Diyala Journal of Engineering Sciences

ISSN 1999-8716
Printed in Iraq

Second Engineering Scientific Conference
College of Engineering –University of Diyala
16-17 December. 2015, pp. 343-354

SHORT CIRCUIT ANALYSIS FOR POWER SYSTEM NETWORKS

AHMED MAJEED GHADBAN [1], Mohamed Waleed Abdulwahhab [2]
[1, 2] Assistant lecturer, College of Engineering, Electrical Power & Machines Department
Asm725@yahoo.com [1], mz d1984@mail.ru [2]

ABSTRACT:- In this paper analysis to electrical power network design under applying many types of a short circuit on lines and buses. In order to maintain the continuation of power supply to all customers which is the core purpose of the power system existence, Short circuit problem is one of the most important and complex task in electrical Power Engineering. The studies and detection of these faults is necessary to ensure that the power system is reliable and stable. The severity of the fault depends on the short-circuit location, and the path taken by fault current, the system impedance and its voltage level. In This paper analyzes the behavior of a system under fault conditions and evaluates different types of faults. Power world simulator was used to simulate IEEE30- bus. All results achieved and discussed.

1- INTRODUCTION

During normal operating conditions, current will flow through all elements of the electrical power system with in pre-designed values which are appropriate to these elements' ratings. Any power system can be analyzed by calculating the system voltages & currents under normal & abnormal scenarios [1]. Unfortunately, faults could happen as a result of natural events or accidents where the phase will establish a connection with another phase, the ground or both in some cases[2]. A falling tree on a transmission lines could cause a three-phase fault where all phases share a point of contact called fault location. In different occasions, fault could be a result of insulation deterioration, wind damage or human vandalism.

Faults can be defined as the flow of a massive current through an improper path which could cause enormous equipment damage which will lead to interruption of power, personal injury, or death. In addition, the voltage level will alternate which can affect the equipment insulation in case of an increase or could cause a failure of equipment start-up if the voltage is below a minimum level. As a result, the electrical potential difference of the system neutral will increase [1].Hence, People and equipment will be exposed to the danger of electricity which is not accepted. In order to prevent such an event, power system fault analysis was introduced.

The process of evaluating the system voltages and currents under various types of short circuits is called fault analysis which can determine the necessary safety measures & the required protection system [2]. It is essential to guarantee the safety of public [3]. The analysis of faults leads to appropriate protection settings which can be computed in order to select suitable fuse, circuit breaker size and type of relay [1]. The severity of the fault depends on the short-circuit location, the path taken by fault current, the system impedance and its voltage level. In order to maintain the continuation of power supply to all customers which is the core purpose of the power system existence, all faulted parts must be isolated from the system temporary by the protection schemes. When a fault exists within the relay protection zone at any transmission line, a signal will trip or open the circuit breaker isolating the faulted line.

To complete this task successfully, fault analysis has to be conducted in every location assuming several fault conditions. The goal is to determine the optimum protection scheme by determining the fault currents & voltages. In reality, power system can consist of thousands of buses which complicate the task of calculating these parameters without the use of computer software.

There are two types of faults which can occur on any transmission lines; balanced faults & unbalanced faults. In addition, unbalanced faults can be classified into single line-to-ground faults, double line faults and double line-to-ground faults. In this peppier will calculate the fault by using power word program in all types of the fault.

In this paper all types of fault cases was considered, power world simulator was used to accomplish this work.

2- DESIGN AND POWER WORLD SIMULATION

IEEE 30 bus base case load flow was setup using Power World simulator. Figure 1 shows the setup in Power World in Edit Mode and Figure 2 shows the setup in Power World software in Run Mode

3-Results and Discussion

This discussion done for all types of fault listed earlier. Then, the comments and recommendations will be provided based on that. When using power word program we can calculate the current fault in all types of fault

I. Single Line-to-Ground Fault

The single line-to-ground fault is usually referred as “short circuit” fault and occurs when one conductor falls to ground or makes contact with the neutral wire. The general representation of a single line-to-ground fault is shown in Figure 3. Where **F** is the fault point with impedances Zf. Figure 4 shows the sequences network diagram. Phase a is usually assumed to be the faulted phase, this is for simplicity in the fault analysis calculations (1) .

Since the zero-, positive-, and negative-sequence currents are equals as it can be observed in Figure 4. Therefore,

$$I_{a0} = I_{a1} = I_{a2} = \frac{1.0\angle 0^\circ}{Z_0 + Z_1 + Z_2 + 3Z_f} \qquad \text{……………………………………..1}$$

Since

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \qquad \text{…………………………………….2}$$

Solving Equation the fault current for phase a is

$$I_{af} = I_{a0} + I_{a1} + I_{a2} \qquad \text{…………………………………..3}$$

It can also be

$$I_{af} = 3I_{a0} = 3I_{a1} = 3I_{a2} \qquad \text{………………………………..4}$$

From Figure 3it can be observed that,

$$V_{af} = Z_f I_{af} \qquad \text{……………………………5}$$

The voltage at faulted phase a can be obtained by substituting Equation 2 into Equation 5. Therefore,

$$V_{af} = 3Z_f I_{a1} \quad \ldots\ldots 6$$

$$I_{af}=I_{a0}+I_{a1}+I_{a2} \quad \ldots\ldots 7$$

$$I_{af}=3I_{a0}=3I_{a1}=3I_{a2} \quad \ldots\ldots 8$$

$$V_{af}=Z_f I_{af} \quad \ldots\ldots 9$$

$$\begin{aligned} V_{a0} &= -Z_0 I_{a0} \\ V_{a1} &= 1.0 - Z_1 I_{a1} \\ V_{a2} &= -Z_2 I_{a2} \end{aligned} \quad \ldots\ldots 10$$

$$\begin{aligned} V_{bf} &= V_{a0} + a^2 V_{a1} + a V_{a2} \\ V_{cf} &= V_{a0} + a V_{a1} + a^2 V_{a2} \end{aligned} \quad \ldots\ldots 11$$

Figure 5 show power world simulators to calculate fault current the type single line to ground.

I. Line-to-Line Fault

Line to line fault the figure 2 show the magnitude of current in per unit when we selected the bus number 23 and the voltage under fault condition in phase B & C it lower than all phases.

The general representation of a line-to-line fault is shown in Figure 3.12 where F is the fault point with impedances Zf. Figure 6 shows the sequences network diagram. Phase b and c are usually assumed to be the faulted phases; this is for simplicity in the fault analysis calculations

From Figure 7 it can be noticed that

$$\begin{aligned} I_{af} &= 0 \\ I_{bf} &= -I_{cf} \\ V_{bc} &= Z_f I_{bf} \end{aligned} \quad \ldots\ldots 12$$

And the sequence currents can be obtained as

$$I_{a0} = 0$$

$$I_{a1} = -I_{a2} = \frac{1.0\angle 0^\circ}{Z_1 + Z_2 + Z_f} \quad \ldots\ldots 13$$

If $Z_f = 0$, ……14

$$I_{a1} = -I_{a2} = \frac{1.0\angle 0^\circ}{Z_1 + Z_2}$$

With the results obtained for sequence currents, the sequence voltages can be obtained from

$$\begin{bmatrix} V_{a0} \\ V_{b1} \\ V_{c2} \end{bmatrix} = \begin{bmatrix} 0 \\ 1.0\angle 0^\circ \\ 0 \end{bmatrix} - \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \qquad \text{………………………………15}$$

The sequence voltages can be found similarly by substituting Equations 13 and 14 into Equation 14

$$V_{a0} = 0$$
$$V_{a1} = 1.0 - Z_1 I_{a1}$$
$$V_{a2} = -Z_2 I_{a2} = Z_2 I_{a1} \qquad \text{…………………………………16}$$

Finally, the line-to-line voltages for a line-to-line fault can be expressed as

$$V_{af} = V_{a1} + V_{a2} = 1.0 + I_{a1}(Z_2 - Z_1)$$
$$V_{bf} = a^2 V_{a1} + a V_{a2} = a^2 + I_{a1}(aZ_2 - a^2 Z_1)$$
$$V_{cf} = a V_{a1} + a^2 V_{a2} = a + I_{a1}(a^2 Z_2 - aZ_1) \qquad \text{……………….17}$$

$$V_{ab} = V_{af} - V_{bf}$$
$$V_{bc} = V_{bf} - V_{cf}$$
$$V_{ca} = V_{cf} - V_{af} \qquad \text{………………………………18}$$

The figure 8 show using power world program to calculate current in the type fault line to line

I. Double Line-to-Ground Fault

Double line to ground fault figure 4 show the magnitude of current in per unit when we selected the bus number 23 and the voltage under fault condition in B & C is 0

The general representation of a double line-to-ground fault is shown in Figure 3.14 where F is the fault point with impedances Zf and the impedance from line to ground Zg. Figure 3.15 shows the sequences network diagram. Phase b and c are assumed to be the faulted phases, this is for simplicity in the fault analysis calculations. [1]

From Figure 10 it can be observed that

$$I_{af} = 0$$
$$V_{bf} = (Z_f + Z_g) I_{bf} + Z_g I_{cf}$$
$$V_{cf} = (Z_f + Z_g) I_{cf} + Z_g I_{bf} \qquad \text{…………………………………..19}$$

An alternative method is,

$$I_{af} = 0 = I_{a0} + I_{a1} + I_{a2}$$
$$I_{a0} = -(I_{a1} + I_{a2}) \qquad \text{………………………………..20}$$

If Zf and Zg are both equal to zero, then the positive-, negative-, and zero- sequences can be obtained from

$$I_{a1} = \frac{1.0\angle 0^{\circ}}{(Z_1) + \frac{(Z_2)(Z_0)}{(Z_2 + Z_0)}}$$

$$I_{a2} = -[\frac{(Z_0)}{(Z_2 + Z_0)}]I_{a1}$$

$$I_{a0} = -[\frac{(Z_2)}{(Z_2 + Z_0)}]I_{a1} \qquad \text{.......................................21}$$

From Figure 9 the current for phase a is

$$I_{af} = 0 \qquad \text{.......................................22}$$

Now, substituting Equations 21 into Equation 2 to obtain phase b and c fault currents

$$I_{bf} = I_{a0} + a^2 I_{a1} + aI_{a2}$$

$$I_{cf} = I_{a0} + aI_{a1} + a^2 I_{a2} \qquad \text{....................................23}$$

The total fault current flowing into the neutral is

$$I_n = 3I_{a0} = I_{bf} + I_{cf} \qquad \text{....................................24}$$

And the sequences voltages can be obtained by using Equation 15

$$V_{0a} = -Z_0 I_{a0}$$

$$V_{a1} = 1.0 - Z_1 I_{a1}$$

$$V_{a2} = -Z_2 I_{a2} \qquad \text{..................................25}$$

The phase voltages are equal to

$$V_{af} = V_{a0} + V_{a1} + V_{a2}$$

$$V_{bf} = V_{a0} + a^2 V_{a1} + aV_{a2}$$

$$V_{cf} = V_{a0} + aV_{a1} + a^2 V_{a2} \qquad \text{..............................26}$$

The line-to-line voltages can be obtained from

$$V_{ab} = V_{af} - V_{bf}$$

$$V_{bc} = V_{bf} - V_{cf}$$

$$V_{ca} = V_{cf} - V_{af} \qquad \text{..............................27}$$

The figure 11 show using power world program to calculate current in the type fault double line to ground.

II.Three-Phase Fault

Three phase balanced fault the figure 3 show the magnitude of current in per unit when we selected the bus number 23 and the voltage under fault condition in all phases is 0.A general representation of a balanced three-phase fault is shown in Figure 12 where F is the fault point with impedances Zf and Zg . Figure 13 shows the sequences networks interconnection diagram.

From Figure 13 it can be noticed that the only one that has an internal voltage source is the positive-sequence network. Therefore, the corresponding currents for each of the sequences can be expressed as

$$I_{a0} = 0$$
$$I_{a2} = 0$$
$$I_{a1} = \frac{1.0\angle 0^{\circ}}{Z_1 + Z_f} \qquad \text{……………………………28}$$

If the fault impedance Zf is zero,

$$I_{a1} = \frac{1.0\angle 0^{\circ}}{Z_1} \qquad \text{………………………..29}$$

If equation is substituted into equation

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ I_{a1} \\ 0 \end{bmatrix} \qquad \text{……………………………30}$$

Solving Equation 22

$$I_{af} = I_{a1} = \frac{1.0\angle 0^{\circ}}{Z_1 + Z_f},$$
$$I_{bf} = a^2 I_{a1} = \frac{1.0\angle 240^{\circ}}{Z_1 + Z_f},$$
$$I_{cf} = aI_{a1} = \frac{1.0\angle 120^{\circ}}{Z_1 + Z_f}. \qquad \text{…………………………31}$$

$$I_{af} = \frac{1.0\angle 0^{\circ}}{Z_1}$$
$$I_{bf} = \frac{1.0\angle 240^{\circ}}{Z_1},$$
$$I_{cf} = \frac{1.0\angle 120^{\circ}}{Z_1}$$

The phase voltages becomes,

$$V_{af} = 0$$
$$V_{bf} = 0 \qquad \text{………………………………………………………………33}$$
$$V_{cf} = 0$$

And the line voltages,

$$V_{a0} = 0$$
$$V_{a1} = 0 \qquad \text{……………………………………………34}$$
$$V_{a2} = 0$$

The figure 14 show using power world program to calculate current in the type fault three phase

4-CONCLUSIONS

In this paper, fault analysis was done for a 30 bus system where bus number twenty three was the main focus of this report. The following observations have been made based on the results obtained from the analysis:

- In three-phase fault, the voltages at faulted bus phases dropped to zero during the fault. The faulted bus is bus number four where Phase A, B and C has a zero voltage potential.
- However, only voltage at Phase A is equal to zero in single line-to-ground fault. In addition, only Phase A has current since it is the faulted phase in this type of fault as we assumed earlier in the mathematical model. This current is the second highest fault currents of all types.
- Since Phase B and Phase C are in contact in line-to-line fault, the voltages at both phases are equal. The fault current are passing from B to C. in Phase A, the current is equal to zero compared to the fault current.
- In double line-to-ground fault, Phase B and C voltages are equal to zero. The faulted current is flowing through both phases only. In addition, this type of

5-References

1. Paul M. Anderson, “Analysis of Faulted Power Systems”, the Institute of Electrical and Electronics Engineers, Inc., 1995.
2. Jun Zhu. “Analysis of Transmission System Faults the Phase Domain”, Texas A&M University. Master Thesis, 2004.
3. T.K Nagsarkar and M.S Sukhija, “Power System Analysis”, New York Oxford University Press, pp.14-25, 2005
4. Miroslav D. Markovic, “Fault Analysis in Power Systems by Using the Fortescue Method”, TESLA Institute, 2009.
5. Norliana B. Salimun. “Phase Coordinates in Faulted Power System Analysis”, University Teknologi Malaysia. Master Thesis, 2010.
6. Hadi Saadat. Power System Analysis. Milwaukee Scholl of Engineering. WBC McGraw-Hill

Tabl-1 show the result of voltage at bus bar [23] under single line to ground fault

Bus No.	NAME	PHASE A VOLT	PHASE B VOLT	PHASE C VOLT	PHASE A ANGLE	PHASE B ANGLE	PHASE C ANGLE
23	23	0.00000	1.27608	1.19202	0.00000	-144.04	117.06

Tabl-2 show the result of voltage at bus bar [23] under line to line fault

NUMBER	NAME	PHASE VOLT A	PHASE VOLT B	PHASE VOLT C	PHASE ANGLE A	PHASE ANGLE B	PHASE ANGLE C
23	23	1.08320	0.54159	-15.16	-15.16	164.84	164.84

Tabl-3 show the result of voltage at bus bar 23 under double line to ground fault

NUMBER	NAME	PHASE VOLT A	PHASE VOLT B	PHASE VOLT C	PHASE ANGLE A	PHASE ANGLE B	PHASE ANGLE C
23	23	1.29446	0.0000	0.0000	-13.57	0.00	0.00

Tabl-4 show the result of voltage at bus bar [23] under three phase fault

NUMBER	NAME	PHASE VOLT A	PHASE VOLT B	PHASE VOLT C	PHASE ANGLE A	PHASE ANGLE B	PHASE ANGLE C
23	23	0.0000	0.0000	0.0000	0.00	0.00	0.00

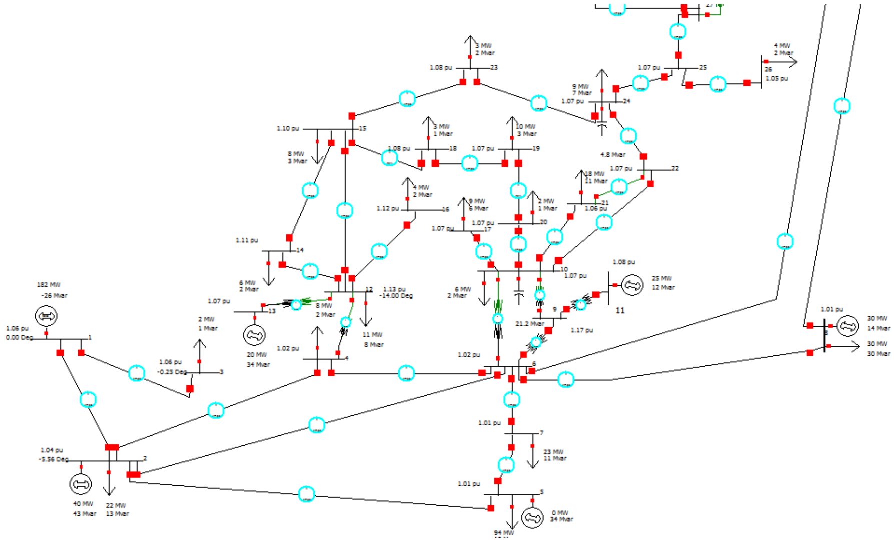

Figure 1: IEEE 30 bus base case load flow in edit mode.

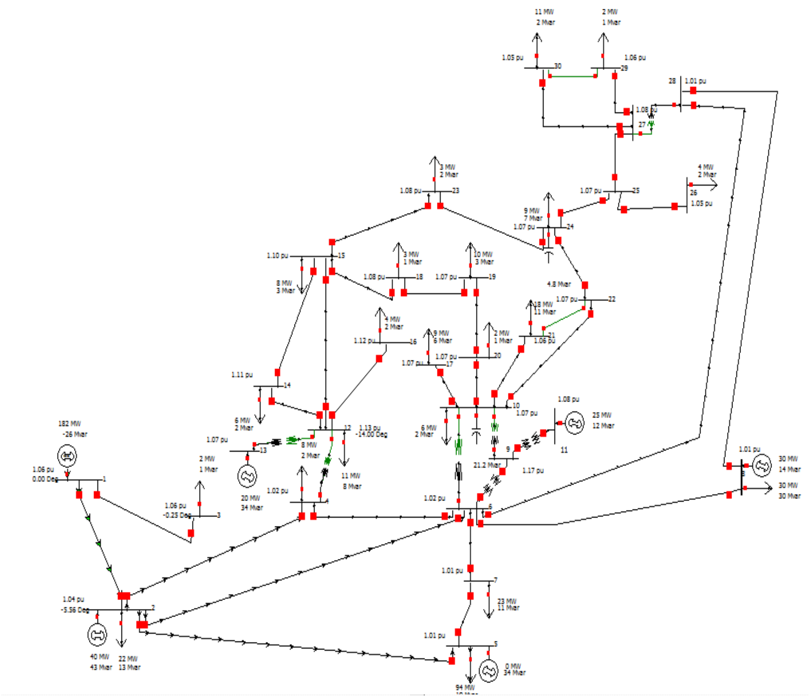

Figure 2 shows the setup in Power World in Run Mode

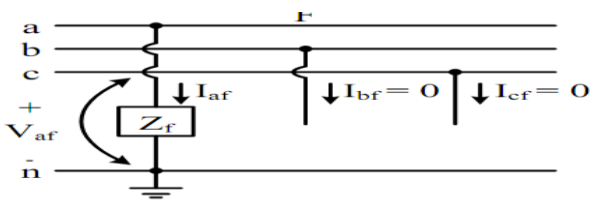

Figure 3 General representation of a single line-to-ground fault.

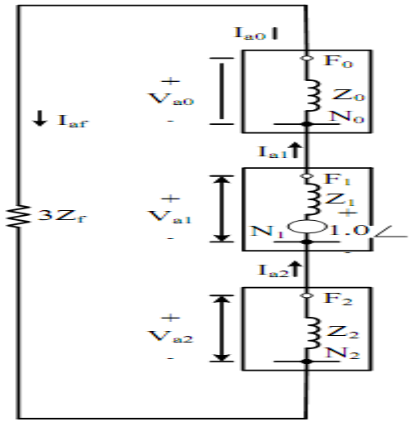

Figure 4 Sequence network diagram of a single line-to-ground fault.

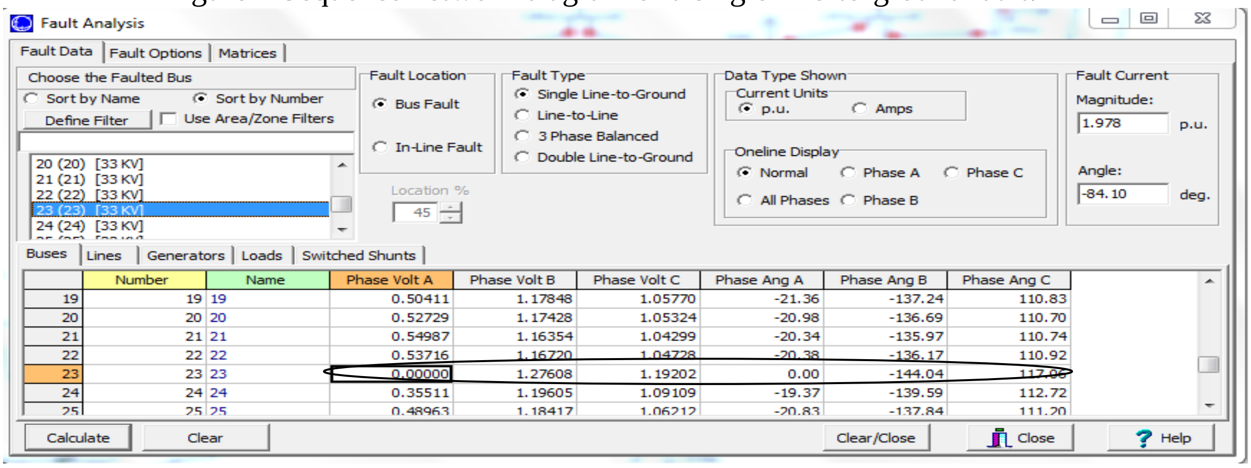

Figure 5 show power world simulators to calculate fault current the type single line to ground.

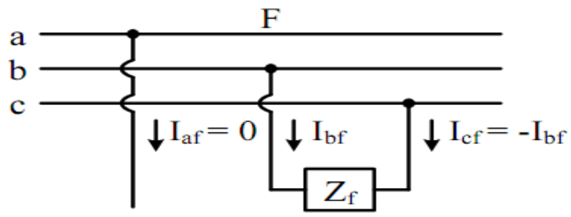

Figure 6 Sequence network diagram of a line-to-line fault

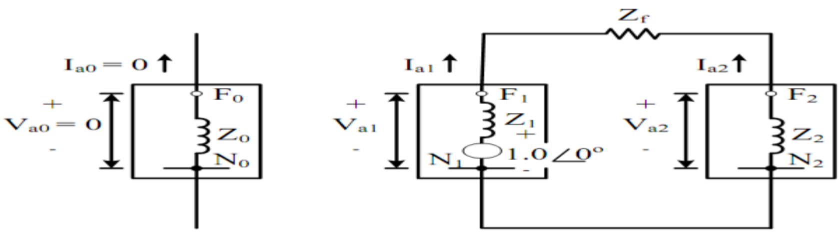

Figure 7 Sequence network diagram of a line-to-line fault.

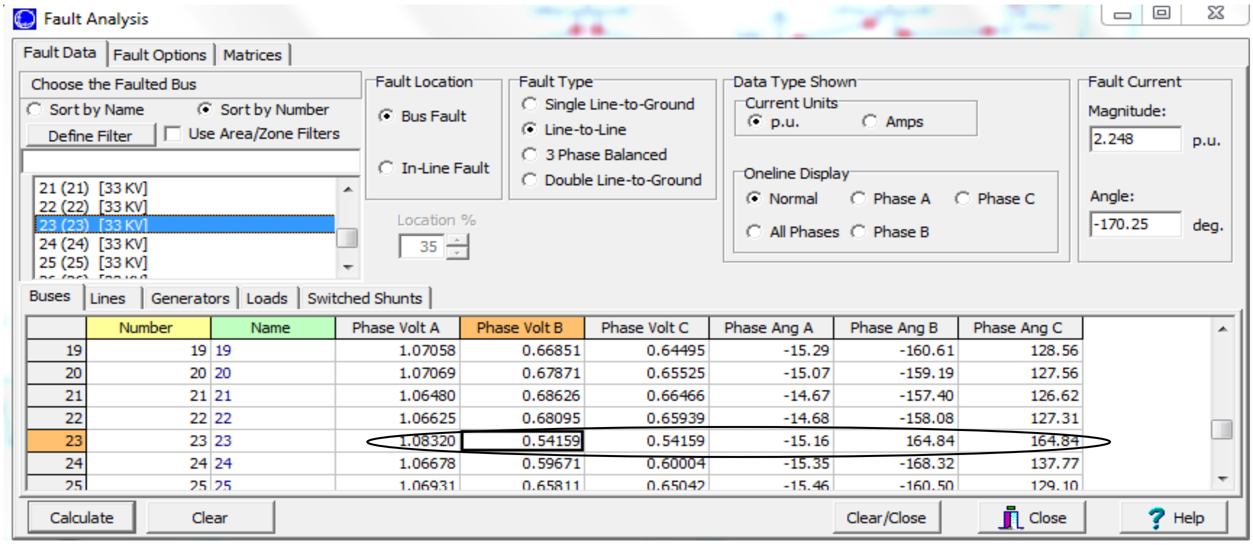

figure 8 show using power world program to calculate current in the type fault line to line

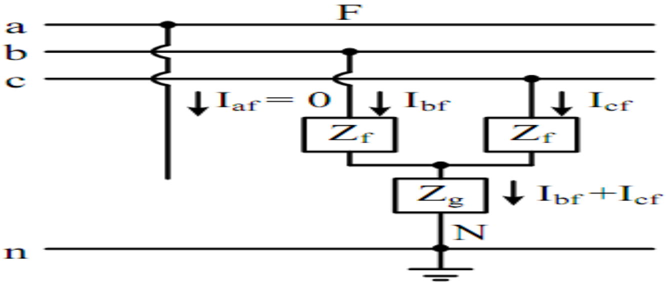

Figure 9 General representation of a double line-to-ground fault.

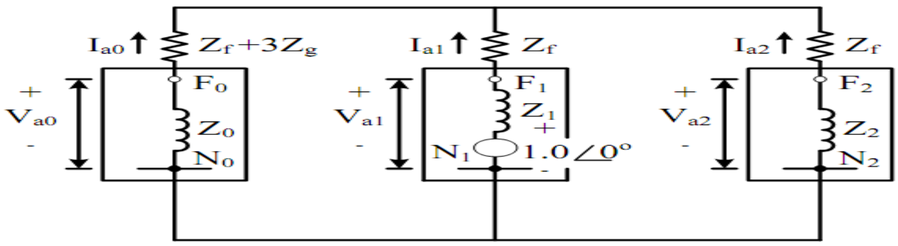

Figure 10 Sequence network diagram of a double line-to-ground fault.

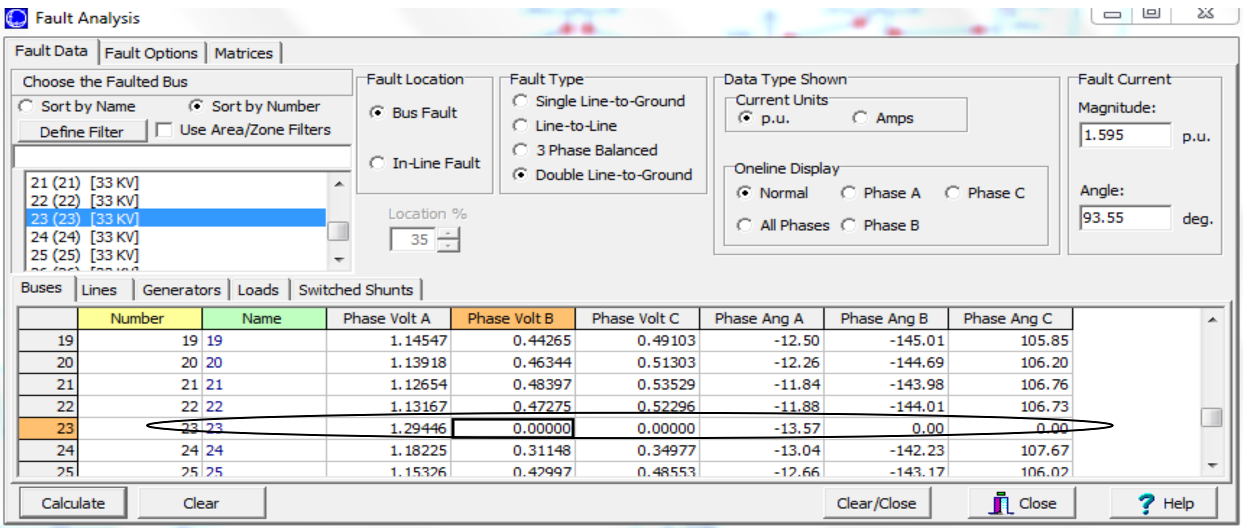

figure 11 show using power world program to calculate current in the type fault double line

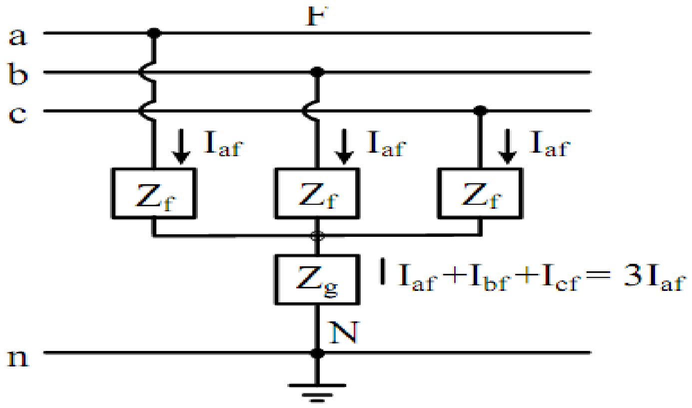

Figure 12 General representation of a balanced three-phase fault

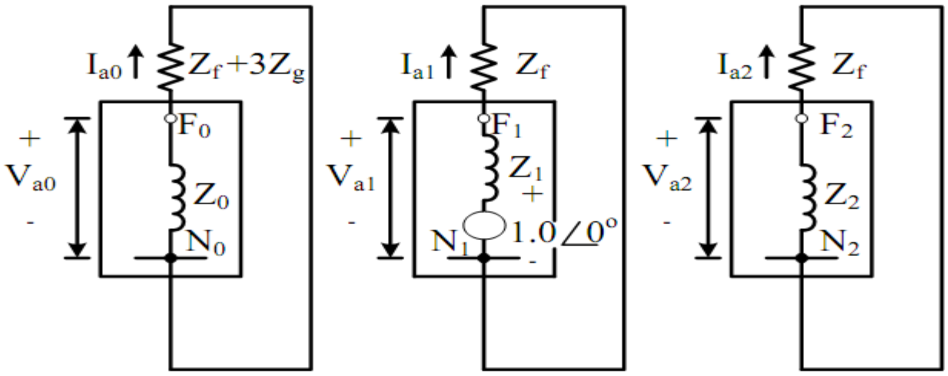

Figure 13 Sequence network diagram of a balanced three-phase fault

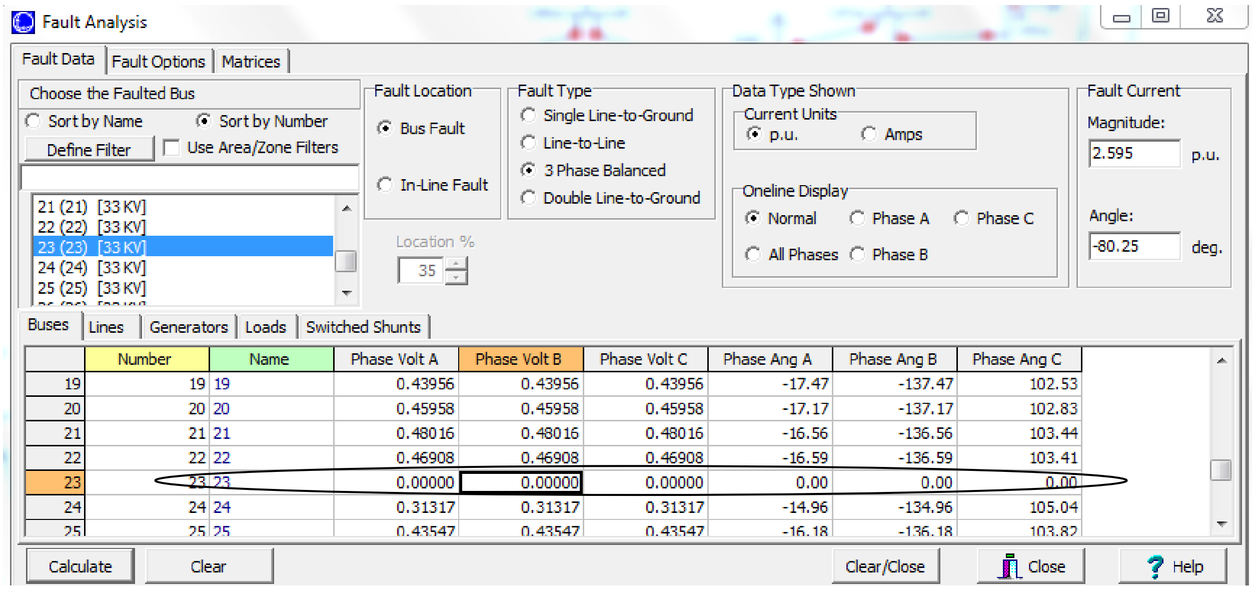

figure 14 show using power world program to calculate current in the type fault three phase

تحليل دوائر القصر الكهربائي في شبكات أنظمة القدرة الكهربائية

الخلاصة

لضمان وصول القدرة الكهربائية للمستهلك بصورة مستمرة وبدون انقطاع مع موثوقية واستقرارية تجعل من خدمات القدرة هي الأفضل , في هذا البحث دراسة تحليلية لجميع انواع دوائر القصر(faults). تعتبر عملية التحليل الرياضي لدوائر القصر في شبكات أنظمة القدرة الكهربائية من اهم واصعب المهام في انظمة القدرة. ولهذا فان دراسة واكتشاف العطل يعتبر من الضروريات للتأكد من ان القدرة مستقرة وموثوقة لاستخدام المستهلك. اعتماد قوة العطل الكهربائي على على موقعه بالنسبة للشبكة مما يجعل مسار تيار العطل يحدد من مستوى الفولتية وقيمة الممانعة بالنسبة للخط الذي حدث فيه العطل.في هذا البحث تحليل لسلوك النظام الكهربائي تحت تاثير عدة انواع من العطل الكهربائي. (Power world simulator) استخدم كأداة لمحاكاة شبكة نظام قدرة كهربائية تتكون من 30عقدة (IEEE30−bus). كل النتائج المستحصلة تمت مناقشتها في متن هذا البحث.