BUS IMPEDANCE MATRIX COMPUTATION USING ELECTRICAL ENTITIES

Akhmad Toyib Raharjo
Electrical Engineering Department, Hasanuddin University
Jl. Perintis Kemerdekaan km. 10 Makassar, toyib_raharjo@yahoo.com

1. Introduction

Entities are the people, goods, things, event, and concept whose data are recorded. In an electrical system, entities may consist of generators, transformers, buses, line transmissions. Nevertheless, some times an entity can represent an electric load.

In some cases, people separate the electrical problem solving and the adminitration problem solving. The result of an electrical solving is usually printed-out. Its report may be forwarded to the decision makers without a direct connection (off-line method) through the computer network since no linking between engineering's software and administrative's software. To address this difficulty, a solution method using computer's software is required. A database using entity is one of the solution. This paper covers the technical approach on developing the database system which applicable on the electrical problem solving.

There are several approximations taken into account to simplify the complexity of the designed database system. For instance, the bus impedance matrix can be used in short circuit study to determine the short circuit power. The aim to be achieved is find the capacity of circuit breaker should be installed.
.

2. Entities in a simple electric system.

The following figure illustrate a simple electrical system which consisted of two generators, three transformers, three buses, and three transmission lines. The assumption that Bus #3 supplies an electric load to the entire system, is applied.

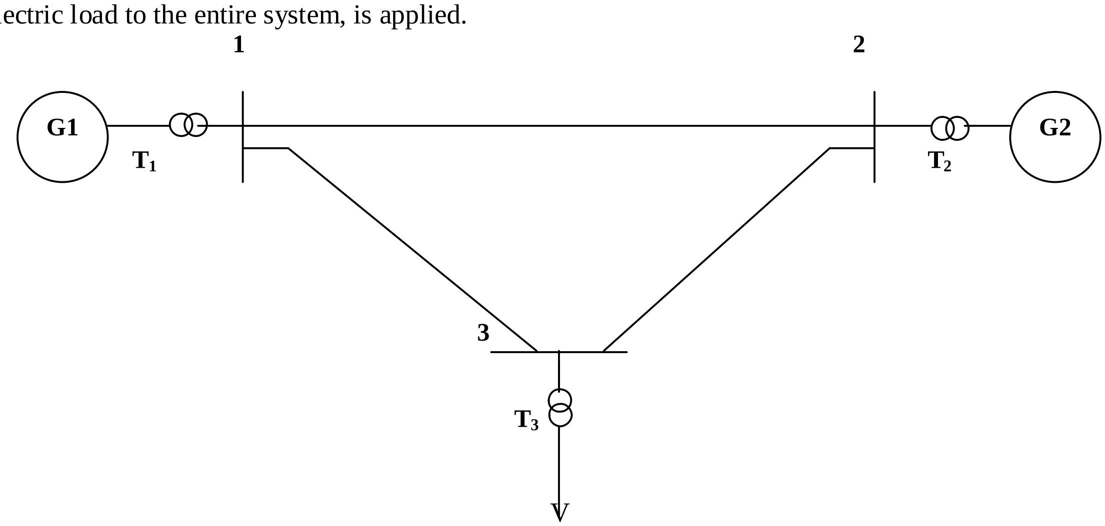

Fig. 1 A Simple Electric System

In the simple circuit as shown on Figure 3 there are some entities described. These are including the generators (G1 and G2), the transformers (T1, T2 and T3), three network lines (line 1-2, line 1-3 and line 2-3), the buses (1,2,3). The load in bus #3 sometime can be defined as an entity (in load flow study) but sometimes it is not necessary (in short circuit sudy).

In practical, each entity has one or more tuples. These are the elements in one connnection that inform the entity completely. As for example, an entity of one generator may consist some tuples i.e : 1) the place of the generator (depend on the bus where it is positioned), 2) group of the generator) 3) parallel path of the generator, 4) working voltage of the generator, 5) active power of the generator, 6) subtransient reactance of the generator, 7) positive sequence reactance, 8) zero sequence reactance, 9) activity of the generator (for example: the activity is equal 1 means active, 0 means not active), 10) year when the generator is bought, 11) technical year of the the generator. The last two tuples are connected with the administrative‘s need. Of course, people may increase the amount of the tuples depending on his or her need. Each of the entity such as the transformer, bus, and transmission line has some tuples, respectively.

3. Key of entity and computer’s software required

Each of the tupple can be stated as **key**. This key can represent the entity for connecting with other entities. This key can be discussed furthermore in another part in this paper.

Before we discuss about an entity in advance, we may discuss about computer’s software that can be used to solve the electric problem. Due to the limited knowledge of the author on searching the information of some softwares traded in the computer market, especially in Indonesia, there are only two softwares that can be operated for the computation of the **complex number** i.e : FORTRAN (Formula Translation) and Matlab (Matrix Laboratory). Both has a number of the disanvantages. For instance, FORTRAN has no ability to provide diagrams, to create the key(s) in alphabetic, meanwhile Matlab has the drawback in filing an operation and even it has no ability to create the key(s). However, one filing system can be created to connect one to another file using key(s) consists of integer number : 1, 2, 3, etc. The file is Direct File, which can be operated with its **record number** as key.

4. Creating the entities and its tuples in an electric system

Before we creat the entities, we should consider that some power plant usually have some generators and transformers. The created generators must have an identical characteristic, then they must be grouped as a unite element. This process results what we called a **group.** Within the group, every generator is numbered as member of **parallel path.** The application of these terms in the diagram of a power plant are shown in Figure 2.

If the number of the bus is 4, the second generator in group 1 has place number 4, 1, 2. Where 4 is the number of the bus, 1 is the number of the group and 2 is the number of its parallel path. The place number can be a record key. The transformers have similar place number with the generators. However, when some generators in one group have only one transformer, we change it for a while, by using one generator with one transformer that has lower capacity. For example, let us assume four generators with capacity 5 MVA respectively, in one group, use one transformer together with 20 MVA capacity, we can change to four generators connected with 5 MVA transformer respectively. Through this assumption the entities that can be built in an electrical system together with their tuples are illustrated in Figure 3.

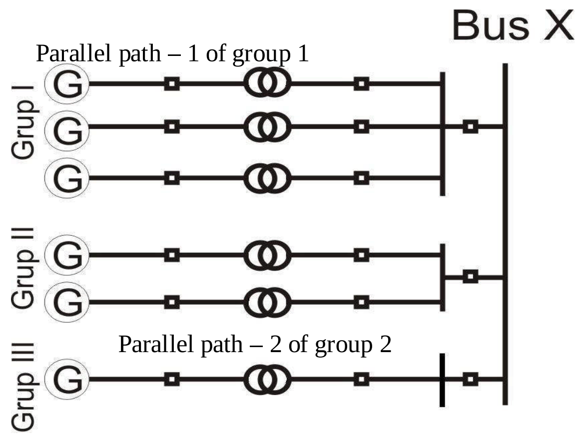

Fig. 2 Group and parallel path in a power plant`

GENERATOR
PLG: place of generator
GRG:group of generator
PPG:parallel path of gen.
VG:voltage of generator
PG:power of generator
XSUBG: Xsubtransient of gen.
X1G: Reactance pos. Of gen.
X0G: Zero reactance of gen.
ACG: Activity of generator
YG:year when it is bought
TYG:technical year of gen.

TRANSFORMER
PLT: place of transformer
GRT: group of transformer
PPT: parallel path of transf.
HVT:high voltage of transf.
LVT:low voltage of transf.
PT:power of transf.
X1T: Positive react. of transf.
X0T: Zero react. of transf.
ACT:activity of tansformer
YT: year when it is bought
TYT: technical year of transf.
VGT:vector group of transf.

BUS
NRB: Number of bus
ABB: abbreviation name
TB:type of bus, gen.or load
FNB:full name of bus
APB:active power of bus
RPB:reactive power of bus
ACB: activity of bus
VB: voltage of bus

LINE
NRL: number of line
BTB: from bus to bus
ACL: activity of line
CL: circuit of line (1 or 2)
LL: length of line
Z1L2: pos. imped. (2 lines-Ω)
Z0L2: zero imped. (2 lines- Ω)
Z1L1:pos.imped. (1 line - Ω)
Z0L1:.zero imped.(1 line - Ω)
VL: Line voltage

Fig. 3 Entity tables in a power system

However, in database study, sometimes we need to produce other entities, called : **transaction entity** which is a connection between two or more entities. The entities discussed previously called: **main entities** and it always have **keys.** For example, GENERATOR entity has key: PLG, TRANSFORMER entity has key: PLT, BUS entity has key: NRB and LINE entity has key: NRL. The transaction entity will be used in other parts in this paper.

In connection with FORTRAN programming application, an **entity** can represent the **file** and the **tuples** can represent **fields**. Thus, to find a bus impedance matrix, the connection amongts the files and the programs can be seen in table below.

Table 1. Programs, their purpose, input and output

Nr	Program's name	Goal of Programing	Input	Output
1	INGEN01.FOR	Inputting data of generators in system	Written data of generators	FGEN
2	RUGEN02.FOR	Updating generator's data	FGEN	FGEN (updated)
3	INTRA03.FOR	Inputting data of transformers in system	Written data of transformers	FTRAF
4	RUTRAF04.FOR	Updating transformer's data	FTRAF	FTRAF(updated)
5	INBUS05.FOR	Inputting data of buses in system	Written data of buses	FBUS
6	RUBUS06.FOR	Updating buses' data	FBUS	FBUS (updated)
7	INLIN07.FOR	Inputting data of linees in system	Written data of lines	FLIN
8	RULIN08.FOR	Updating lines' data	FLIN	FLIN (updated)
9	PZNN09.FOR	A proses to get impedance between bus and its reference bus	FGEN FTRAF FBUS	ZNN
10	PDAYA10.FOR	Creating Power's file	FBUS	ZDAYA
11	PZ11.FOR	Processing fikes for getting Bus Impedance Matrix	FLIN ZNN	ZHS (for Short Circuit Study) ZSAB (for Load Flow Study)
12	PHS12.FOR	To get CB's capacity	ZHS	HS.DOC etc

Note: Former letter F means file
Former letter Z means impedance
Former letter P means process
Number 01, 02, ... means sequence of programs use
The most difficult program to create is PZNN09.for, since it uses some matrices and its computation procedure is not too easy

Usually, the entities are recorded in computer system as **files,** and it is named nearly similar with the entities for example the entity of generator will be named FGEN etc.

A database relationship are not the same with **system flowchart,** because the relationship shows only relations among the entities. It is not important to show input nor output to and from program. System Flowchart is a flowchart that shows file(s) as input or output include written data, process (progam), the output required and what kind of accesories used.

A system flowchart is not the same with **program flowchart**. Where the last mentioned show how the data are processed in a program and what the output needed as well. It is included the file(s) as data and file(s) as output. Printer, for example, in the program, is known as a file. So, Video Display Unit (screen), and others pheriperal both input or output, such as input-ouput pheriperal to record(s) and to read file(s) such as disk, floppy disk, and flash disk.

Then, we try to get a database relationship amongts the entities, for instance, generator (GEN), transformer (TRANSF), bus (BUS) and tansmission line (LINE), to get Bus ImpedanceMatrix that will be used for the short circuit study. It is not too clear how data are processed, however it is important to get what tupples needed in every entity. The database relationship can be clearly understood by analysing the process diagram and the system flowchart to compute the bus impedance matrix. These are outlined in Figures 4 and 5, respectively.

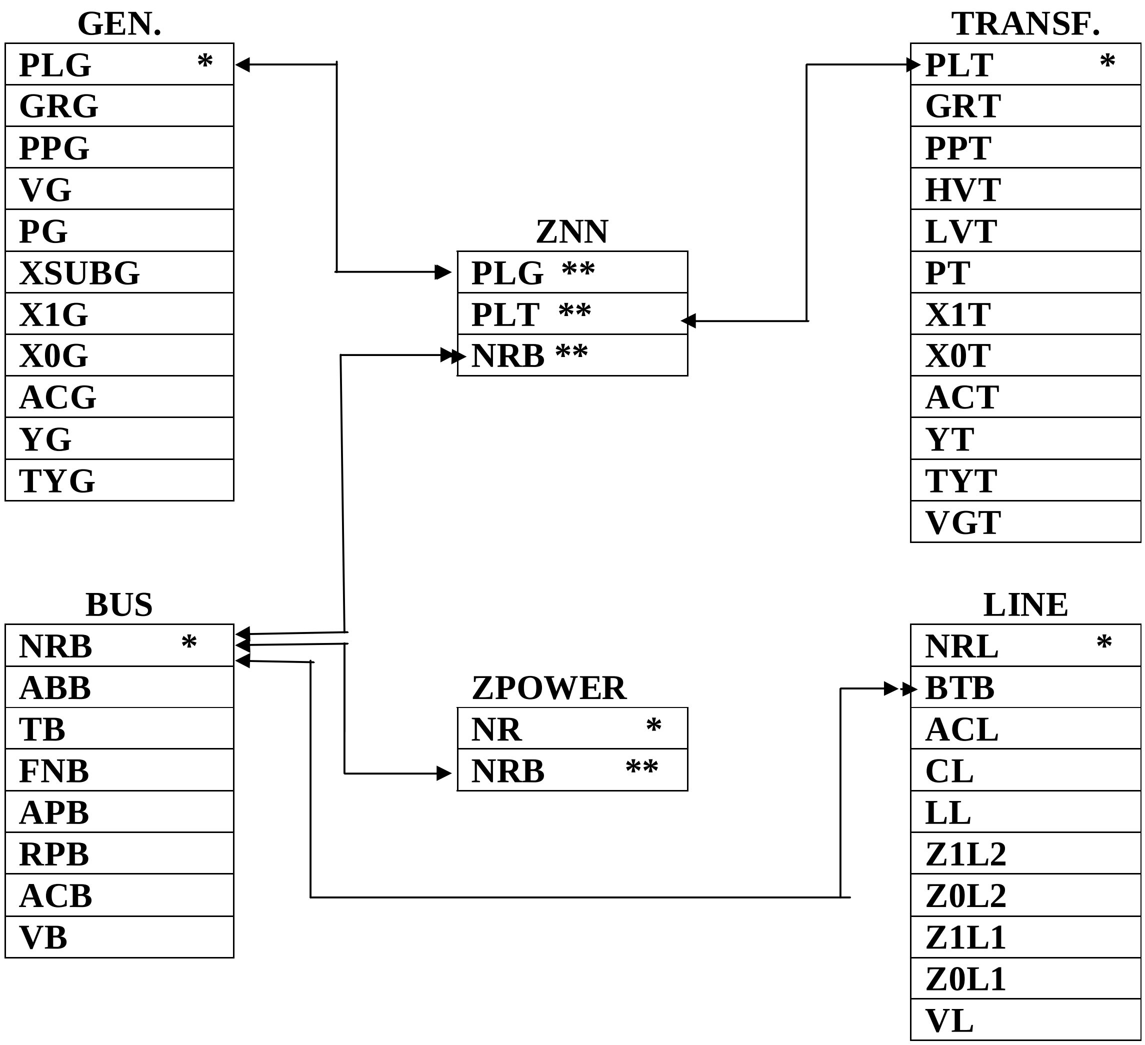

Fig. 4 Database relationship to obtain the bus impedance matrix

Note : * = main key
** = foreign key
⟷ = one to one relationship
⟷⟫ = one to many relationship

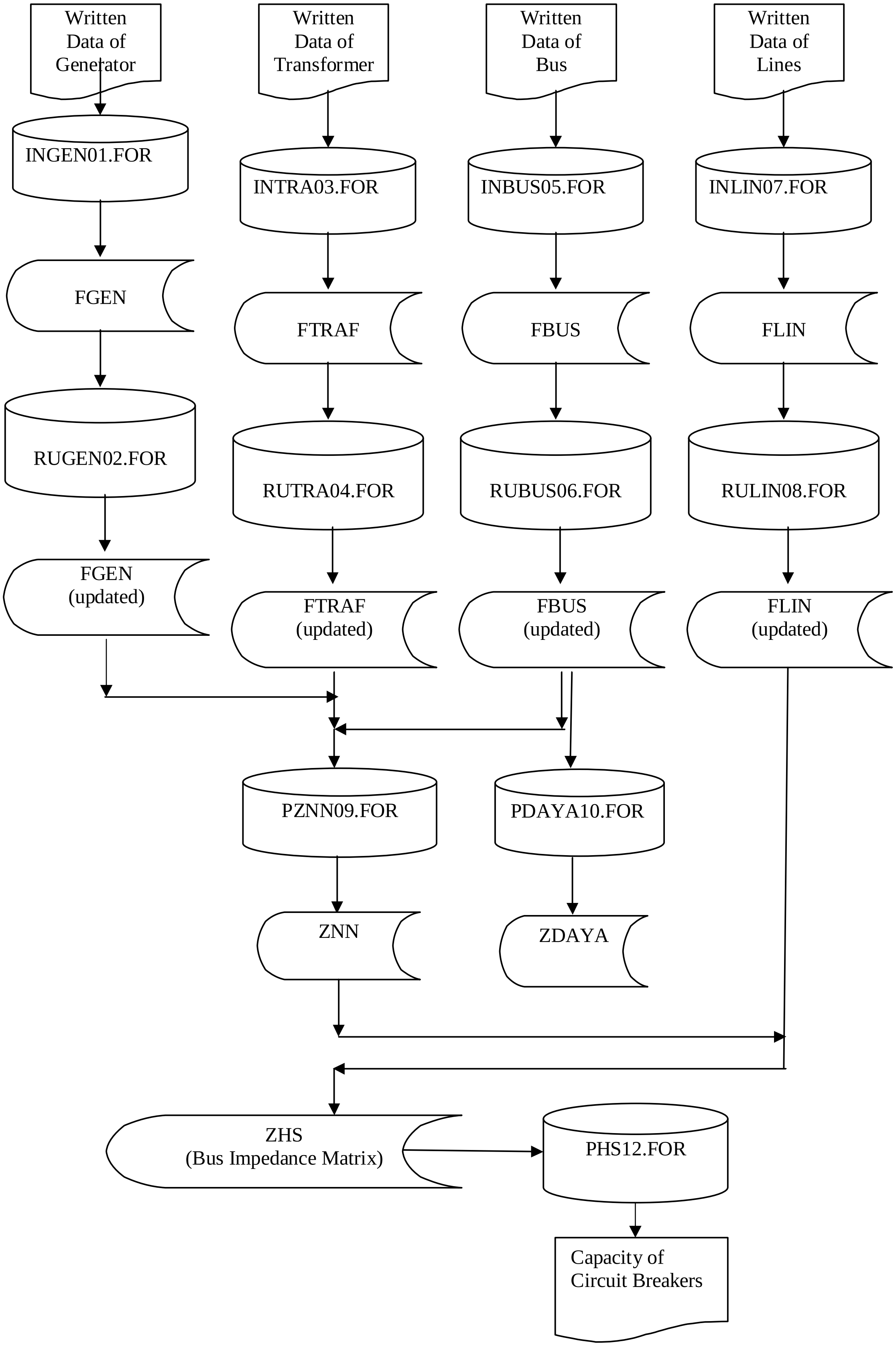

Fig. 5: The system flowchart to compute the bus impedance matrix

5. The application of the bus impedance matrix for the calculation of the circuit breaker's capacity

The following tutorials we are going to use the bus impedance obtained in short circuit calculation. For the case study we can utilise the South Sulawesi Electrical System. In reality, the system has 43 buses as descriptively tabulated in Table 2.

Table 2. The data of the bus in Sulawesi Selatan Electrical System

Nr	Abb	gen/ load	Nama of Power Plant	Nr	Abb	gen/ load	Nama of Power Plant
1	SKANG	1	SENGKANG	23	BLKMB	2	BULUKUMBA
2	BKARU	1	BAKARU	24	JNPTO	2	JENEPONTO
3	TLO15	1	TELLO 150 KV	25	MJENE	2	MAJENE
4	TLLO3	1	TELLO 30	26	SNJAI	2	SINJAI
5	SUPPA	1	SUPPA	27	MKALE	2	MAKALE
6	TLLO7	1	TELLO 70	28	SIWA	2	SIWA
7	BILI2	1	BILI-BILI	29	TIP57	2	TP 57/58
8	TLO34	1	TELLO 34.5	30	WOTU	2	WOTU
9	PLOPO	1	PALOPO	31	MLILI	2	MALILI
10	MALEA	1	MALEA	32	TLLSA	2	TALLASA
11	MMUJU	1	MAMUJU	33	DAYA	2	DAYA
12	PRANG	1	PINRANG	34	SGMSA	2	SUNGGUMINASA
13	PLTUJ	1	PLTU JENEPONTO	35	TBNGA	2	TANJUNG BUNGA
14	BARRU	2	BARRU	36	SPENG	2	SOPPENG
15	BWAJA	2	BARAWAJA	37	BONE	2	BONE
16	BRLOE	2	BORONGLOE	38	MNDAI	2	MANDAI
17	MAROS	2	MAROS	39	TAMA7	2	TELLO LAMA 70
18	PPARE	2	PARE-PARE	40	TLAMA	2	TELLO LAMA
19	PWALI	2	POLEWALI	41	PKANG	2	PANAKUKANG
20	BSOWA	2	BOSOWA	42	PNKEP	2	PANGKEP
21	TNASA	2	TONASA	43	BNTLA	2	BONTOALA
22	SDRAP	2	SIDRAP				

Suppose, we have found the data in generator's file (FGEN), transformer's file (FTRAF), bus'file (FBUS) and transmission line's file (FLIN) and have been updated, where both are **entities** in the system. By utilising some programs that are shown in the System Flowchart outlined previously, we found file named ZHS as a result of the data operation: FLIN and ZNN and the program called PZ11.FOR. Finally, by using a short circuit program called PHS12.FOR, and for intance there is short circuit in the biggest power plant: Sengkang, we will obtain the results as shown in Table 3.

Table 3. The circuit breaker's capacity as the fault occured in Sengkang (the biggest power plant) in South Sulawesi Electric System. The location of the short circuit is in the bus of Sengkang.

Nr.	**From Bus**	**T o Bus**	**CB Capacity (MVA)**
1	Reference	Sengkang	568.182
2	Siwa	Sengkang	165.592
3	Soppeng	Sengkang	363.439

6. Conclusions

Entities in electrical power system can be a generator, transformer, bus and transmission line. The technical perspective on developing the database system to be applied on the calculation of the bus impedance matrics offered in this paper is useful on the determination of the capacity of circuit breaker to be installed in case the short circuit study.

Despite the many disadvantages belongs to the software program available in the market, FORTRAN is an adequate software that can be used to overcome the difficulties on the computation of the electrical program using entities, by using direct files, with the record number are the main key that show the place of entities. Bus Impedance Matrix can be found to gobtain the CB's capacity using the short circuit calculation based on the entities. Since PLN prepares all the CB's in the capacity 2500 MVA, when three phase short circuit occurs, the system is safety to open circuits.

7. References

[1] Stevenson, W.D, and John J. Grainger, "Power System Analysis", 2nd edition, Mc Graw Hill International Edition, Singapore, pp 470-590, 2000

[2] Stevenson W.D,. "Analisis Sistem Tenaga" , 6th-edition. Erlangga (translation), pp 235-315, 1999

[3] Microsot,"Fortran 5.1 Version", 5th edition, Microsot Inc. New York, 1999

[4] Microsoft Theosophy, Vol 42, No. 10, Microsoft, New York, pp 464-469, 1954

[5] Beaty M., H. Wayne, *Handbook of Electric Power Calculation,*, Mc. Graw Hill, New York, 1998.

[6] Fathansyah, "Buku Teks Ilmu Komputer *: Basis Data" , Informatika Bandung,pp1-50, 2004*

[7] *Gonen, Turan,* "Electrical Power Transmission System Engineering Analysis and Design",, John Wily & Sons, New York,pp 231-235, 1991

[8] Greenwood, Allan, "Electrical Transient in Power Systems", John Wilwy & Sons, New York, pp 3422-255,1991

[9] Hanseman, D and Bruce Littlefield, "MATLAB Bahasa Komputasi Teknis", translation, Penerbit Andi Jogyakarta,*pp. 1-250,* 2002

[10]Kadir, Abdul,"Konsep dan Tuntunan Praktis Basis Data", Penerbit Andi, Jogyakarta, pp 1-67,2001

[11]Saadat, Hadi, ."Power System Analysis", Mc Graw Hill, pp 40-90, printed in Singapore, 1999.

[12]Stagg and El Abiad, "Computer Methods in Power System Analysis", International Student Edition,printed in Singapore ,pp 37 – 52, 1990.