MENU DRIVEN INTELLIGENT TUTORING FOR POWER SYSTEM MODELING

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ABSTRACT

The Graphical User Interface (GUI) provides the user with interactive visual communication to analyse and model the power systems. Applying the advantages of the GUI, new menu driven intelligent tutoring system was developed. The software allows the user to draw the single line diagram representing the power system with ratings of each component. The software calculates the corresponding per-unit values and the change of impedance of individual component referred to the common system MVA. These per-unit values can be used to draw the reactance diagram of symmetrical components automatically. Therefore, it becomes a convenient approach for creating an interactive tool in teaching and learning the power system. The aim of this project is to make teaching and learning more productive and efficient by employing modern technologies. It is hoped that this software will enhance the learning process and make it more interactive, interesting and user friendly.

Keywords : *Expert System, Graphical User Interface (GUI), Per-Unit Representation, Power Engineering Education, Power System Modeling*

INTRODUCTION

Many students have difficulty in understanding the concepts and mastering the analytical skills required in their first course in power systems. This becomes apparent in subsequent courses when the students falter in applying those concepts and skills to the design, model and analyse the power systems. They lose interest in power system and will result in a decrease in enrollment. Modeling the symmetrical components is quite complex especially visualising the zero-sequence components. Unlike the positive- and negative- sequence diagram, a zero-sequence diagram is affected by the transformer and machine winding configurations and by the various device's neutral grounding arrangement. Therefore, constructing a zero- sequence diagram is much more complicated than constructing a positive- or negative sequence.

The project featured in this paper is aimed at the development of educational software to help students to understand more on power system modeling especially when dealing with symmetrical components. Using this software, student will be able to see the effect of different type of transformer and machine winding configurations, and this can make the subject more interesting. The interactive and comprehensive software supplements and enhances the learning process in the classroom, as well as in the student's self-study.

2.0 POWER SYSTEM MODELING

Power system is a complicated electrical network. Therefore, it is necessary to create an equivalent representation as a model of practical diagram that is easier to read, understand and analyse. This representation will show all-important information in power system networks and represent it using standard symbols rather than a complex mathematical model.

2.1 SINGLE-LINE DIAGRAM

Single-line or *one-line* diagram is a simplified diagram which is drawn by omitting the circuit line to neutral, indicating the components by standard symbols rather than by their equivalent circuits [1-2,6-9]. It shows by a single line representation and standard symbols how the transmission lines and associated apparatus of an electrical system are connected together. The purpose of this single-line diagram is to show important information of power system networks in a more simplified and compact form. It will also show the location and connection between generator, transformer, transmission line, motor, static load, circuit breaker, reactor and different switches using their own standard symbol [1-2,6-9].

2.2 IMPEDANCE DIAGRAM

An impedance diagram is used to draw a single-phase of per-phase equivalent circuit of the system and it can be used to calculate performance of the system under load condition or upon the occurrence of a fault. The impedance diagram is very useful in power system analysis because all circuit parameters have always been given in per-unit scale. Standard network analysis is used to analyse impedance diagram due to the changing of voltage levels in calculating the per-unit quantity. Resistance is often omitted when making fault calculations, even in computer programs. These small values of resistance (less than 0.1 percent) [1,2,6-9] compared to the reactance of generator and transformer and sometimes transmission line, will not affect the result of calculation. The omission of this resistance will change the impedance diagram to the reactance diagram.

2.3 PER-UNIT SYSTEM

The solution of interconnected power system having several different voltage levels requires the cumbersome transformation of all impedances to a single MVA system. In this way, all reactance in this system can be expressed as a percentage or per unit A minimum of four base quantities is required to completely define a per-unit system: volt-ampere, voltage, current and impedance. Selected MVA_B is chosen from the biggest available in the system and usually at generation part. Base current and base impedance are then calculated from S_B and V_B and must obey the circuit laws [1-10].

The new impedance can be calculated from the change of impedance referring to the old system and is given by:

$$Per\text{ - }unit\ Z_{new} = per\text{ - }unit\ Z_{given}\left(\frac{base\ kV_{given}}{base\ kV_{new}}\right)\left(\frac{base\ MVA_{new}}{base\ MVA_{given}}\right) \tag{2.1}$$

2.4 SYMMETRICAL COMPONENTS

The method of symmetrical components was introduced by Fortescue [1-10] in 1918 and had been improved by Wanger and Evans in 1993 [1,2,6-9]. According to Fortescue's theorem, three unbalanced phasors of a three-phase system can be resolved into three balanced systems of phasors. The balanced sets of components are *positive-*, *negative-* and z*ero- sequence* as shown in Figure 1.

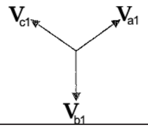
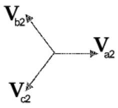
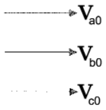
COMPONENT	CRITERIA	PHASE DIAGRAM
Positive-sequence	-a-b-c sequence -Same magnitude -Phase different 120°	
Negative-sequence	-a-c-b sequence -Same magnitude -Phase different 120°	
Zero-sequence	-Same magnitude -Phase different 0°	

Figure 1: Symmetrical components

2.4.1 SEQUENCE NETWORKS FOR GENERATOR, SYNCHRONOUS MOTOR AND INDUCTION MOTOR

The sequence networks of the generator are shown in Figure 2. Since a three-phase generator is designed to produce balanced internal phase voltages, therefore, a source voltage E_{g1} is included only in the positive sequence network.

The sequence networks for three-phase synchronous motor and for three-phase induction motor are shown in Figure 3. Synchronous motor have the same sequence networks as synchronous generator, except that the

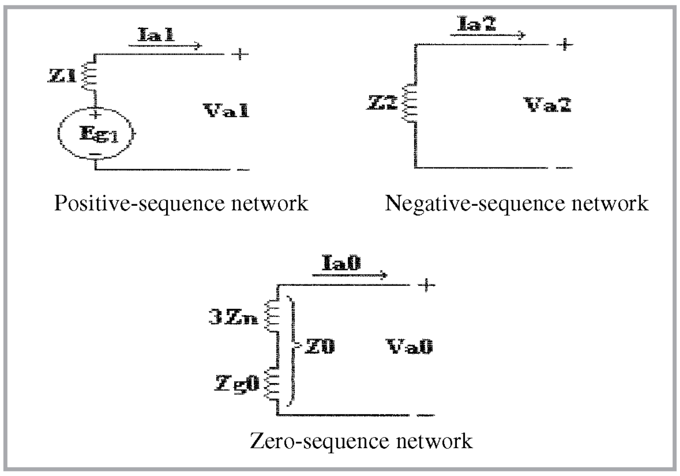


Figure 2: Sequence networks of generator

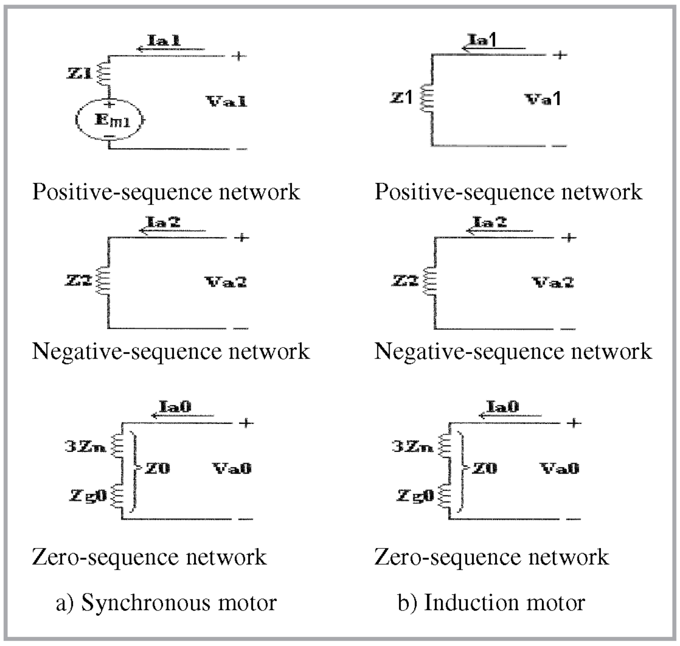


Figure 3: Sequence networks of three-phase motor

sequence currents for synchronous motor are referredinto rather than out of sequence networks. Also, induction motor has the same sequence networks as synchronous motor, except that the positive-sequence voltage source E_{m1} is removed.

2.4.2 ZERO-SEQUENCE NETWORKS FOR THREE PHASE TRANSFORMERS

The positive- and negative- sequence networks are equal for three-phase transformer. In positive- and negative-sequence networks, a three-phase transformer can be replaced with a reactance connecting the primary to the secondary. However, in zero-sequence networks, connections depend on *wye*, *grounded wye* and *delta* configurations as shown in Figure 4.

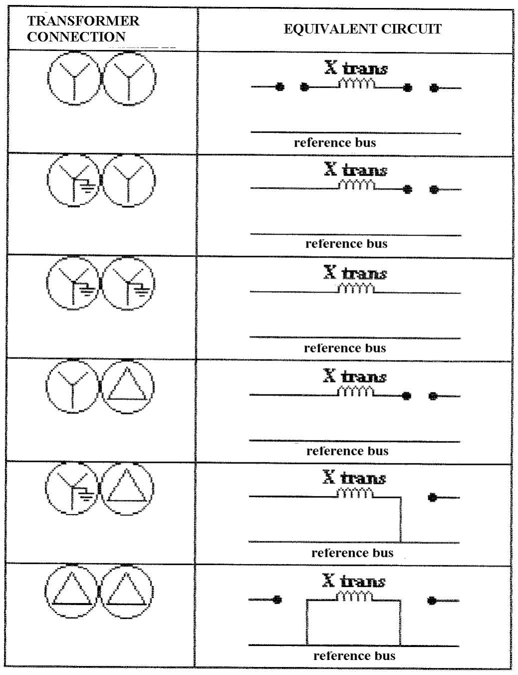


Figure 4: The zero-sequence network for 6 type connections for 3-phase transformer

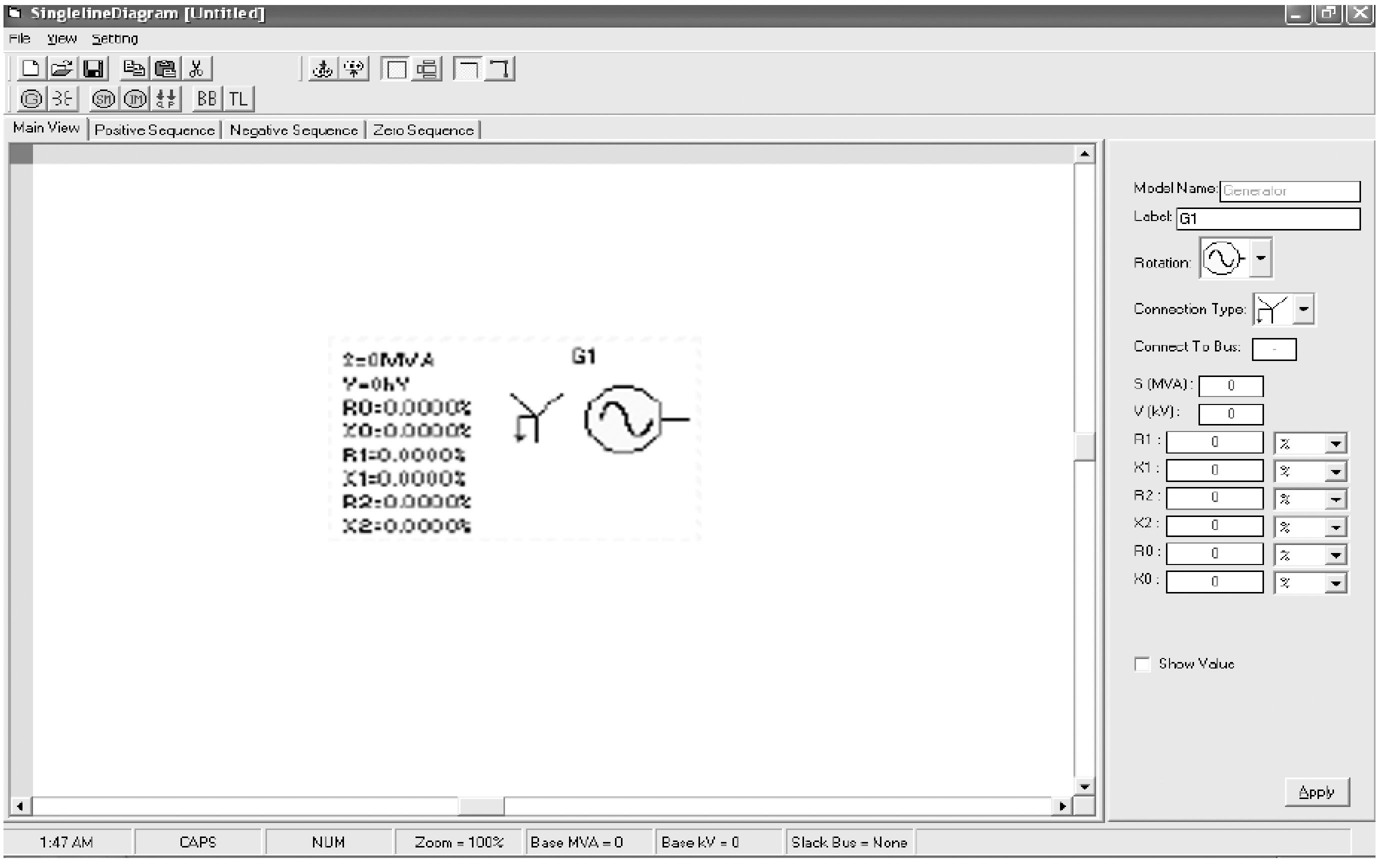


Figure 5: Software main interface

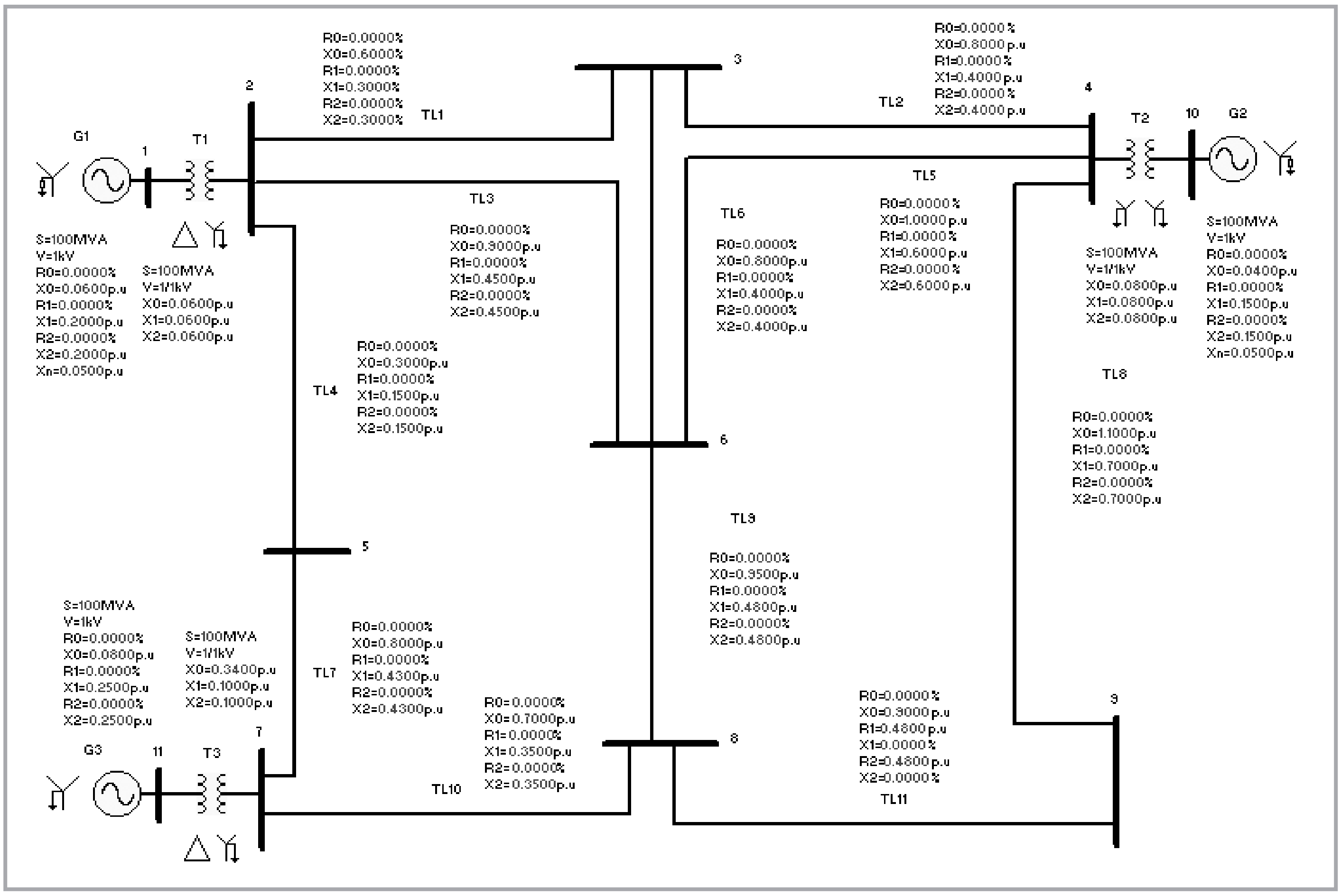
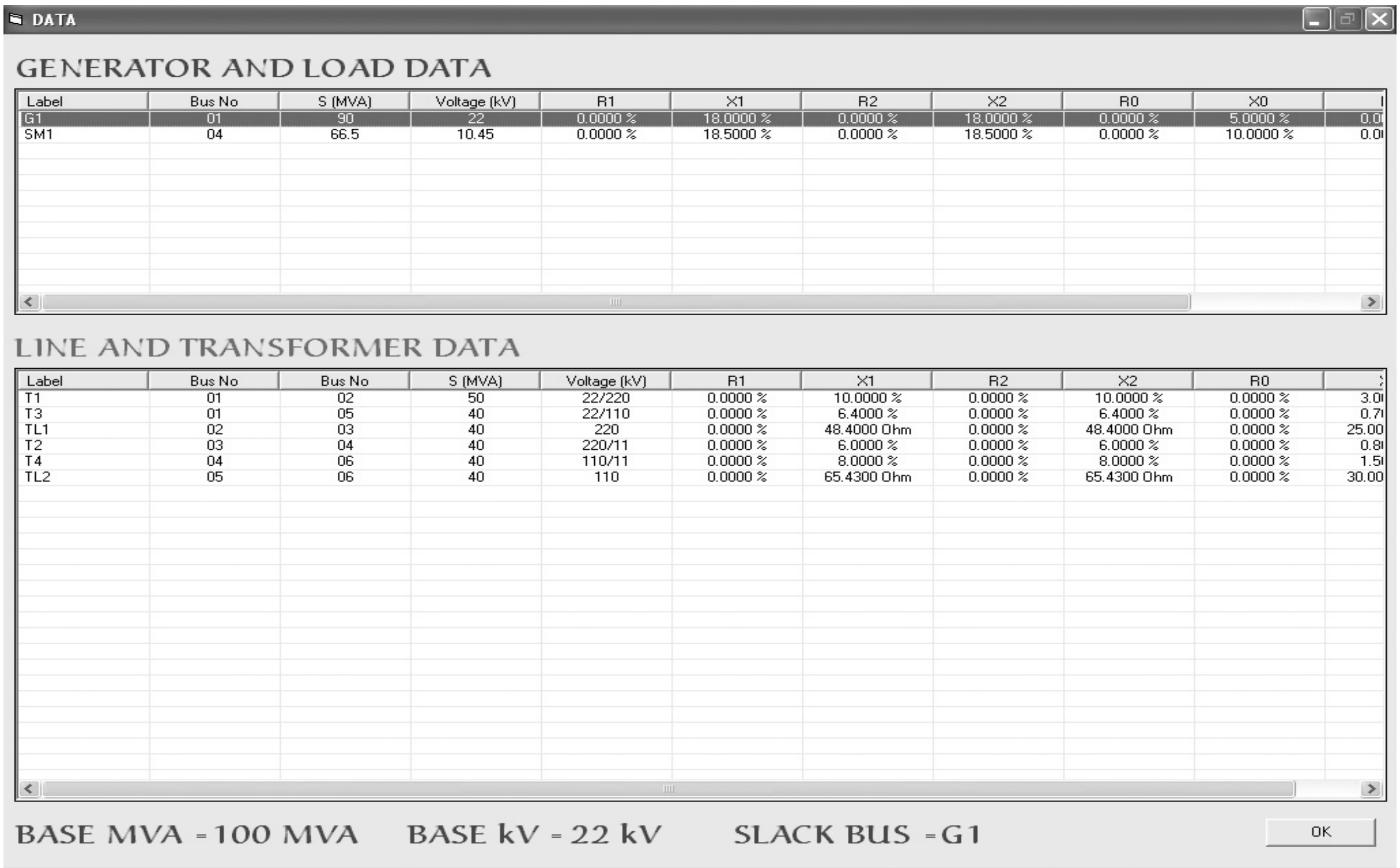


Figure 6: Example of an 11-bus single-line diagram



DATA

GENERATOR AND LOAD DATA

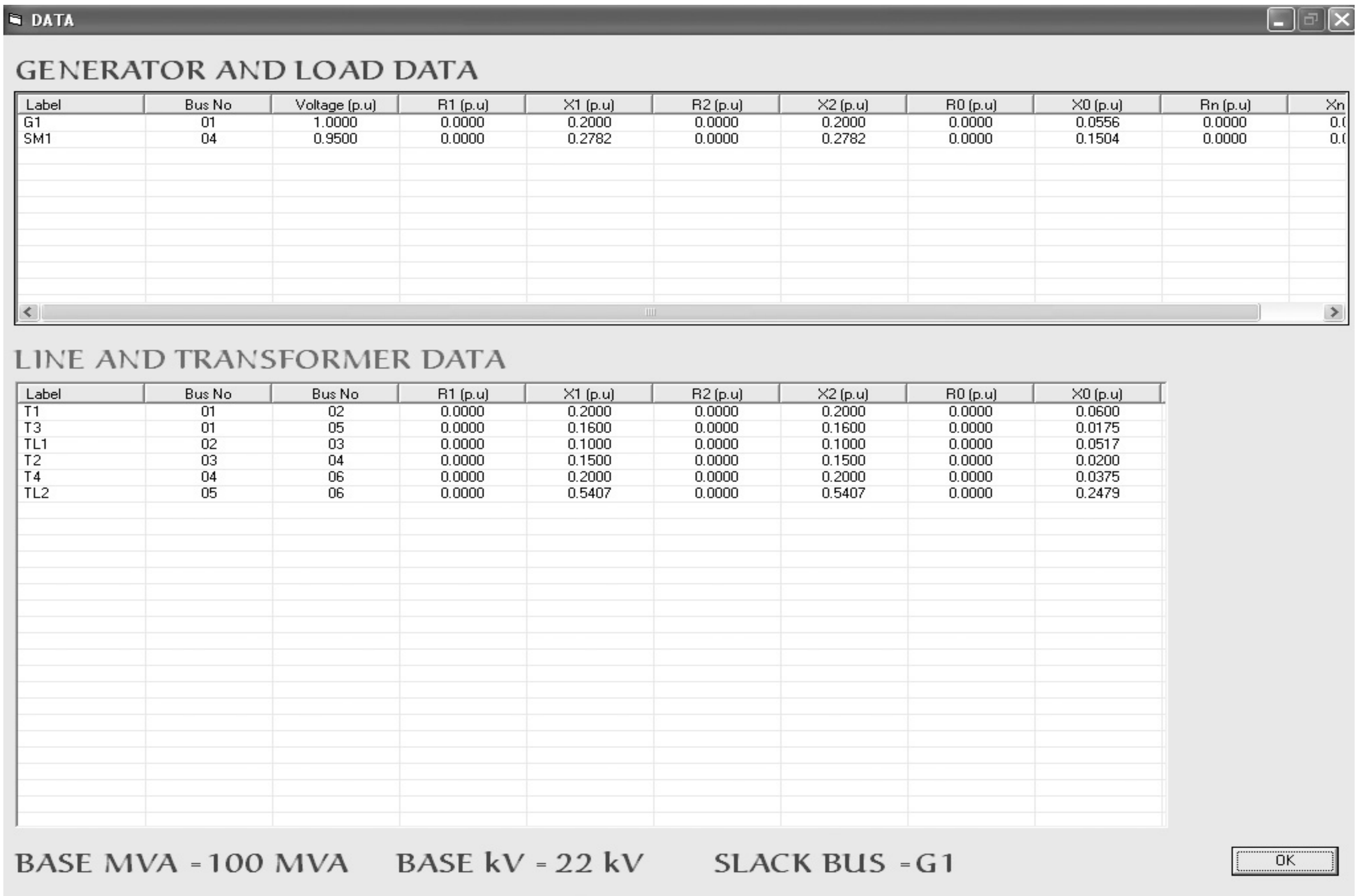
Label	Bus No	S (MVA)	Voltage (kV)	R1	X1	R2	X2	R0	X0	
G1	01	90	22	0.0000 %	18.0000 %	0.0000 %	18.0000 %	0.0000 %	5.0000 %	0.0
SM1	04	66.5	10.45	0.0000 %	18.5000 %	0.0000 %	18.5000 %	0.0000 %	10.0000 %	0.0

LINE AND TRANSFORMER DATA

Label	Bus No	Bus No	S (MVA)	Voltage (kV)	R1	X1	R2	X2	R0	
T1	01	02	50	22/220	0.0000 %	10.0000 %	0.0000 %	10.0000 %	0.0000 %	3.0
T3	01	05	40	22/110	0.0000 %	6.4000 %	0.0000 %	6.4000 %	0.0000 %	0.7
TL1	02	03	40	220	0.0000 %	48.4000 Ohm	0.0000 %	48.4000 Ohm	0.0000 %	25.00
T2	03	04	40	220/11	0.0000 %	6.0000 %	0.0000 %	6.0000 %	0.0000 %	0.8
T4	04	06	40	110/11	0.0000 %	8.0000 %	0.0000 %	8.0000 %	0.0000 %	1.5
TL2	05	06	40	110	0.0000 %	65.4300 Ohm	0.0000 %	65.4300 Ohm	0.0000 %	30.00

BASE MVA = 100 MVA   BASE kV = 22 kV   SLACK BUS = G1   OK

Figure 7: Input values for system of Figure 6



DATA

GENERATOR AND LOAD DATA

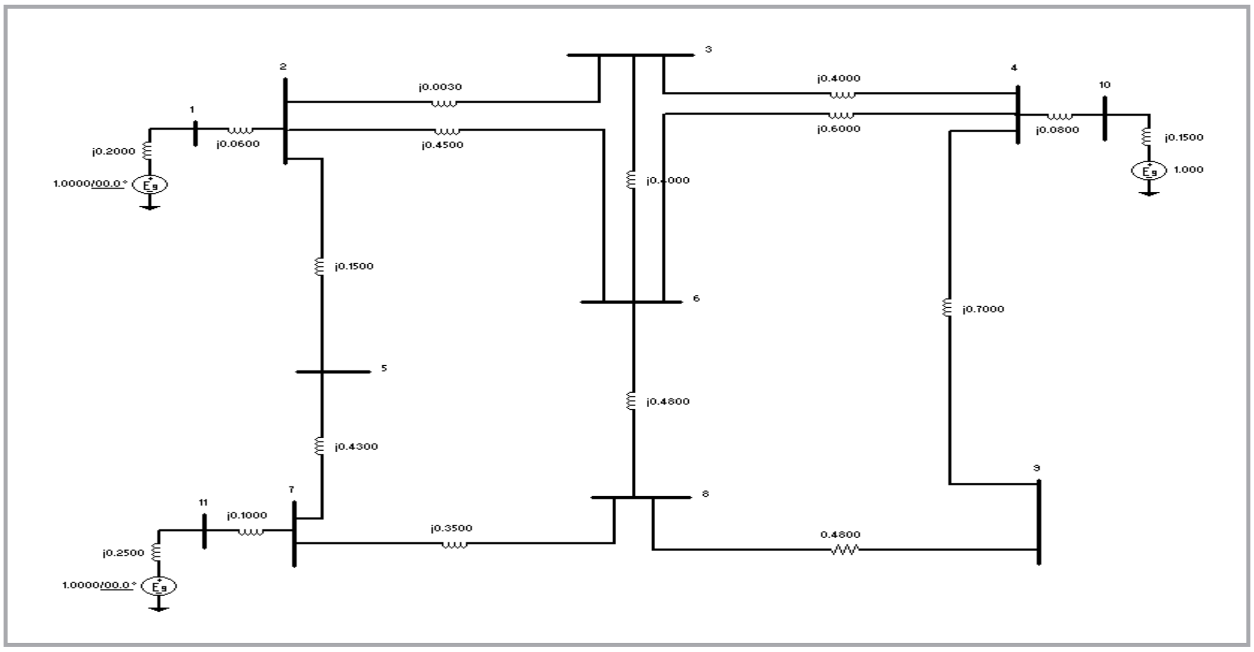
Label	Bus No	Voltage (p.u)	R1 (p.u)	X1 (p.u)	R2 (p.u)	X2 (p.u)	R0 (p.u)	X0 (p.u)	Rn (p.u)	Xn
G1	01	1.0000	0.0000	0.2000	0.0000	0.2000	0.0000	0.0556	0.0000	0.0
SM1	04	0.9500	0.0000	0.2782	0.0000	0.2782	0.0000	0.1504	0.0000	0.0

LINE AND TRANSFORMER DATA

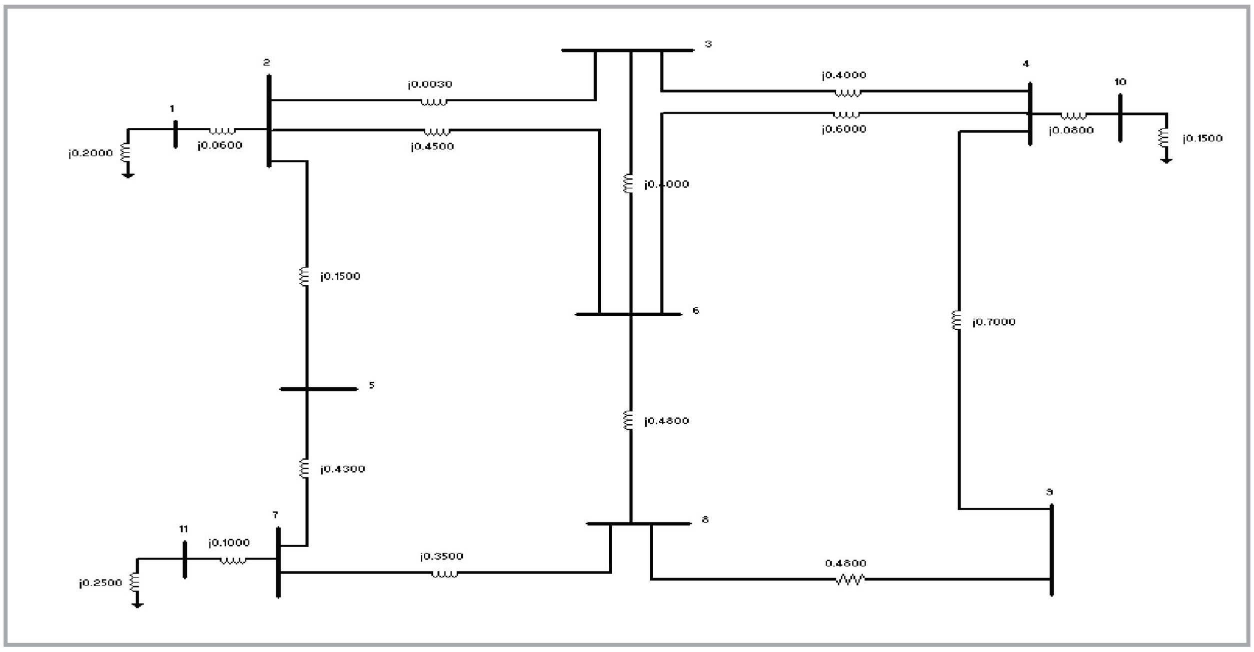
Label	Bus No	Bus No	R1 (p.u)	X1 (p.u)	R2 (p.u)	X2 (p.u)	R0 (p.u)	X0 (p.u)
T1	01	02	0.0000	0.2000	0.0000	0.2000	0.0000	0.0600
T3	01	05	0.0000	0.1600	0.0000	0.1600	0.0000	0.0175
TL1	02	03	0.0000	0.1000	0.0000	0.1000	0.0000	0.0517
T2	03	04	0.0000	0.1500	0.0000	0.1500	0.0000	0.0200
T4	04	06	0.0000	0.2000	0.0000	0.2000	0.0000	0.0375
TL2	05	06	0.0000	0.5407	0.0000	0.5407	0.0000	0.2479

BASE MVA = 100 MVA   BASE kV = 22 kV   SLACK BUS = G1   OK

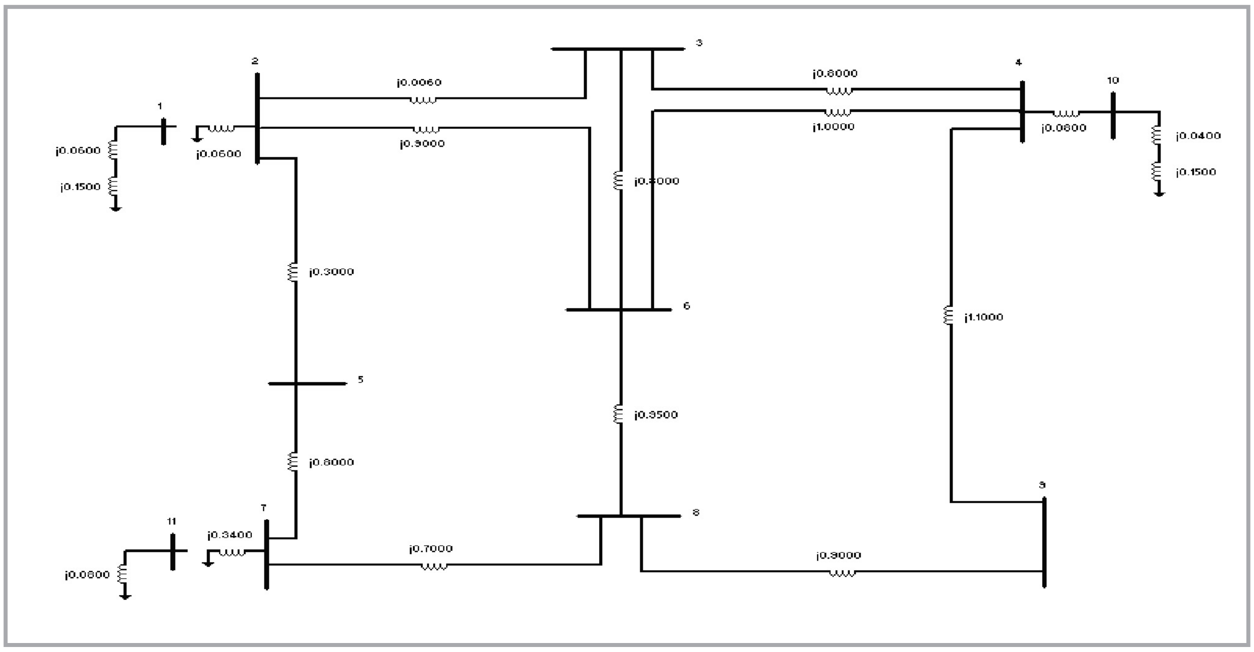
Figure 8: Input values in per-unit for system of Figure 6



9a) Positive-sequence diagram for system of Figure 6



9b) Positive-sequence diagram for system of Figure 6



9c) Zero-sequence diagram for system of Figure 6

3.0 SOFTWARE DEVELOPMENT TOOL

A Windows based Graphical User Interface (GUI) software tool was developed to facilitate the teaching and learning of power system. This software is written in Microsoft Visual Basic 6.0 (VB) which is known as one of the best Windows programming tools because of its' coding environment. Hence, VB can be used to develop many Windows based applications from the simplest to the complicated ones.

The main advantage of VB is the combination between graphical visual programming and code programming. That is to say, the visual description of the application can be seen on the development and design process. Therefore, the application criteria such as size, color, interface and position of each component can be decided before the coding is created. The programmer can also use standard built-in functions or can make a little modification of these functions depending upon the applications; this makes VB a choice to create high quality and professional applications. Besides, VB is easy to learn and more fun rather than using other programming language either FOTRAN or C++.

4.0 IMPLEMENTATION OF SOFTWARE

In generally, this software can be divided into few main parts or steps that user must follow to complete the analysis of power system. The first part is to draw a *single-line* diagram. With interactive GUI, user can draw corresponding *single-line* diagram by selecting the graphical menu that represent the common power system symbols. User can choose graphical menus using *mouse* and then place it at the white canvas to create a complete *single-line* diagram. The value of component such as voltage and impedance can be entered after user placed the selected component on canvas and this value can be changed from time to time. Figure 6 shows the example of *single-line* diagram created by this software. User can also review all the input value by selecting menu Data>Input value (Enter Value). This facility will help user to do a double-checking all the input data. The input data for example in Figure 6 was shown in Figure 7. Rather than that, user can also view the corresponding per-unit value by accessing menu Data<Input Value (Conversion Value). This per-unit value calculated based on the user input based MVA and based voltage. Figure 8 shows the per-unit value for example in Figure 6.

The second part is to view the corresponding sequence network. Figure 9 shows the sequences impedance diagram with respective per-unit value that had been obtained from the *single-line* diagram drawn in Figure 6. This diagram can be viewed when user clicks on the "Positive Sequence" tab to view positive- sequence diagram or "Negative Sequence" tab to view negative- sequence diagram or "Zero Sequence" tab to view zero- sequence diagram and only one sequence impedances diagram can be viewed at a certain time. The "Main View" tab can be used to show the original *single-line* diagram.

5.0 CONCLUSION

A Windows based graphical form to facilitate the learning of power system analysis was presented in this paper. This package is written in Microsoft Visual Basic 6.0. This software provides a user-friendly environment and easy to use tool to aid students for better visualising on power system analysis. This tool has three main modules: 1. A user designed single-line diagram, 2. Automatic or manual per-unit conversion, and 3. Displaying the corresponding positive-, negative and zero- sequence diagrams. Using this tool, the students can easily view the individual sequence diagrams and observe the effect of the winding configurations on the zero-sequence network.

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ABSTRACT

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