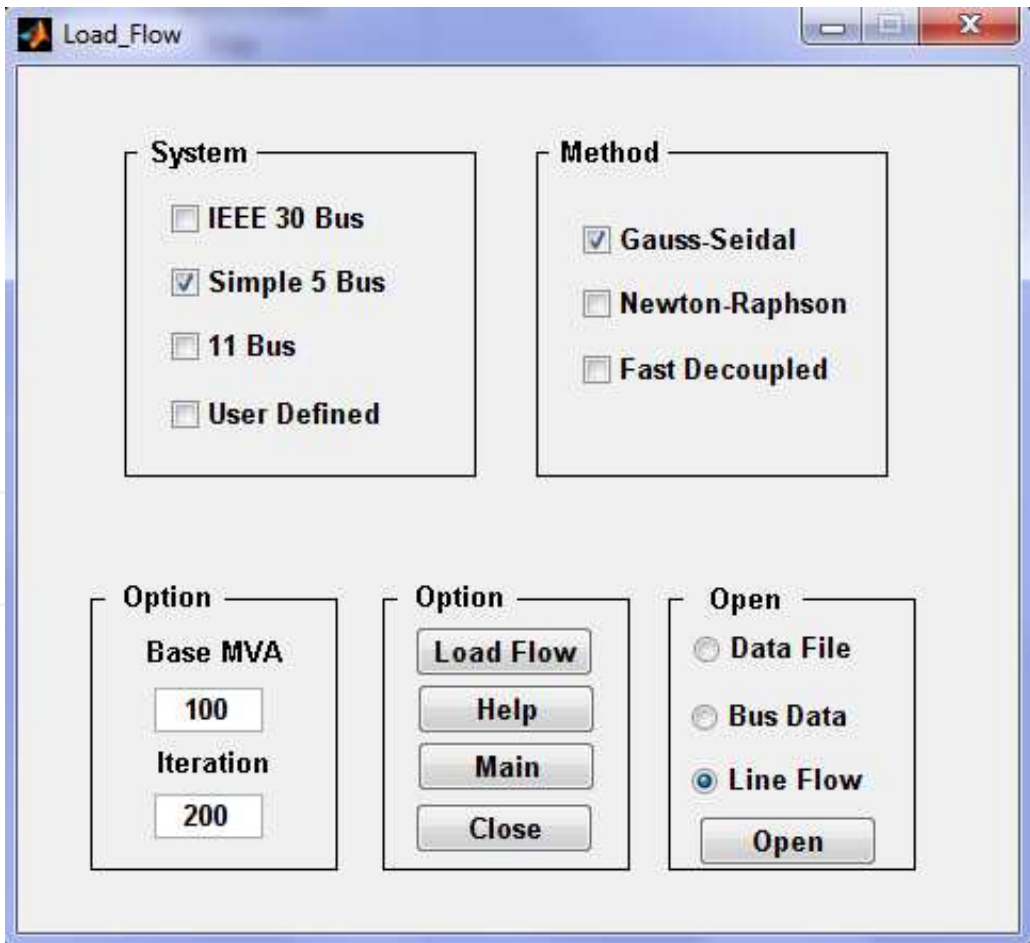
10. Load Flow Analysis

Fig. 15. Load flow analysis module

Load flow or power flow analysis is performed in a power system analysis course to determine voltage magnitudes and angles of various bus bars as well as real and reactive power flow in a power system. It is basically a problem of solving a system of nonlinear equations and various methods have been proposed in the literatures for solving load flow problems efficiently. Gauss-Seidel, Newton-Raphson, Decoupled Newton-Raphson methods are very much common for undergraduate studies and these are considered in building the toolbox. The module is shown in Fig. 15. There are various test systems like IEEE-30 bus system, 11 bus system as in Fig. 10 and simple 5 bus system as in Fig 15 (Stevenson, 1982) are made available with this toolbox. User can build own system also. After running the load flow program the *Bus Data* and *Line Flows* are available.
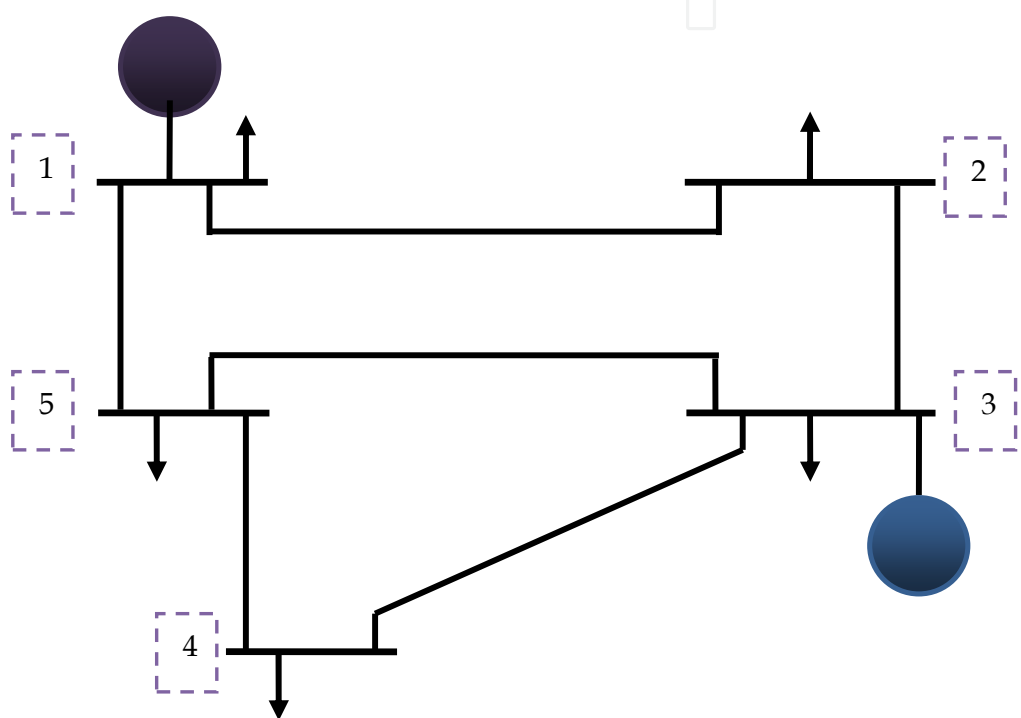

Fig. 16. Simple 5-bus power system for load flow analysis

The input required to conduct load flow of a simple 5 bus system is given in Fig. 16 whereas Fig. 17 and 18 gives the output of the load flow study using Gauss-Seidel method.

```
File  Edit  Text  Go  Cell  Tools  Debug  Desktop  Window  Help

2      %          Bus Bus  Voltage Angle    ---Load----  -------Generator-----  Static Mvar
3      %          No  code Mag.    Degree   MW    Mvar   MW  Mvar Qmin Qmax    +Qc/-Ql
4  -   busdata=[1  1    1.04    0.0      65    30     0   0    0    0       0
5              2   0    1.00    0.0      115   60     0   0    0    0       0
6              3   2    1.02    0.0      70    40     180 0    0    0       0
7              4   0    1.00    0.0      70    30     0   0    0    0       0
8              5   0    1.00    0.0      85    40     0   0    0    0       0];
9
10     %
11     %          Bus  bus    R        X        1/2 B       1 for Line code or
12     %          nl   nr    p.u.     p.u.      p.u.           tap setting value
13     %          Bus  bus    R        X       1/2 B    1 for Line code or
14     %          nl   nr    p.u.     p.u.     p.u.        tap setting value
15 -   linedata=[1  2    0.042   0.168    0.041/2            1
16             1   5    0.031   0.126    0.031/2            1
17             2   3    0.031   0.126    0.031/2            1
18             3   4    0.084   0.336    0.082/2            1
19             3   5    0.053   0.21     0.051/2            1
20             4   5    0.063   0.252    0.061/2            1];
```

Fig. 17. Input for load flow analysis of system in Fig. 16

```
Editor - C:\Users\nasiruzzaman\Desktop\work\Fault Analysis\Power Flow.txt*
File  Edit  Text  Go  Tools  Debug  Desktop  Window  Help

1              Power Flow Solution by Gauss-Seidel Method
2                  Maximum Power Mismatch = 0.000855708
3                      No. of Iterations = 79
4
5    Bus  Voltage  Angle     ------Load------     ---Generation---     Injected
6    No.  Mag.     Degree    MW       Mvar        MW       Mvar        Mvar
7     1   1.040    0.000     65.000   30.000      234.588  100.157     0.000
8     2   0.961   -6.324     115.000  60.000      0.000    0.000       0.000
9     3   1.020   -3.717     70.000   40.000      180.000  110.249     0.000
10    4   0.920  -10.878     70.000   30.000      0.000    0.000       0.000
11    5   0.968   -6.163     85.000   40.000      0.000    0.000       0.000
12
13   Total                   405.000  200.000     414.588  210.406     0.000
```

Fig. 18. Bus data after load flow for the system in Fig. 16

11. Conclusion

Programs developed in this software package cover all the topics of basic power system analysis course. Examples from various widely available textbooks (Bergen & Vittal, 1999; Elgerd, 1983; Glover, 2007; Grainger & Stevenson, 1994; Saadat, 2009; Stevenson, 1982; Wood & Wollenberg, 1996) are taken as examples. These textbooks are used all over the world. So, students running the software find a familiar environment around. Apart from this, other examples can be tested using this toolbox since the programs are written in a generalised

way. Although codes are written in MATLAB, the software is compiled so that it can run without MATLAB. This feature is very much useful for computers having low memory, which increases the versatility of the toolbox. Extended help files are available with step by step solution procedure. So the toolbox can be used as alternative to textbook, albeit this is not recommended. Anyone can see the inner structure of the program and learn to code power engineering problems.
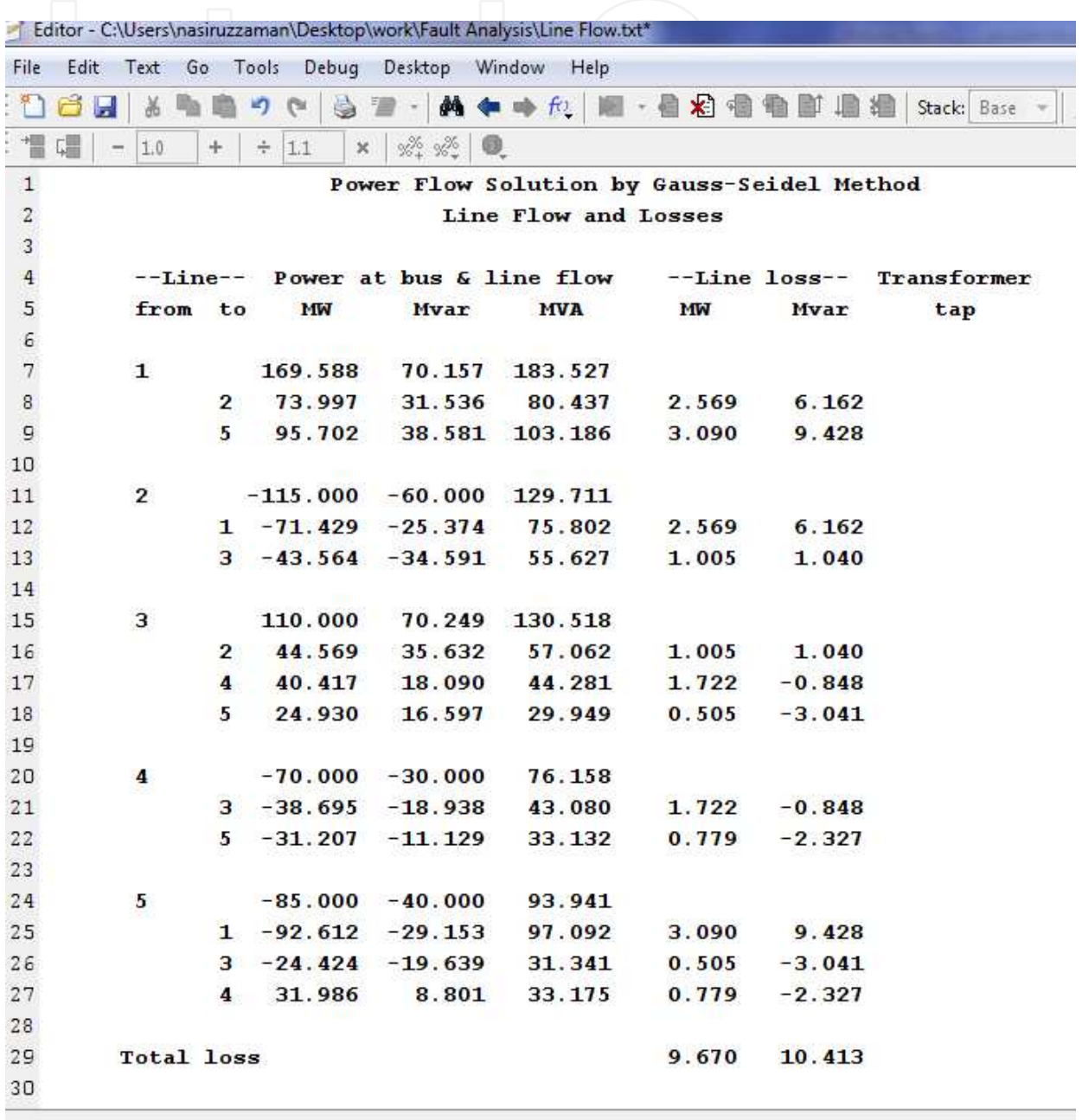

Fig. 19. Line flows and losses for the system in Fig. 16

The toolbox is currently used as a supplement to Power System Analysis (EEE 461) course in the Department of Electrical & Electronic Engineering, Rajshahi University of Engineering & Technology, Kazla, Rajshahi-6204, Bangladesh (*www.ruet.ac.bd*). The author can be contacted at *nasiruzzaman@ieee.org* in case of any enquiry about the software.

12. References

BCP, Inc. (2010). http://www.neplan.ch/html/e/e_home.htm

Bergen, A. R. & Vittal, V. (1999). *Power System Analysis*, (2nd), Prentice Hall, 0136919901

Elgerd, O. I. (1983). *Electric Energy Systems Theory: An Introduction*, (2nd), McGraw-Hill Higher Education, 0070192316

Fortescue, C. L. (1918). Method of Symmetrical Co-Ordinates Applied to the Solution of Polyphase Networks. *AIEE Transactions*, Vol. 37, No. 2, (Jul 1918)

Glover, J. D., Sarma, M. S. & Overbye, T. (2007). *Power System Analysis and Design*, (4th), CL Engineering, 0534548849

Grainger, J. J. & Stevenson Jr, W. D. (1994). *Power System Analysis*, (1st), McGraw-Hill Higher Education, 0071133380

Kundur, P., Paserba, J., Ajjarapu, V., Andersson, G., Bose, A., Canizares, C., Hatziargyriou, N., Hill, D., Stankovic, A., Taylor, C., Van Cutsem, T. & Vittal, V. (2004). Definition and classification of power system stability IEEE/CIGRE joint task force on stability terms and definitions. *IEEE Transactions on Power Systems*, 19, 3, (Aug 2004) (1387 - 1401), 08858950

MathWorks, Inc. (2009). *MATLAB® Creating Graphical User Interfaces*, The MathWorks, Inc, Natick, MA 01760-2098, USA

Milano, F. (2005). An Open Source Power System Analysis Toolbox. *IEEE Transactions on Power Systems*, Vol. 20, No. 3, (Aug 2005), 08858950

Operation Technology, Inc. (2009). http://etap.com

PowerWorld Corporation (2009). http://www.powerworld.com

Rabbani, M. G., Nasiruzzaman, A. B. M., Sheikh, R. I. & Anower, S. (1996). MATLAB Based Fault Analysis Toolbox for Electrical Power System, *Proceedings of International Conference on Electrical and Computer Engineering, 2006. ICECE '06.*, pp. 116-119, 98432-3814-1, Dhaka, Dec 2006, IEEE Bangladesh Section, Dhaka

Saadat, H. (2009). *Power System Analysis*, (2nd), McGraw-Hill Higher Education, 0071281843

Siemens, PTI. (2009). http://www.energy.siemens.com/us/en/services/power-transmission-distribution/power-technologies-international/software-solutions/pss-e.htm

Songur, M. & Ercan, B. (1997). POWERHU-a PC-based electric power system analysis software package for electric power system courses. *IEEE Transactions on Education*, Vol. 40, No. 4, (Nov 1997), 00189359

Stevenson Jr, W. D. (1982). *Elements of Power System Analysis*, (4th), McGraw-Hill Higher Education, 0070665842

Wood, A. J. & Wollenberg, B. F. (1996). *Power Generation, Operation, and Control*, (2nd), Wiley Interscience, 0471586994
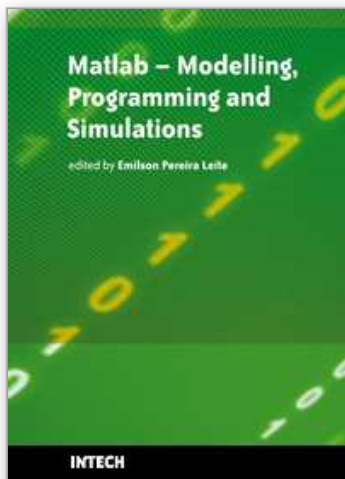
Matlab - Modelling, Programming and Simulations

Edited by Emilson Pereira Leite

This book is a collection of 19 excellent works presenting different applications of several MATLAB tools that can be used for educational, scientific and engineering purposes. Chapters include tips and tricks for programming and developing Graphical User Interfaces (GUIs), power system analysis, control systems design, system modelling and simulations, parallel processing, optimization, signal and image processing, finite different solutions, geosciences and portfolio insurance. Thus, readers from a range of professional fields will benefit from its content.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

A. B. M. Nasiruzzaman (2010). A Student Friendly Toolbox for Power System Analysis Using MATLAB, Matlab - Modelling, Programming and Simulations, Emilson Pereira Leite (Ed.), ISBN: 978-953-307-125-1, InTech, Available from: http://www.intechopen.com/books/matlab-modelling-programming-and-simulations/a-student-friendly-toolbox-for-power-system-analysis-using-matlab

INTECH
open science | open minds