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Fault Analysis based on Selection of the Grounding Reactance At Generators Terminals of Iraqi Supper Grid

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Abstract— The growth in size and complexity of power system networks with a large number of interconnections has exposed the system to various contingencies that would lead to system instability. Thus, it is important for a power system to be able to remain in a state of operating equilibrium under normal operating condition and to regain an acceptable state of equilibrium after being subjected to a disturbance, this paper discusses effect of the grounding reactance value to limit fault current at generators terminals of iraqi supper grid.

The modern digital computer has a distinct advantage in that it provides mean for solving such large networks accurately. Therefore systematic procedure suitable for digital computer calculation is necessary.

Modern fault-current programs for the digital computer are usually based on the bus impedance matrix. The program uses the data listed for the lines and their impedance as provided for the load flow program and includes the appropriate reaction for each machine in forming the positive, negative and zero sequence bus impedance matrices.

In the present paper a computer program is developed using MATLAB package to analyze the effect of grounding rectance on fault calculations for Iraqi super grid.

The result obtain show that it is possible to select the grounding reactance to limit the signle line to ground fault current lower than the three phase fault current at terminals of generation units.

Keyword—Fault Analysis; Contingency Analysis and Power System Security.

1- Introduction

The current and voltages appearing during a short circuit fault in electric power systems play an important role in their operation because of the following primary reasons :

i- Short circuit currents and voltages from the basis of circuit breaker selection can be treated as the fundamental parameters in the design of any electrical equipment, cable or line.

ii- Short circuit currents and voltages serve as input variables of the protective gear; even they may be helpful in detecting the location of the fault.

iii- Earth fault carrents can have induction effects on metal enclusures and other communication circuits and hence can affect the communication signal. [1]

The current and/or voltage that activate the relays are those currents or voltages which flow or appear immediately after the occurance of the fault and the fault current is usually high. This current is to be interrupt by the circuit breaker. Both fault currents and voltages are to be calculated. The voltages and currents during faults are used to set the relays so that they can detect as fast as possible the faulted conditions the initial fault current is used to determine the required momentary duty of the breaker. The current and voltage, a short while later, are used to calculate the required interrupting capacity of the breaker .the voltages and currents are also used to calculate the short circuit capacity the basic a spect of the fault study is the determination of the impedance matrix of the system, the elements of which can be used, along with the conditions imposed by the type of the fault in order to directly solve for fault current and post-fault voltages.[2]

Short circuits occur in three-phase power system as follows, in order of frequency of occurance : single line-to-ground, line-to-line, double line-to-ground, and balanced three-phase faults. The path of the fault current may have either zero impedance, which is called a boltaed short circuit, or nonzero impedance. Other types of faults include one-conductor –open and two-conductors open, which can occur when conductors break or when one or two phase of a circuit breaker inadvertently open.

When an unsymmetrical fault occurs in an otherwise balanced system, the sequence networks are interconnected only at the fault location. As such, the computation of fault currents is greatly simplified by the use sequence networks. [2]

Symmetrical and unsymmetrical faults have two components of fault current: an ac or symmetrical components including subtransient, transient, and steady-state currents-and a dc component. The dc offset current need to be considered unless it is too large-for example, when the X/R ratio is too large . [3]

2- System modeling :

The zero-, positive - , and negative –sequence networks of system components-generators, motors, transformers and transmission lines can be used to construct transmmion line can be used to construct system zero-, positive-, an d negative-sequence networks we make the following assumptions : [4]

i. The power system operates under balanced steady-state conditions before the fault occurs. Thus the zero-, positive- , and negative-sequance networks are uncoupled before the fault occurs. During unsymmetrical faults they are interconnected only at the fault location.
ii. Prefault load current is neglected, because of this, the positive sequence internal voltages of all machine are equal to the prefault voltage vf. Therefore, the prefault voltage at each bus in the positive-sequence network equals vf.
iii. Transformer winding resistances and shunt admiances are neglected.
iv. Transmission-line series resistance and shunt admittances are neglected.
v. Synchronous machines armature resistance saliency, and saturation are neglected.
vi. All nonrotating impedance loads are neglected.
vii. Induction motors are either neglected (especially for motors rated 50 hp or less) or represented in the same manner as synchronous machine.

3- Determination of symmetrical fault current methods :

3.**1 determination of symmetrical fault current using zbus inversion:**

The easiest way to find symmetrical fault current bus in a multi-bus power system is olotained directly from [zbus] (bus impedance matrix) provided [zbus] is formed by [ybus] (bus admittance matrix) inversion. For large system this approach becomes unacceptable because of the need of inverting a very largematrix; also for any change in the network, the full [ybus] is to be rebuilt and again the inversion technique needs to be applied.[4,5]

3.2 determination of fault current by formulating the impedance matrix using network theory:

For a passive n-port liner network, from circuit theory concepts,

$$[V] = [Z][I] \qquad 1$$

The general entry in the $[Z_{bus}] = [Z]$ can then be calculated from the following equation,

$$Z_{ik} = \frac{V_i}{I_k}\bigg|\ I_1 = I_2 = \cdots = I_n = 0\ ;\ I_k \neq 0 \qquad (2)$$

This method presents great difficulty in solving for V_i and hence not widly accepted for multi-bus system. On the other hand, we prefer $[Z_{bus}]$ building algorithm as this technique is a programmable step-by-step method and any modification in the network dose not require a complete rebuilding of $[Z_{bus}]$. [4,5]

4- Generalized fault analysis using Z_{bus} building algorithm.

The process of Z_{bus} building can be directly applied to develop sequence networks of linear passive networks. Let the fault be applied to the i-th bus bus of the n-bus power system, the reference bus being the r-th bus.

The generalized representation of the sequence network where we indicate all the bus currents except i-th bus current are zero (since bus- is terminated by a fault, sequence currents $I_i^0, I_i^1, and\ I_i^2$ would flow). No other sequence model except positive sequence network does have source (E). [4,6]

5- Unbalanced Fault Analysis Using Bus Impedance Matrix

When the network is balanced, the symmetrical components impedances are diagonal, so that it is possible to calculate Z_{bus}separately for zero-, positive-, and negative-sequence networks. also, for a fault at bus k, the diagonal element in the k axis of the bus impedance matrix Z_{bus} in the Thevenin's impedance to the point of fault. In order to obtain a solution for the unbalanced faults, the bus impedance matrix for each sequence network is obtained separately, then the sequence impedance Z_{kk}^0, Z_{kk}^1, Z_{kk}^2 are connected together in Figures (1,2,3). The fault formulas for various unbalanced fault are summarized below. In writing the symmetrical components of voltage and currents, the subscript a is left out and the symmetrical components are understood to refer to phase a.[7,8]

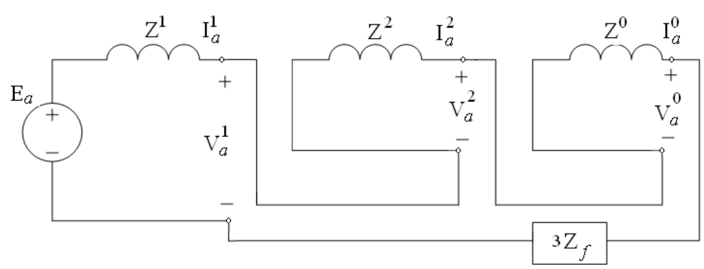


Figure 1 Sequence network connection for line-to-ground fault.

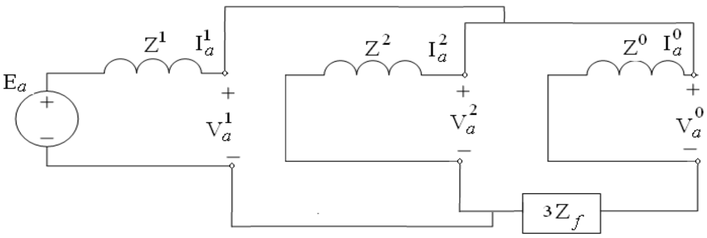


Figure 3 Sequence network connection for double line-to-ground fault

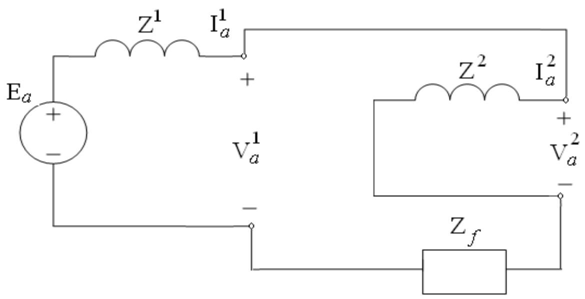


Figure 2 Sequence network connection for line-to-line fault

5.1- SINGLE LINE-TO-GROUND FAULT USING Z_{bus} [8,9]

The line-to-ground fault requires that positive-, negative-, and zero-sequence networks for phase *a* be placed in series as shown in Fig. (1) in order to compute the zero-sequence fault current. Thus, in general, for a fault at bus *k*, the symmetrical components of fault current is

$I_k^0 = I_k^1 = I_k^2 = V_k^0/(Z_{kk}^1 + Z_{kk}^2 + Z_{kk}^0 + 3Z_f)$ (3)

The fault current is

$I_k = 3I_k^0$ (4)

The fault phase current is

$I_k^{abc} = AI_k^{012}$ (5)

5.2- LINE-TO-LINE FAULT USING Z_{bus} [8,9]

The phase a sequence network of Figure (2) is applicable here, where the positive- and negative-sequence networks are placed in opposition. The symmetrical components of the fault current as given.

$I_k^0 = 0$ (6)

$I_k^1 = -I_k^2 = V_k^0/(Z_{kk}^1 + Z_{kk}^2 + Z_f)$ (7)

5.3- DOUBLE LINE-TO-GROUND FAULT USING Z_{bus} [8,9]

The phase a sequence network of Figure (3) is applicable here, where the positive-sequence impedance is placed in series with the parallel combination of the negative- and zero-sequence networks. the symmetrical components of the fault current as given

$I_k^1 = V_k^0/\left(Z_{kk}^1 + \frac{Z_{kk}^2(Z_{kk}^0 + 3Z_f)}{Z_{kk}^1 + Z_{kk}^2 + 3Z_f}\right)$ (8)

$I_k^2 = (V_k^0 + Z_{kk}^1 I_k^1)/(Z_{kk}^2 + 3Z_f)$ (9)

$I_k^0 = (V_k V_k^0 + Z_{kk}^1 I_k^1)/(Z_{kk}^0 + 3Z_f)$ (10)

The phase current are obtained from (5) and the fault current is

$I_k^f = I_k^b + I_k^c$ (11)

5-4 open conductor faults : [10,11]

The sequence currents and voltages are suitably connected to represent the complete sequence network depending on the type of fault, i.e wether a single conductor fault or two conductor fault.

5.4.1-single conductor open fault :

For one conductor open (Fig (4))

$V_{yy'} = V_{bb'} = 0$ (12)

$I_r = 0$ (13)

In terms of symmetrical components, we have

$V_{rr'}^1 = V_{rr'}^2 = V_{rr'}^0 = \frac{1}{3} V_{rr'}$ (14)

$I_r^1 + I_r^2 + I_r^0 = 0$ (15)

Thus, the sequence network is clearly a parallel connected networks show in fig. (4.b)

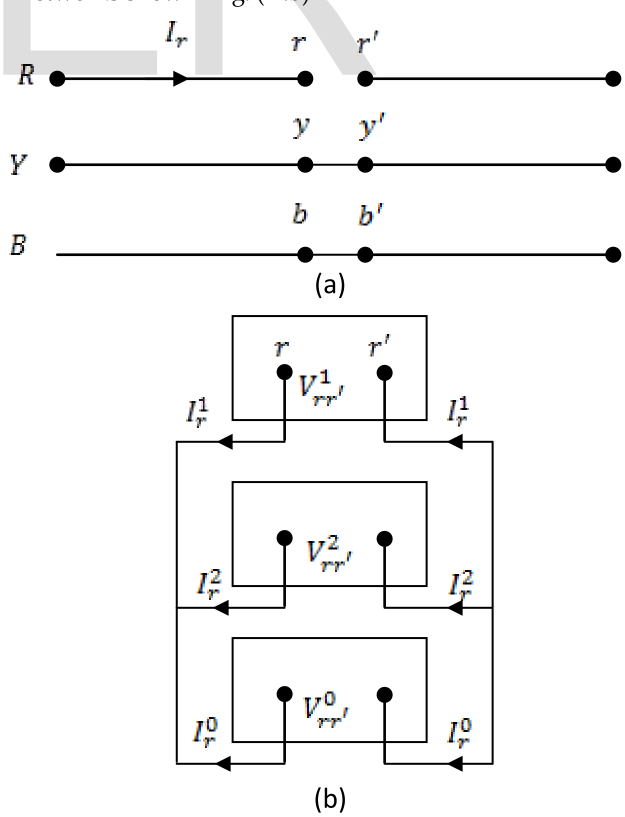


Fig (41) connection of sequence diagram of one conductor open fault.

5-4.2 Two conductor open fault : [10,11]

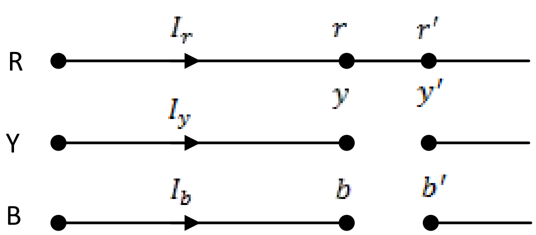
We assume conductor y and b are open obviously, $V^0_{rr'} = 0$ & $I_y = I_b = 0$

In term of symmetrical components, we have

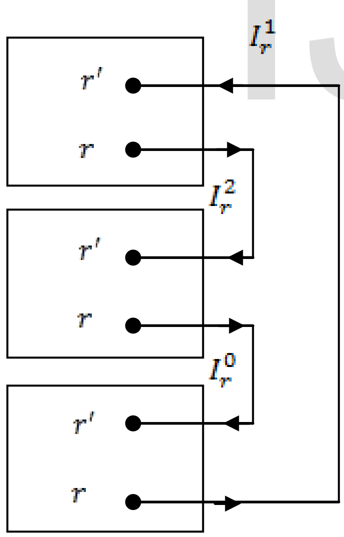
$$V^1_{rr'} = V^2_{rr'} = V^0_{rr'} = 0 \qquad (16)$$

$$I^1_r + I^2_r + I^0_r = \frac{1}{3} I_r \qquad (17)$$

These equations suggest that the connection diagram is a series connected sequence network as shown in fig. (5.b)



(a)



(b)

Fig.(5) connection of sequence diagram of two conductor open fault.

6- Effect of neutral grounding on fault current: [12,13]

For a solid L.G. fault, Z_f become zero. Hence the fault current at phase R can be obtained as

$$I_R = 3\left(\frac{E}{Z^0_{ii} + Z^1_{ii} + Z^2_{ii}}\right) \qquad (18)$$

$$I^0 = I^1 = I^2 = \frac{1}{3} I_f \qquad (19)$$

Assuming the resistance part of the impedance component to be negligible and assuming the postion and negative sequence reactance equal, we can further modify the above equation as

$$I_R = \frac{3E}{2X^1_{ii} + X^0_{ii}} \qquad (20)$$

On the other hand, for a solid three phase fault, we have

$$I_R = \frac{E}{X^1_{ii}} \qquad (21)$$

Comparing equation (20) & (21), we find that for a generator with equal positive and negative sequence reactances and neutral solidly grounded, we have the single line to ground fault is more severe than the three phase fault while the zero sequence reactance is of low value. Howver, if X^0_{ii} is much higher than X^1_{ii}, there is a possibility that the three-phase current is higher in magnitude than the line to ground fault curent. In practical context, we find that if fault occurs at the generator terminals, due to lower value of X^0_{ii} ,

$$I_{R(L-g)} > I_{R(3L)}$$

while for a fault in the tramsmission line ,

$$I_{R(3L)} > I_{R(L-g)} \qquad (22)$$

If we want to make the fault curent due to L_G fault less tha three-phase fault current at generator terminals using a grounding reactance (X_n) at the neutral, we can write

$$\frac{3E}{2X^1_{ii} + X^0_{ii} + 3X_n} < \frac{E}{X^1_{ii}} \qquad (23)$$

Or

$$2X^1_{ii} + X^0_{ii} + 3X_n > 3X^1_{ii} \qquad (24)$$

$$\therefore X_n > \frac{(X^1_{ii} - X^0_{ii})}{3} \qquad (25)$$

Thus, it is possible to select the grounding reactance (X_n) to limit the L-G fault current lower than the L-L-L fault current.

7- BUS VOLTAGES AND LINE CURRENTS DURING FAULT. [10]

The symmetrical components of the i^{th} bus voltages during fault are obtained

$$V_i^{0f} = 0 - Z_{ik}^0 I_k^0 \quad (26)$$

$$V_i^{1f} = V_i^1 - Z_{ik}^1 I_k^1 \quad (27)$$

$$V_i^{2f} = 0 - Z_{ik}^2 I_k^2 \quad (28)$$

The phase voltage during fault are

$$V_i^{abc} = AV_1^{012} \quad (29)$$

The symmetric components of fault current in line *i* to *j* is given by

$$I_{ij}^0 = \left(V_i^{0f} - V_j^{0f}\right)/Z_{ij}^0 \quad (30)$$

$$I_{ij}^1 = \left(V_i^{1f} - V_j^{1f}\right)/Z_{ij}^1 \quad (31)$$

$$I_{ij}^2 = \left(V_i^{2f} - V_j^{2f}\right)/Z_{ij}^2 \quad (32)$$

Having obtained the symmetrical components of line current, the phase fault current in line *i* to *j* is

$$I_{ij}^{abc} = AI_{ij}^{012} \quad (33)$$

7.1 Determine of line current during fault condition :

The current flowing through any line during the faulted condition can be obtained once the bus voltages at both the ends of the line are known :

$$I_{ik}^s = \frac{V_i^s - V_k^s}{Z_{ik}^s} \quad (34)$$

8. Test system data.

8.1 First System data

The first system consists of 11 bus and 14 Transmission lines.

8.2 Second system data

The second system consist of 24 Bus and 35 Transmission lines. Fig.(6) shows a configuration of this system.

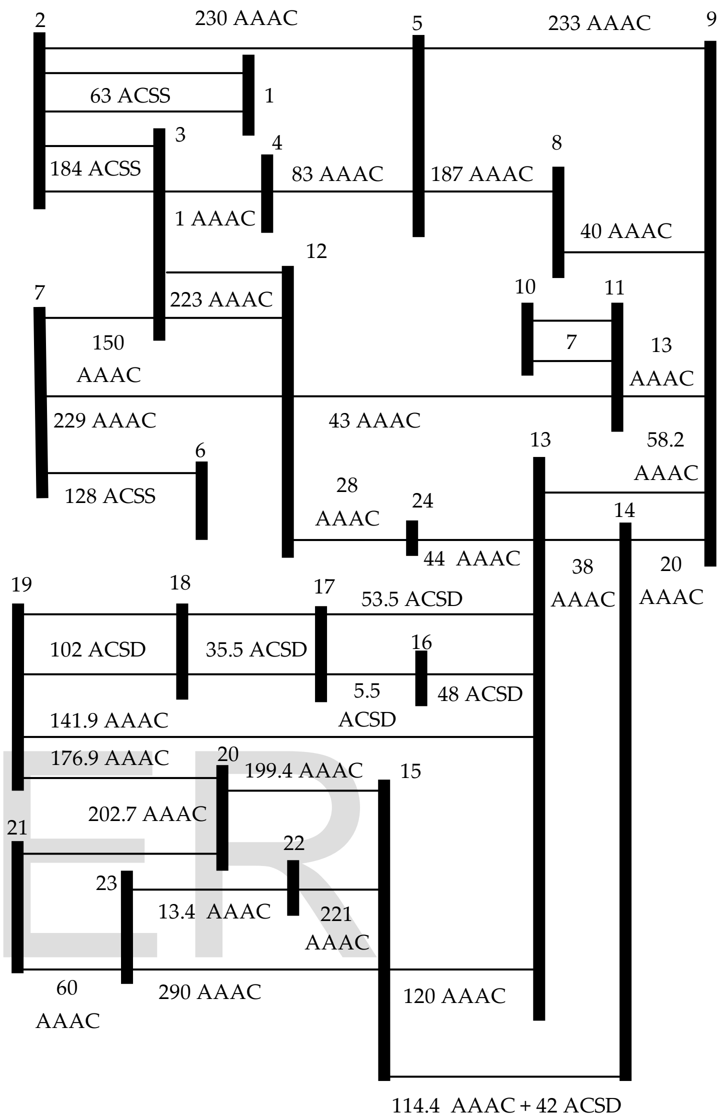


Figure (6) Iraqi super grid configuration.[15]

Table 1 : Classification of Iraq super Grid buses.

Bus No.	Bus Name	Bus Type	Bus No.	Bus Name	Bus Type	Bus No.	Bus Name	Bus Type
1	MMDH	Gen.	9	BGE4	Load	17	MUSP	Gen.
2	MSL4	Load	10	QDSG	Gen.	18	BAB4	Load
3	BAJP	Gen.	11	BGN4	Load	19	KDS4	Load
4	BAJG	Gen.	12	BGW4	Load	20	NSRP	Gen.
5	KRK4	Gen.	13	BGS4	Load	21	KAZG	Gen.
6	QIM4	Load	14	AMN4	Load	22	AMR4	Load
7	HDTH	Gen.	15	KUT4	Load	23	HRTP	Gen.
8	DAL4	Load	16	MUSG	Gen.	24	BGC4	Gen.

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9- Flowchart for short circuit studies.

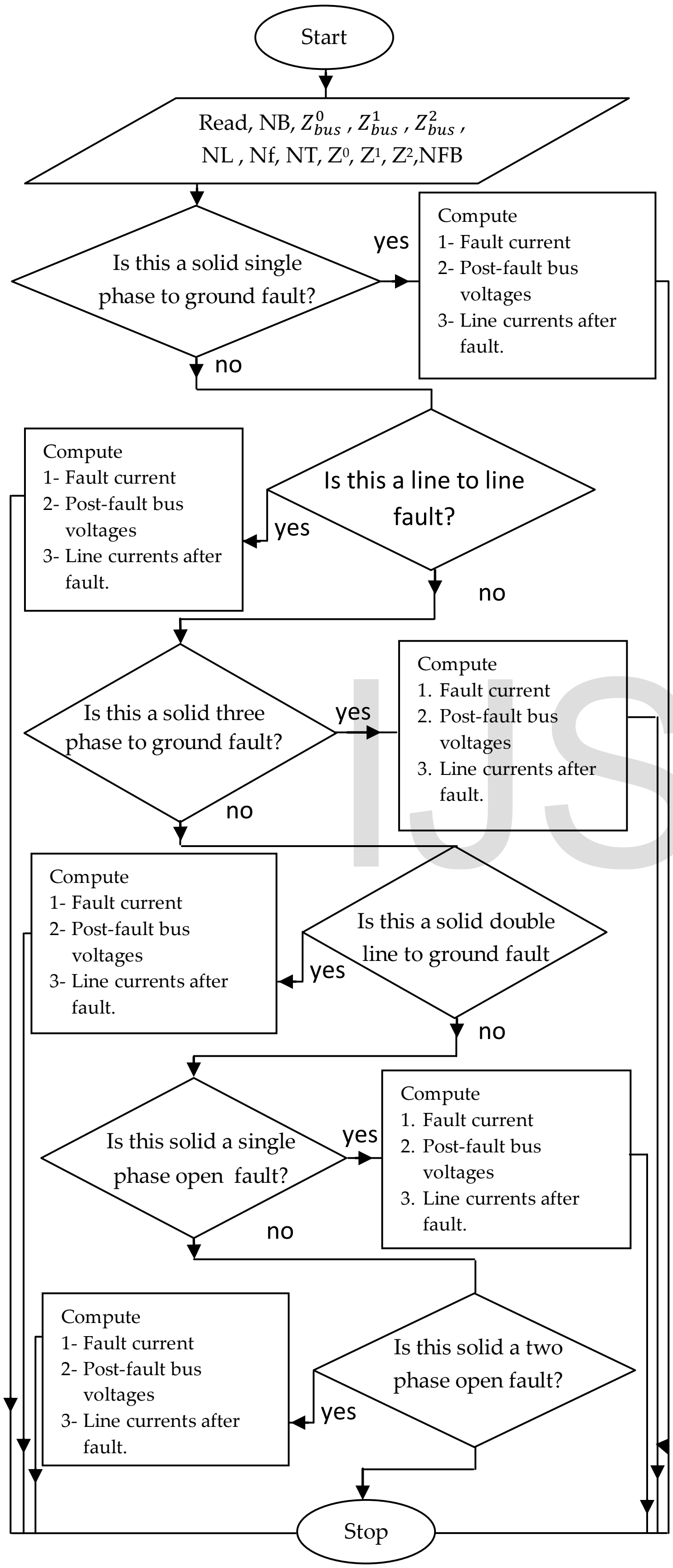


Figure (7) flow chart for short circuit studies

10- Result and discussion:

The result show that for a generator with equal positive and negative neactances and neutral solidly grounded, the single line to ground fault is greater than the three phase fault while the zero sequence reactance is of low value.

As shown at tables 2,3,5 & 6, because the fault occurs at the generator terminals and due to lower value of zero sequence reactance and neutral solidly grounded the fault current at single line to ground fault more than three-phase fault current.

And as shown at tables 4&7 when we use a grounding reactance at the neutral the line to ground fault current become lower than the 3-phase fault current.

Figure 8 & 10 show the simulation of symmetrical faulted current at first system and second system.

Figure 9 & 11 show the simulation of unsymmetrical faulted current at first system and second system.

Table (2) fault current at xn = 0

Faulted bus	Gen.	Faulted current at			
		Three phase fault	L-L fault	L-G fault	D-L-G fault
1	First	7.35	6.36	9.03	8.65
10	Second	8.45	7.32	10.93	10.64
11	Third	5.76	4.99	7.03	6.72

Table (3) fault current at $X_n = \frac{1}{6}(X_1 - X_0)$

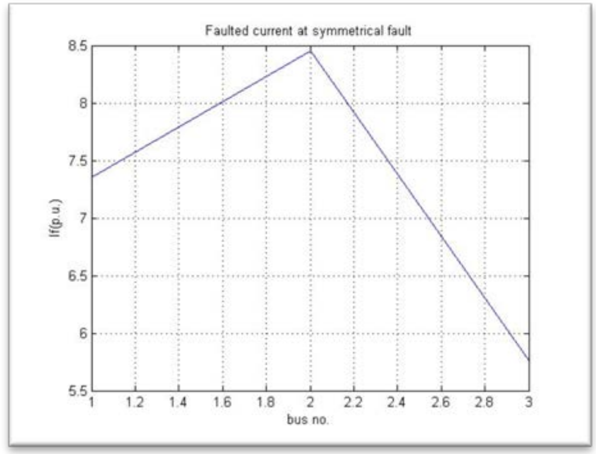
Faulted bus	Gen.	Faulted current at			
		Three phase fault	L-L fault	L-G fault	D-L-G fault
1	First	7.35	6.36	7.48	4.2
10	Second	8.45	7.32	9.58	9.18
11	Third	5.76	4.99	5.87	2.8

Table (4) fault current at $X_n = \frac{2}{3}(X_1 - X_0)$

Faulted bus	Gen.	Faulted current at			
		Three phase fault	L-L fault	L-G fault	D-L-G fault
1	First	7.35	6.36	4.91	3.68
10	Second	8.45	7.32	7.38	6.55
11	Third	5.76	4.99	3.96	2.96

Table (5) fault current at xn=o.

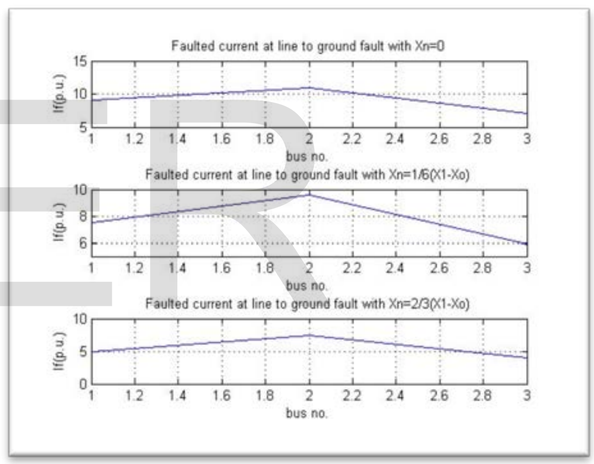
Faulted bus	Gen.	Faulted current at			
		Three phase fault	L-L fault	L-G fault	D-L-G fault
1	MMDH	6.34	5.49	7.33	7.00
3	BAJP	15.70	13.60	17.28	16.78
4	BAJG	10.60	9.18	11.11	10.92
5	KRK4	10.03	8.66	10.65	10.38
7	HDTH	7.89	6.83	8.79	8.45
10	QDSG	4.77	4.13	6.11	5.93
16	MUSG	16.88	14.62	18.85	18.09
17	MUSP	8.71	7.55	9.71	9.33
20	NSRP	7.24	6.27	8.51	8.12
21	KAZG	10.74	9.30	12.56	11.99
23	HRTP	7.65	6.63	8.12	7.91



Figure(8) Faulted current of generator bus bar during symmetrical fault of the first system.

Table (6) fault current at $X_n = \frac{1}{6}(X_1 - X_0)$

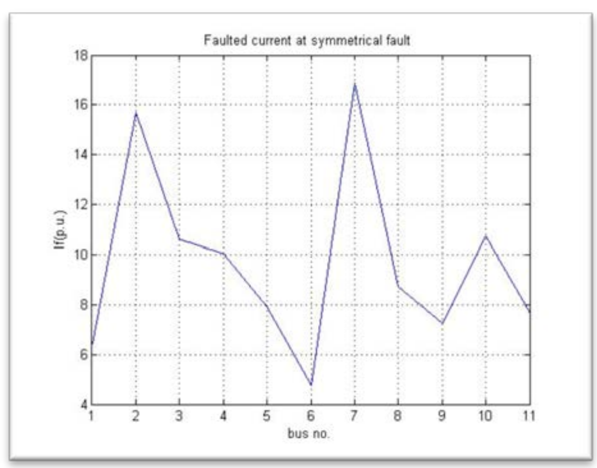
Faulted bus	Gen.	Faulted current at			
		Three phase fault	L-L fault	L-G fault	D-L-G fault
1	MMDH	6.34	5.49	6.84	6.29
3	BAJP	15.70	13.60	15.83	15.31
4	BAJG	10.60	9.18	10.80	10.17
5	KRK4	10.03	8.66	10.63	9.83
7	HDTH	7.89	6.83	7.97	7.93
10	QDSG	4.77	4.13	5.75	5.50
16	MUSG	16.88	14.62	16.94	16.77
17	MUSP	8.71	7.55	8.84	8.78
20	NSRP	7.24	6.27	7.66	7.47
21	KAZG	10.74	9.30	10.95	10.70
23	HRTP	7.65	6.63	7.84	7.31



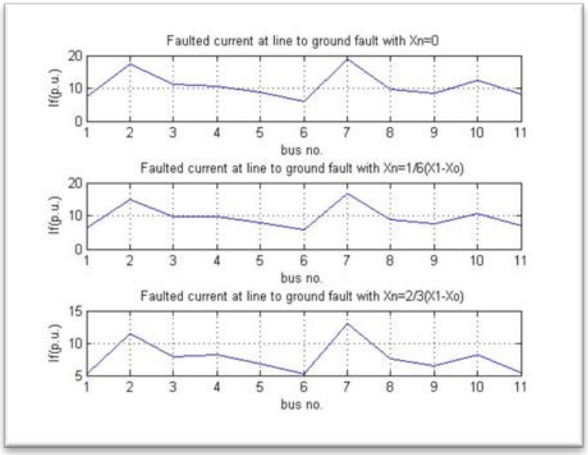
Figure(9) Faulted current of generator bus bar during unsymmetrical fault of the first system.

Table (7) fault current at $X_n = \frac{2}{3}(X_1 - X_0)$

Faulted bus	Gen.	Faulted current at			
		Three phase fault	L-L fault	L-G fault	D-L-G fault
	MMDH	6.34	5.49	5.15	5.90
3	BAJP	15.70	13.60	11.50	14.34
4	BAJG	10.60	9.18	7.83	9.69
5	KRK4	10.03	8.66	8.20	9.33
7	HDTH	7.89	6.83	6.83	7.47
10	QDSG	4.77	4.13	3.20	5.02
16	MUSG	16.88	14.62	12.98	15.54
17	MUSP	8.71	7.55	7.60	8.26
20	NSRP	7.24	6.27	6.47	6.92
21	KAZG	10.74	9.30	8.15	9.86
23	HRTP	7.65	6.63	5.39	6.95



Figure(10) Faulted current of generator bus bar during symmetrical fault of the second system.



Figure(11) Faulted current of generator bus bar during unsymmetrical fault of the second system.

11- **Conclusion**:

A short circuit computer program may be utilized in power system design to select, set, and coordinate protective equipment such as circuit breaker, fuses, relays, and instrument transformer.

For each terminal of the eleven generators select a suitable circuit breaker. For each breaker that you select should have arated short circuit current larger than the maximum fault current for any type of fault at the bus where the breaker is located. This conservative practice of selecting a breaker to interrupt the entive fault current, not just the contribution to the fault current through the breaker, allows for future increase in fault current since higher-rated circuit breaker cost more, you should select the circuit breaker with the lowest rating that satisfies.the design constraint.

REFRENCES

1- A.R. Bergen and V.vittal, “Power System Analysis”, 2nd ed., prentice Hall, 2000.
2- P.M Anderrson, “Analysis of Faulted Power System”, Ames: Iowa state university Press, 1973.
3- P. kundar, “Power System Stability and control” , McGraw-Hill, 1994.
4- A. Chakrobarti & S. Halder, “Power System Analysis Operation and Control”, 3rd ed., PHI Learning Private Limited, New Delhi, 2011.
5- J.D. Glover, M. S. SARMA & T. J. overbye “Power System Analysis and Design) 4th ed., Thomson learning, United States of America, 2008.
6- B. R. Gupta, “Power System Analysis Design”, S. chand, 2008.
7- H. saadat, “Power System Analysis” In. ed (New York: WCB/McGraw-hill, 1999).
8- D.P. Kothari & I.J. Nagrath, “Modern Power System Analysis” 4th ed., Tata McGraw-Hill, 2009.
9- A.R. Bergan and V. Vittal, “Power System Analysis”, 2nd ed. (Upper Saddle River, NJ: Prentice Hall, 2000).
10- S.A. Soman, and S. Pandit, “Computational Methods For Large Sparse Power Systems Analysis” KAP, Boston, 2002.
11- J.J. Grainger & W.D. Stevenson, Jr., Elements of Power System Analysis, 4th ed. (New York: McGraw-hill, 2007).
12- A.R. Bergen, “Power System Analysis”, Englewood cliffs, NJ: Prentic-Hall, 1986.
13- Arthur R. Bergen, “Power System Analysis Prentie-Hall Inc., 1985.
14- E.W. Kimbark, “Power System Stability : Elements of Stability Calulation” Vol.1, IEEE press power system Engineering series, 1995.
15- Republic of Iraqi / Ministry of Electricity / Training and Development office / control & operation office and Generation and Production of Electrical Energy / Planning Section, (technical operating data of 2012).