Effect Of Fault Resistance On The Performance Of Mho Relays

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Abstract

For distance protection to perform its function perfectly without errors, it should be characterized with ideal characteristics that is to operate within forward faults those are included by protection zone, and to exclude the outer faults.

In order to get an ideal tripping area for distance relays, all the factors and limitations imposed by power system on the measuring accuracy of distance relays must be identified.

This paper includes a study of the fault resistance effect on the performance of distance protection when using mho relays.

This study is done by steady state analysis of fault circuit to find the current & voltage at the relay location for different value of fault resistance for Line to ground faults and double line to ground faults.

Keywords: fault resistance, Protective relays, Mho relays.

تأثير مقاومة العطل على أداء المرحلات المسامحية

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الخلاصة

لضمان قيام حماية المسافة بدورها بشكل جيد ودون حدوث تقصير في الأداء، يجب أن تتصف مرحلة المسافة بخواص عمل مثالية، بحيث تعمل في حالة الأعطال الأمامية والواقعة

ضمن القطاع المحمي من قبل المرحلة وتستثني الأعطال التي تقع خارج القطاع المحمي من قبل المرحلة.

ومن اجل الحصول على خواص عمل مثالية للمرحلة، يجب الإلمام بجميع العوامل والمحددات المفروضة من قبل منظومة القدرة والتي تؤثر على عمل المرحلة.

يتناول البحث دراسة لواحد من هذه العوامل المؤثرة على دقة عمل حماية المسافة وعند استخدام المرحلات المسامحية، حيث تم بيان تأثير مقاومة العطل على عمل أنواع مختلفة من المرحلات المسامحية، وتمت هذه الدراسة بتحليل دائرة الحالة المستقرة لأعطال الطور والطورين مع الأرض وعند قيم مختلفة لمقاومة العطل.

Received 15 Feb. 2007 Accepted 16 July 2007

Types Of Single Phase Mho Relays

The operating characteristic of mho elements are derived either by amplitude or phase comparator of two vectors derived from the voltage and current signals of the protected line. But the most available distance relays derive a mho characteristic from two input phase comparators, which operate when the phase angle between two vectors S_1 and S_2 lies between $\Pi/2$ & $3\ \Pi/2$. Theses two vectors are:-

$$S_1=K_1V_\Phi-I_\Phi Z_R \quad .....(1)$$

$$S_2=K_2V_\Phi-K_3 I_\Phi Z_R+K_4V_p \quad ......(2)$$

Where :-

Z_R is the relay impedance setting.

V_Φ,I_Φ are the voltage & current at relay location .

K_1, K_2, K_3& K_4 are real or complex constants.

V_p is a polarizing voltage.

Three typical mho elements are considered which are currently used in electronic distance relays and which exemplify the various form of polarization. A non polarized mho element is studied for comparison purpose, and these types are classified as reference [1]. These types are:-

1)Non polarized. Which is characterized by :

$K_1=K_2=1$, $K_3=K_4=0$

2)Lightly cross polarized, Which is characterized by :

$K_1=K_2=1$, $K_3=0.001$ for offset in the positive direction, $K_4=0.09$ to provide cross polarization .

3)Moderately cross polarized, Which is characterized by :

$K_1=K_2=1$, $K_3=0$, $K_4= -0.98<60^0$ for Φ-G element ,$K_4=-0.33<85$ for Φ-Φ elements

4)Strongly cross polarized plus memory polarized Which is characterized by :

$K_1=1$, $K_2= K_3=0$, $K_4=1$.

Where V_p is selected such that is composed of 80% of positive sequence fault voltage & 20% pre-fault voltage at relay location.

The Response Of Mho Relay

The response of mho relay can be found by using of one of these methods

1-Loop impedance method.

2-Line impedance method.

3-Apparent impedance method.

The simplest & the best method for finding the response of mho relay is the third one (apparent impedance method), it requires the calculation of an apparent impedance only (impedance measuring by the relay),as given in appendix (A) with characteristic is a circle passing through the origin, reach point, invariant with the fault type & system parameter [2].

In order to find the voltage & current at relay location before & after fault occurrence SPICE program has been used for the analysis of steady-state fault circuits.

To achieve the phase voltages & phase currents from sequences voltages & sequences currents the following equation are used.

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \quad \ldots(3)$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \quad \ldots\ldots(4)$$

By using equation (A_6) the apparent impedance for the types of mho relays can be obtained.

Effect Of Fault Resistance

In the cases of lines short circuits, the fault resistance are small & do not exceed a few ohms. However, it may become much higher during ground faults owing to the tower footing & arc resistance.

In order to show the effect of polarizing and fault resistance on the response of mho elements, the response of the four typical mho elements has been found which exemplify the various forms of polarizing at location (1) as shown in fig.(1) , which represent transmission line between two stations at rated voltage of (15kV), when two lines to ground fault & line to ground fault occurs at different locations of T.L.[3]. Different fault location are examined (F_1,F_2,F_3) such that:-

F_1: fault at (1/4) of T.L

F_2: fault at (1/2) of T.L.

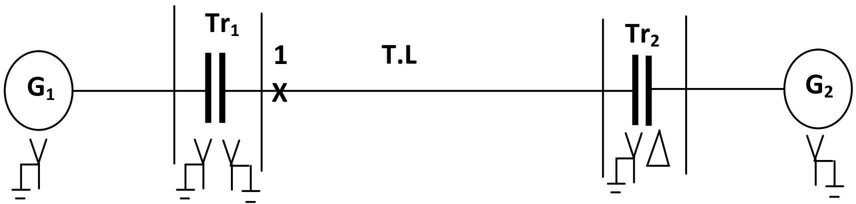


Fig.(1) single line diagram of power system

The MVA rating, voltage rating, and sequence impedances of the element of fig.(1) are listed in table (1) in appendix (C).

1-Single Line To Ground Fault (LG).

In general the single line to ground fault on a transmission system occurs when one conductor falls to ground or contacts the neutral wire. Figure(2) (in appendix (D)) shows the interconnection of the resulting sequence networks when LG fault occur.

Table (2) (in appendix (C))shows an apparent impedance for four types of mho relay (which are calculated by using equation (A_6)) in per-unit to the relay impeding setting (Z_R) (when Z_R is 80% of T.L and 120% of T.L) as abase impedance, for different values of fault resistance R_F

which is suggest resistance for case studying, when L-G occurs at different location on T.L ,

Where Za_1= apparent impedance for non polarized type.

Za_2= apparent impedance for Lightly cross polarized type.

Za_3= apparent impedance for Moderately cross polarized.

Za_4= apparent impedance for Strongly cross polarized plus memory polarized.

The response of mho relays at location (1) when L-G fault occur at positions (F_1,F_2 & F_3) is shown in figures (4a,4b,&4c respectively).

It is shown in fig.(4a), that Z_{a1},Z_{a2} & Z_{a3} become outside the relay characteristic zone when R_F equal to (10Ω), while Z_{a4} remain inside the characteristic zone and becomes outside when R_F equal to (20Ω).

In fig(4b and 4c) Z_{a1},Z_{a2} & Z_{a3} become outside the relay characteristic when R_F equal to (10Ω), while Z_{a4} remain inside the characteristic and it's become outside when R_F equal to (15Ω)

2-Double Line To Ground Fault.

In general, the double Line to ground (DLG) fault on a transmission system occurs when two conductors fall and are connected through ground or when two conductors contact the neutral of a three phase grounded system.

Figure(3)(in appendix (D)) shows the interconnection of the resulting sequence networks when DL-G fault occur.

Table (3) (in appendix(C) shows an apparent impedance for four types of mho relay in per-unit to the relay impeding setting (Z_R) (as abase impedance)for different values of fault resistance when DL-G occurs at different location on T.L .

The response of mho relays at location (1) when DL-G fault occur at positions (F_1,F_2 & F_3) is shown in figures (5a,5b,&5c respectively).

It is see that in fig.(5a), Z_{a1},Z_{a2},Z_{a3} & Z_{a4} remain inside the relay characteristic when increase R_F to (20Ω) and in fig(4b and 4c) Z_{a1}&Z_{a2} become outside the relay characteristic when R_F equal to (20Ω), while Z_{a3} & Z a4 remain inside the characteristic

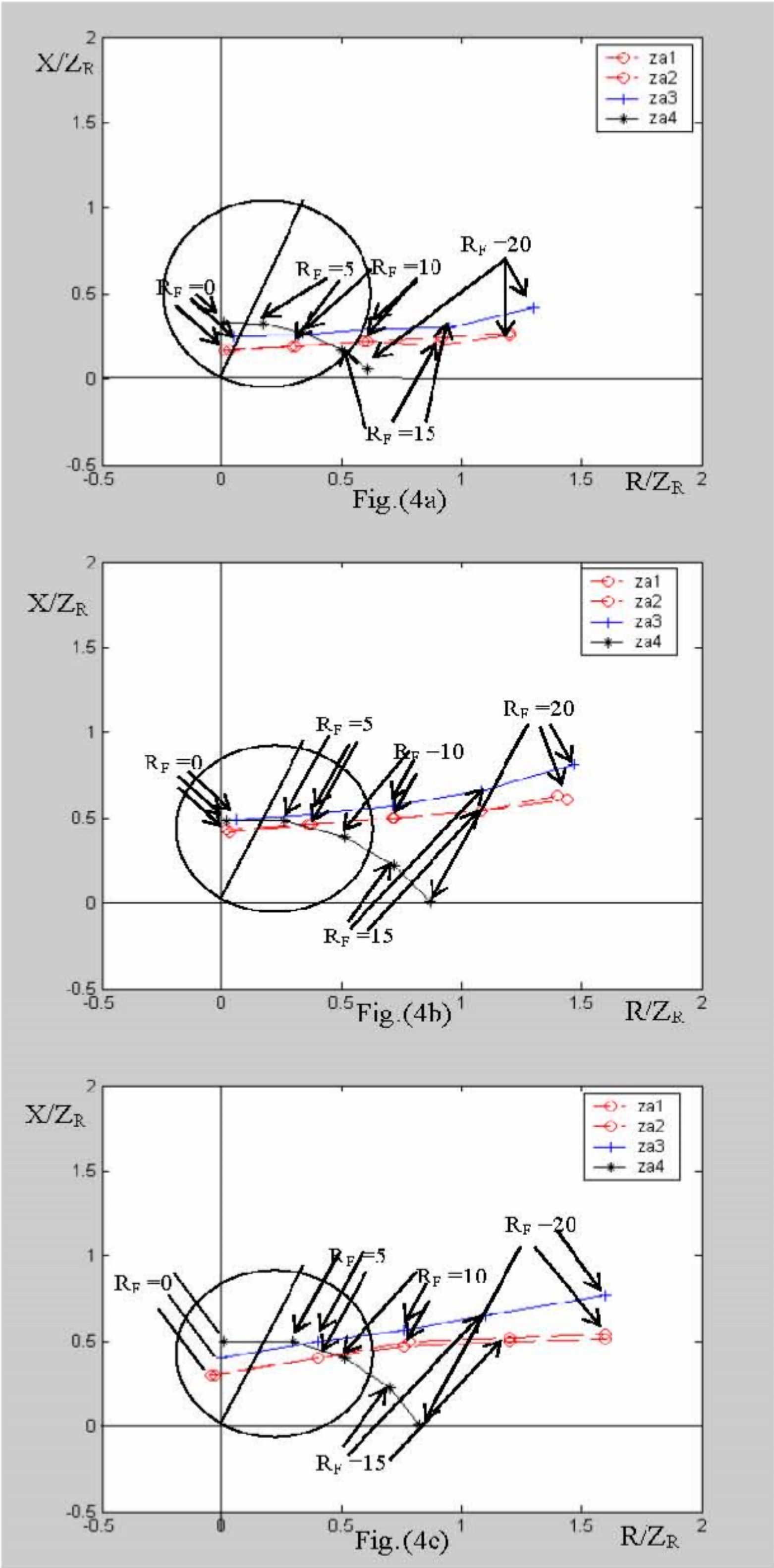


Fig.(4)The response of mho elements when LG fault occurs for different value of fault resistance (a) Fault at F_1 (b) Fault at F_2 (c) Fault at F_3.

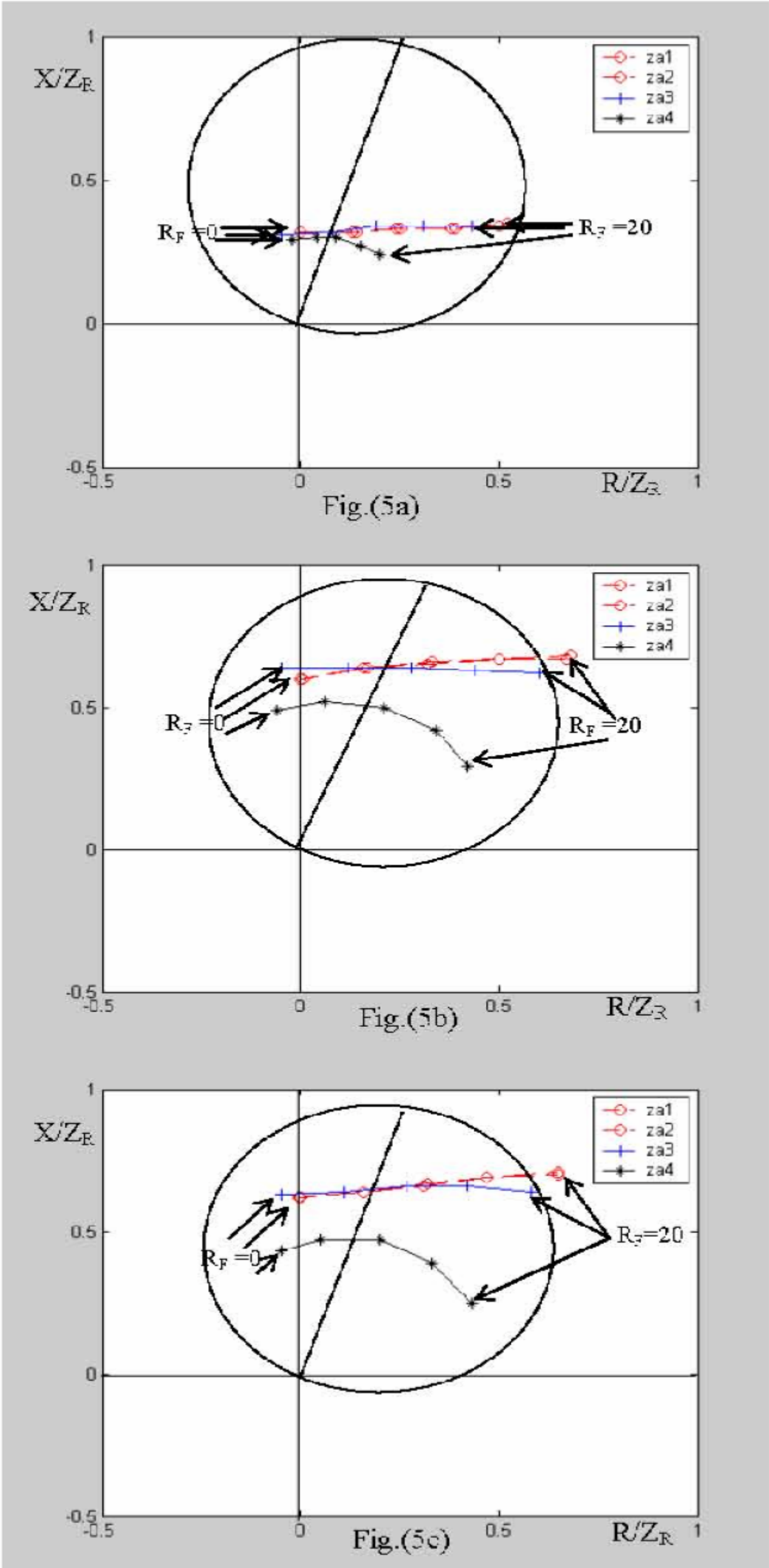


Fig.(5) The response of mho elements when DLG fault occurs for different value of resistance (a)Fault at F_1 (b)Fault at F_2 (c) Fault at F_3 .

Conclusion

The results on the performance of mho elements after analysis for steady state fault circuits (LG-fault & DLG-fault) for different value of fault resistance (R_F) indicate that:-

1-As a fault resistance has been increased, the apparent impedance of mho elements moves out of the characteristic and this, means that the relay will fail to operate (under reach)

2-The effect of (R_F) on the directional of mho element in case of LG-fault was more than in case of 2LG-fault.

3- The effect of (R_F) on the directional of mho element was decreased when the fault is more nearer to the relay location.

4-Apparent impedance measured by mho relay became ($Z_F + R_F$)instead of Z where Z_F is the impedance between relay & fault location. From these results it was evident that, at a certain value of fault resistance, some of mho elements became non directional (apparent impedance becomes outside of the relay characteristic) while other types was still directional (apparent impedance still inside the relay characteristic). On the other hand, the response of mho element depending on the type of polarization.

Reference

1-R.J.Marttila, "Directional Characteristic of Distance Relay Mho Elements" Part I.A new method of analysis,Part II.Results IEEE Trans. On power Apparatus and System,Vol.PAS-100,No.1, January 1981.

2- Noha Abed Al-bary Al-Jawady, "Effect of loading on the performance of mho relays with two phases fault" M.Sc. Thesis, University of Mosul, 1998.

3-Turan Gonen, "Modern Power System Analysis" John Wiley & Sons, INC. 1988

Appendix (A)

Calculation of apparent impedance

An apparent impedance method of representing mho element response can be derived from the fact that the mho characteristic always passes through the origin and the reach point if k_3 & k_4 are zero. Thus an alternate set of phase comparison vectors, such as:

$$\bar{S}_1 = \bar{V}_\phi - \bar{I}_\phi Z_R \qquad \text{.......(A1)}$$

$$\bar{S}_2 = \bar{V}_\phi \qquad \text{.......(A2)}$$

Would define a mho characteristic on the $\bar{Z}_\phi$=R+jX plane having these features. This characteristic would define the range of impedance ($\bar{Z}_\phi$) for which the mho element operates. The general phase comparison vectors, S_1 & S_2 can be transformed into vectors $\bar{S}_1$ & $\bar{S}_2$ by defining.

$$\bar{V}_\phi = K_2 V_\phi + K_3 I_\phi Z_R + K_4 V_P$$

$$\bar{I}_\phi = I_\phi (1 + K_3) + \frac{K_4 V_P}{Z_R} + \frac{K_2 - K_1}{Z_R} V_\phi \qquad \text{......(A}_4\text{)}$$

With this transformation, all mho elements willhave a fixed characteristic represented by a circle passing through the origin and the reach point Z_R on the $\bar{Z}_\phi$ plane, $\bar{Z}_\phi$ is referred to as an apparent impedance and is defined as :

$$\bar{Z}_\phi = \frac{\bar{V}_\phi}{\bar{I}_\phi} = \frac{K_2 V_\phi + K_3 I_\phi Z_R + K_4 V_P}{I_\phi (1 + K_3) + \frac{K_4 V_P + (K_2 - K_1) V_\phi}{Z_R}} \qquad \text{....(A}_5\text{)}$$

And from this equation we see that:

$$\bar{Z}_\phi = Z_R \frac{S_2}{S_2 - S_1} \qquad \text{.....(A}_6\text{)}$$

To determine the response of any mho element to any fault type, this apparent impedance is calculated and compared with the fixed circular characteristic on the $\bar{Z}_\phi$ plane.

Appendix (B)

Operating equations for mho element types

Mho element No.1

Operating equations:-

$S_1=V_\Phi-I_\Phi Z_C$

$S_2= \mathbf{V}_\Phi$

Where Z_C is reach setting impedance.

The variable for the various element types are listed below.

Element type	I_Φ	$\mathbf{V}_\Phi$
A-G	$I_A+k_o\, I_N$	V_A
B-G	$I_B+k_o\, I_N$	V_B
C-G	$I_C+k_o\, I_N$	V_C
A-B	I_{AB}	V_{AB}
B-C	I_{BC}	V_{BC}
C-A	I_{CA}	V_{CA}

Where $k_o=1/3(Z_0/Z_1-1)$=neutral compensation.

Mho element No.2

Operating equations:-

$S_1=V_\Phi-I_\Phi Z_C$

$S_2= \mathbf{V}_\Phi+k_3\, I_\Phi Z_C+k_4 V_p$

Element type	I_Φ	$\mathbf{V}_\Phi$	V_p	k_3	k_4
A-G	$I_A+k_o\, I_N$	V_A	V_{BC}	-0.001	0.02
B-G	$I_B+k_o\, I_N$	V_B	V_{CA}	-0.001	0.02
C-G	$I_C+k_o\, I_N$	V_C	V_{AB}	-0.001	0.02
A-B	I_{AB}	V_{AB}	V_{CA}	-0.001	-0.02
B-C	I_{BC}	V_{BC}	V_{AB}	-0.001	-0.02
C-A	I_{CA}	V_{CA}	V_{BC}	-0.001	-0.02

Mho element No.3

Operating equations:-

$S_1=V_\Phi-I_\Phi Z_C$

$S_2= \mathbf{V}_\Phi +k_4 V_p$

Element type	I_Φ	$\mathbf{V}_\Phi$	$\mathbf{V}_P$	k_4
A-G	$I_A+k_o\, I_N$	V_A	V_C	-0.28<60
B-G	$I_B+k_o\, I_N$	V_B	V_A	-0.28<60
C-G	$I_C+k_o\, I_N$	V_C	V_B	-0.28<60
A-B	I_{AB}	V_{AB}	V_{CA}	-0.33<85

B-C	I_{BC}	V_{BC}	V_{AB}	-0.33<85
C-A	I_{CA}	V_{CA}	V_{BC}	-0.33<85

Mho element No.4

Operating equations:-

$S_1=V_\Phi-I_\Phi Z_C$

$S_2=V_P$

Element type	I_Φ	V_Φ	V_P
A-G	$I_A+k_o I_N$	V_A	$0.2V_{1R}(m)+0.8 V_{1R}$
B-G	$I_B+k_o I_N$	V_B	$(0.2V_{1R}(m)+0.8 V_{1R})a^2$
C-G	$I_C+k_o I_N$	V_C	$(0.2V_{1R}(m)+0.8 V_{1R})a$
A-B	I_{AB}	V_{AB}	$(0.2V_{1R}(m)+0.8 V_{1R})(1-a^2)$
B-C	I_{BC}	V_{BC}	$(0.2V_{1R}(m)+0.8 V_{1R})(a^2-a)$
C-A	I_{CA}	V_{CA}	$(0.2V_{1R}(m)+0.8 V_{1R})(a-1)$

Where V_{1R}=positive sequence voltage with respect to A-phase.

$V_{1R}(m)$=memorized positive sequence voltage.

Appendix (C)

Tables

Table(1) system data for fig.(1)

Network component	MVA Rating	Voltage rating kV	Z_1 Ω	Z_2 Ω	Z_o Ω
G_1	200	15	0+j0.45	0+j0.45	0+j0.1125

G_2	200	15	0+j0.45	0+j0.45	0+j0.1125
T_1	200	15/115	0+j26.45	0+j26.45	0+j26.45
T_2	200	15/115	0+j26.45	0+j26.45	0+j26.45
TL	200	115	0.02+j79.35	0.02+j79.35	0.02+j26.45

Table(2) apparent impedance for the types of mho relay When LG fault occurs .

Rf (Ω)		Fault at F_1 $Z_R=0.8Z_L$	Fault at F_2 $Z_R=0.8Z_L$	Fault at F_3 $Z_R=1.2Z_L$
0	Za_1	0.01+j0.17	-0.05+j0.3	0.02+j0.43
	Za_2	0.03+j0.17	-0.03+0.3	0.03+j0.42
	Za_3	0.05+j0.25	0+j0.4	0.09+j0.49
	Za_4	0.01+j0.33	0.01+0.05	0.02+j0.48
5	Za_1	0.3+j0.19	0.4+j0.4	0.36+j0.46
	Za_2	0.31+j0.19	0.4+j0.4	0.37+j0.46
	Za_3	0.32+j0.26	0.4+j0.5	0.37+j0.52
	Za_4	0.17+j0.32	0.3+j0.5	0.26+j0.48
10	Za_1	0.59+j0.22	0.76+j0.47	0.72+j0.5
	Za_2	0.61+j0.22	0.78+j0.5	0.71+j0.5
	Za_3	0.62+j0.29	0.76+j0.56	0.71+j0.57
	Za_4	0.34+j0.27	0.51+j0.4	0.51+j0.39
15	Za_1	0.9+j0.2	1.15+j0.5	1.08+j0.54
	Za_2	0.92+j0.24	1.17+j0.52	1.08+j0.54
	Za_3	0.95+j0.3	1.14+j0.65	1.08+j0.66
	Za_4	0.5+j0.17	0.7+j0.23	0.72+j0.22

20	Za_1	1.2+j0.26	1.6+j0.51	1.44+j0.62
	Za_2	1.2+j0.27	1.6+j0.54	1.37+j0.72
	Za_3	1.28+j0.42	1.6+j0.77	0.9+j0.64
	Za_4	0.61+j0.06	0.82+j0.01	-0.16-0.57

Table(3) an apparent impedance for the types of mho relays

When DLG fault occurs.

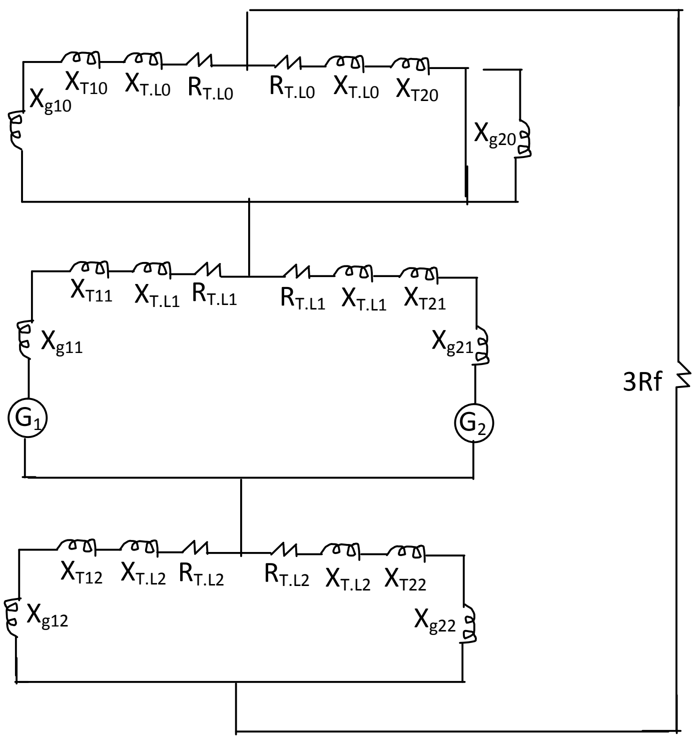
R_F		Fault at F_1 $Z_R=0.8Z_L$	Fault at F_2 $Z_R=0.8Z_L$	Fault at F_3 $Z_R=1.2Z_L$
0	Za_1	0.0+j0.32	-0.001+j0.6	-0.005+j0.62
	Za_2	0.0+j0.32	0.005+jo.6	0.001+j0.62
	Za_3	-0.05+j0.31	-0.05+j0.64	-0.05+j0.63
	Za_4	-0.02+j0.29	-0.06+j0.49	-0.05+j0.43

5	Za_1	0.13+j0.32	0.16+j0.64	0.16+j0.64
	Za_2	0.14+j0.32	0.17+j0.64	0.16+j0.64
	Za_3	0.08+j0.32	0.12+j0.64	0.11+j0.64
	Za_4	0.04+j0.3	0.06+j0.52	0.05+j0.47
10	Za_1	0.24+j0.33	0.32+j0.65	0.31+j0.66
	Za_2	0.25+j0.33	0.33+j0.66	0.32+j0.67
	Za_3	0.19+j0.34	0.28+j0.64	0.27+j0.66
	Za_4	0.09+j0.3	0.21+j0.5	0.2+j0.47
15	Za_1	0.38+j0.33	0.5+j0.67	0.47+j0.69
	Za_2	0.39+j0.33	0.5+j0.67	0.47+j0.69
	Za_3	0.31+j0.34	0.44+j0.63	0.42+j0.66
	Za_4	0.15+j0.27	0.34+j0.42	0.33+j0.39
20	Za_1	0.5+j0.34	0.67+j0.67	0.65+j0.7
	Za_2	0.52+j0.35	0.68+j0.68	0.65+j0.71

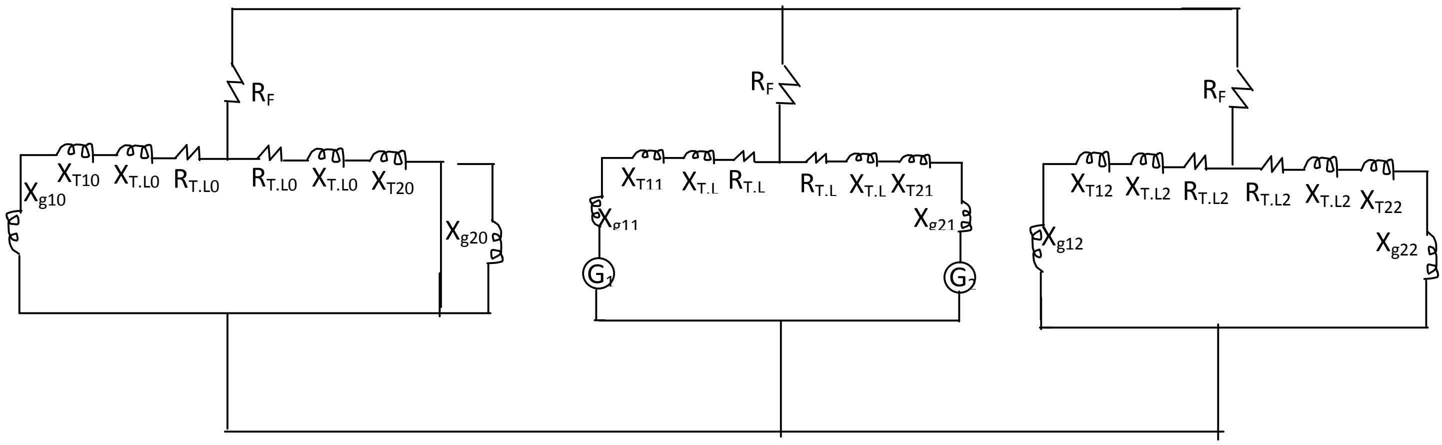
	Za_3	0.43+j0.34	0.6+j0.62	0.58+j0.64
	Za_4	0.2+j0.24	0.42+j0.29	0.43+j0.25

Appendix (D)

Figures



Fig(2) equivalent circuit of network for (LG) fault



Fig(3) equivalent circuit of network for (DLG) fault

The work was carried out at the college of Engg. University of Mosul