Alex. Eng.J., Alex. Univ., Volume 28 No. 4, pp 343-360 (1989)

DETERMINATION OF THE DISTANCE RELAY CHARACTERISTICS AS A FUNCTION OF THE SOURCE-LINE IMPEDANCE RATIO

Samir Deghedi*, Fathy Mabrouk** and Kamelia Youssef***

* Prof. in Electrical Engineering Department,
Faculty of Engineering, Alexandria University
Present Delegated to Faculty of Engineering, Beirut University
as head of Electrical Engineering Department

** Lecturer, Electrical Engineering Depatment,
Faculty of Engineering, Alexandria University

*** Director of High Voltage Department,
Alexandria Electrical Distribution Co.,

Abstract

For any distance protection scheme, the ratio of source-line impedance as seen by the relaying point should be calculated to determine the most suitable relay characteristic. The ratio is calculated from the short circuit analysis of the network under consideration. As an example in the Alexandria 66-30 kV network, it was found that relays with Mho characteristics are the most suitable for protection purposes.

1. Introduction

The overcurrent relay is the simplest method to protect transmission lines. The operating signal of the overcurrent relay depends upon the value of the fault current. For all types of faults, the fault current is considerably higher than the maximum load current. In medium and low voltage distribution circuits, the used lines are usually of relatively short length. Moreover, they have a large cross-sectional area, i.e., low resistance per Km. This causes a large current to flow in case of short circuit even at the farthest end of the transmission line. With high and extra high voltage transmission circuits that transfer large energies over long and very long distances, the situation is quite different and more complex, since the lines, generally have a high impedance per Km. Then, the faults at the end of such lines or elsewhere along the line cause fault currents which may be of the same order or even less than the load current. Overcurrent relays are not used under such cases and other means of detecting faults have to be adopted. The distance relay, for instance, is an apparatus which can discriminate accurately between healthy and faulty line conditions even with a weak supply and far away faults which may cause fault currents of magnitude less than the load current as stated before [1].

The distance relay measures the impedance between the relay and the fault. Since the impedance of the line per unit length is known, then the measured impedance by the relay is a measure of the distance between the relay and the fault.

The basic principle of measurement involves the measurement of the fault current and voltage at the relaying point, dividing these two quantities we obtain the impedance of the line up to the point of fault.

In the past two decades, distance relays of special characteristics were widely used for the protection of high voltage transmission lines. These were Mho, offset Mho, quadrilateral etc. Their characteristics are created from impedance, reactance and Mho characteristics. To get the best characteristics of distance relays for specified high voltage networks, it is essential to calculate the ratio of Z_s/Z_L at the relaying point. From values of Z_s/Z_L we can calculate also the value of the voltage at the relaying point.

The Alexandria zone (66 kV-30kV) network have been analysed during fault conditions to calculate the ratio Z_s/Z_L and voltage at the relaying point. From these values a choice of the most suitable distance relay characteristic is made.

2. Short Circuit Studies

The short circuit calculations provide currents and voltages for any point of a power system during fault conditions. The majority of short circuit studies involve only the calculation of three-phase and line-to-ground faults.

The single line diagram of the Alexandria zone 66 kV - 30 kV network, shown in Fig. (1), is considered for our studies. These studies involve the short circuit analysis for the following cases:

1. Case A : if the coupler of Moharam Bey sub-station is disconnected

2. Case B : if the coupler of Moharm Bey is disconnected and no connection between Semoha and Gleem sub-station
3. Case C : if the coupler of Moharm Bey is connected
4. Case D : if coupler of Moharm Bey is connected and no connection between Semoha and Gleem S.S.
5. Case E : if the coupler of Moharm Bey and Siof thermal are disconnected
6. Case F : if the coupler of Moharm Bey is connected and coupler of Siof thermal is disconnected
7. Case G : if the coupler of Moharm Bey, Gleem and Siof thermal are disconnected, and Semoha is supplied from Gleem

A computer program has been written to estimate the short circuit level at all buses for three-phase short circuit. Table (1) shows the values of three-phase short circuit MVA for all cases, assuming 10 MVA and 66 kV as base values.

3. Source Impedance Determination with Data From Network Analysis for 3-phase fault [2]

The source impedance is the total impedance between the source and the short circuit point. With respect to a distance relay and a fault just ahead of it, it is taken as the impedance behind the relay up to the source, this then results in the smallest source impedance.

For other fault locations along the line it varies as it becomes dependent on the right hand side impedance. Source impedance is therefore not an invariable quantity even for a definite relay location.

ALL TRANSFORMER'S CAPACITY IN MVA.

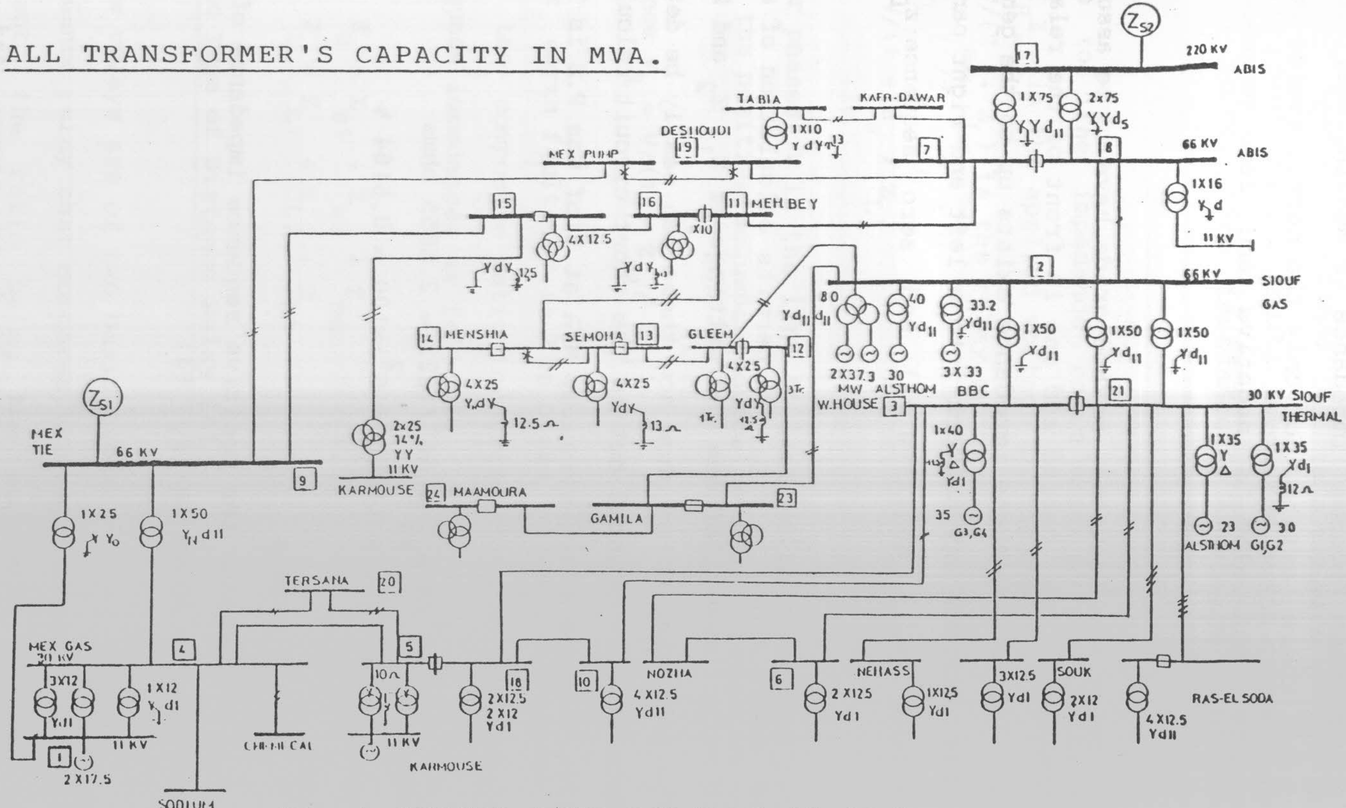

Fig.1 SINGLE LINE DIAGRAM 66-30KV
of
ALEXANDRIA ZONE

During load conditions source impedance is meaningless, for faults involving ground there exists, not only the normal source impedance positive sequence, but also a negative and zero sequence source impedance.

For distance relay applications, meshed grids have to be assumed fed from two directions one behind and one in front of the relay. Then also for the latter a source impedance exists up to the generator. Thus the relay divides any network into a left and right part, each has its positive (z_1), negative(z_2) and zero sequence(z_0) components.

A simplified model shown in Fig. (2) permits calculation of all data required for relay investigations and settings if Z_1, Z_2 and Z_o are known. The following notes show how these can easily be determined from the data usually printed out in the short circuit calculations. From table (1), 3-phase short circuit, MVA at Siof Gas P.S is 1622 MVA and 66 kV,

The $Z_{source} = kV^2/MVA_{sc} = 66^2/1622 = 2.6855$ ohms

$Z_{source}\% = 2.6855 \times (10000/66^2) \times 100 = 0.6164\ \%$

$Z_{1left} = Z\ \%$

$= 0.6164\ \%$

Z_{1right} represents the positive sequence impedance of Siof-Gleem line as shown in Fig. (3)

3.1 Z_s/Z_L Ratio [3]

The impedance Z_s and Z_L are described as source and line impedances because of their position with respect to the relay position. Source impedance Z_s is a measure of the fault level at relaying point and for faults involving earth it is dependent upon the relaying point. Line impedance is a measure of the impedance of the protected zone.

Source to line impedance ratio means by the following expressions:

$V_R = I_R Z_L$ is the applied voltage to the relay

$I_R = V/(Z_s + Z_L)$ is the relay current

$V_R = Z_L\ (1/Z_s + Z_L\ )\ V$

$= V/(1 + Z_s\ /\ Z_L)$

a. For phases; V is the line to line voltage and the ratio (Z_s/Z_L) is the positive sequence source to line impedances ratio

hence $V_R = V/(1 + Z_{s1}/\ Z_{L1})$

b. For earth faults; V is the phase to neutral voltage and the ratio is the composite ratio involving the positive, negative and zero sequnce impedances as follows

$$Z_s = Z_{s1} + Z_{s2} + Z_{so}$$
$$Z_L = Z_{L1} + Z_{L2} + Z_{Lo}$$

4. Basic Type of Distance Relay [4]

Distance relays are of two basic types:

a. Impedance relay that compares the magnitudes of the voltage and the current, the ratio being the magnitude of the impedance. The characteristic is a straight line on the impedance diagram, a circle with the origin as its center in the R,X plane as shown in

Fig. (5b).

b. Reactance relay that compares the magnitude of the component of the voltage 90^{o} out of phase with the current, the ratio being the reactance up to the fault point as shown in Fig. (4).

Several modified typed of relays have been developed, the characteristics of these relays are essentially a modification of, or a combination of, the characteristics of impedance or reactance relays

The purpose of these special relays has been to minimize the danger of undesired relay operation during load swings or other system disturbances, while retaining or improving the ability of the relay to operate for faults in the protected zone with fault resistance present.

The Mho characteristics is generally known as an admittance because its characteristic is a straight line on the admittance diagram. The Mho relay is clearly directional and the characteristic of this relay when plotted on the R/X diagram will be a circle whose cirumference passes through the origin as shown in Fig. (5c), while that of Fig. (5a) represent an offset Mho relay characteristic.

5. Variation of Relay Characteristic with Source Impedance

The suitability of relay characteristics for the protectaon of transmission depends upon the nature of the line or the ratio Z_s/Z_L. For low Z_s/R_L the impedance characteristics of the relay should be a circle and for high ratio it should be a straight line - circle of infinite radius. For intermediate values of the ratio, the intermediate curves would be satisfactory The variable

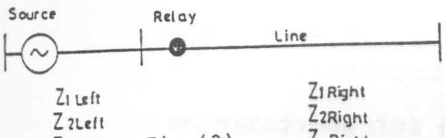

Fig.(2)

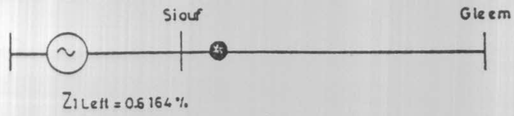

Fig.(3)

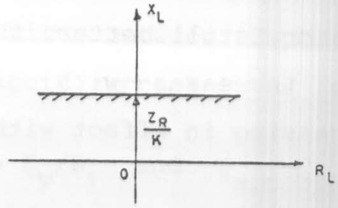

Fig.(4) Reactance characteristic.

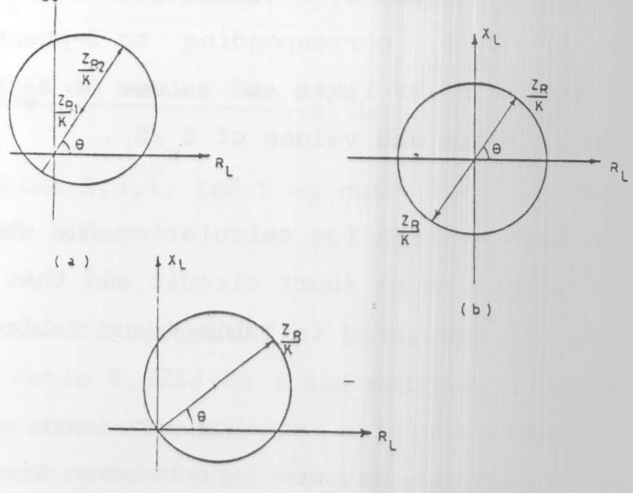

Fig (5) a - Offset impedance characteristic.

b - impedance characteristic.

c - Mho characteristic.

characteristic can be obtained from a Mho relay on phase fault by polarizing it with voltage from the leading unfaulted phase pair. The polarized Mho relay has an offest Mho characteristic, Fig. (5a), the degree of offest is a function of Z_s/Z_L

Since reactance relays are preferable for short lineas (Z_s/Z_L = infinity) and Mho relays for long lines (Z_s/Z_L= suitable value), it would be advantageous if the relay could adjust its characteristic to suit the length of the line or, still better, the ratio Z_s/Z_L, since the fault resistance increases with diminishing current (increasing Z_s) as well as increasing in effect with decreasing Z_L as shown in Fig. (6)

From table (1) and data of 66 kV and 30 kV transmission lines, we can calculate the values of Z_s/Z_L corresponding to 3-phase short circuit Table (2) respresents 66 kV lines and values of Z_s/Z_L Table (3) represents 30 kV lines and values of Z_s/Z_L.

A computer program has been written for calculating the short circuit level at all buses for single-phase short circuit and then the values of Z_s/Z_L are calculated, and tabulated in Table(4) and Table(5).

For phase fault Z_L represents positive sequence impedance of line at first step of the relay setting, say for line between Siof and Gleem 66kV,

$$Z_{lin} = 0.235 \times 7.5 = 1.762 \text{ ohm}$$

$$Z_{line}\% = Z_{lin} \times MVA_b \times 100/(kV_b)^2$$

$= 0.404\ \%$

$Z_{L1} = 0.8\ Z_{line}$

$= 0.3235\ \%$

And from computer results $Z_s = 0.6164\ \%$

Hence $Z_s/Z_L = 1.9039$ and so on

Note the relation between 2-phase short circuit current and three-phase short circuit current is as follow

$$I_{s.c.3\text{-}ph} = E_y/Z_1 \quad \text{and} \quad I_{s.c.2ph\ \text{without earth}} = \frac{\sqrt{3}\ E_Y}{2\ Z_1} = 0.866\ I_{s.c\ 3\text{-}ph}$$

Hence Z_s % (for 2-phase) = $(1/0.866) Z_s$ % (for 3-phase)

6. Results of values for Z_s/Z_L

From Tables 2,3,4, and 5 we get

For 66 kV lines :

(3-phase short circuit):

minimum ratio 0.7254 to 1 and maximum ratio 15.8432 to 1

(2-phase short circuit):

minimum ratio 0.8376 to 1 and maximum ratio 18.2946 to 1

(1-phase short circuit):

minimum ratio 0.833 to 1 and maximum ratio 38.837 to 1

For 30 kV lines

(3-phase short circuit):

minimum ratio 0.451 to 1 and maximum ratio 3.849 to 1

Table (1)
Values of 3-phase short circuit (all values in MVA)

Bus No	Name	case A	case B	case C	case D	case E	case F	case G
1	Mex P.S	813	808	817	928	813	817	808
2	Siouf gas P.S	1622	1235	2155	1235	1612	5145	1235
3	Siouf thermal P.S	1245	1110	1375	1110	890	967	890
4	30 KV Mex P.S	742	436	748	1927	742	747	436
5	Karmouz P.S	600	598	603	1565	600	603	598
6	Nehass S .S	1004	915	1086	915	508	522	508
7	Abis S.S	1182	584	1515	1230	1180	1513	70
8	"	1290	1060	1555	1060	1255	1513	1060
9	Mex 66 KV	3385	3100	3721	3280	3385	3718	3100
10	Nozha S.S	950	870	1023	870	582	614	582
11	Meharram-bey S.S	1268	480	–	–	1264	–	64
12	Gleem S.S	1410	990	2120	990	1405	2113	840/990 bus1/bus2
13	Semouha S.S	1366	445	2146	1237	1360	2140	930
14	Menshia S.S	1311	465	2222	1404	1306	2217	64
15	Wardian S.S	2135	1910	2640	2065	2135	2636	1910
16	Meharram-bey S.S	1495	1380	2350	1595	1495	2346	1380
17	Abis S.S(220KV)	7817	7817	7819	7818	7188	7819	7817
18	Karmouse P.S	590	560	618	560	450	469	450
19	Deshoudi S.S	1462	1097	1476	1325	1460	1475	66
20	Tersana S.S	611	608	615	1590	611	614	608
21	Siouf thermal P.S	–	–	–	–	617	637	617
22	Nozha S.S	–	–	–	–	488	502	488
23	Gamila S.S	–	–	–	–	–	–	1030

NAME	LENGTH IN Km.	SIZE Ω/Km	Z_{LI} = 0.8 Z_L%	CASE A Zs%	CASE A Zs/ZLI	CASE B Zs%	CASE B Zs/ZLI	CASE C Zs%	CASE C Zs/ZLI	CASE D Zs%	CASE D Zs/ZLI	CASE E Zs%	CASE E Zs/ZLI	CASE F Zs%	CASE F Zs/ZLI	LIMIT OF Zs/ZLI
SIOUF-GLEEM	7.50	0.235	0.3235	0.6164	1.9037	0.8104	2.5028	0.4639	1.4340	0.8104	2.5051	0.6204	1.9177	0.4661	1.4408	1.4340:2.5051
GLEEM-SIOUF	7.50	0.235	0.3235	0.7088	2.1875	1.0098	3.1214	0.4718	1.4584	1.0098	3.1183	0.7121	2.2012	0.4732	1.4627	1.4584:3.1214
GLEEM-SEMOHA	4.95	0.1124	0.1022	0.7088	6.9375	——	disconnected	0.4718	4.6164	——	disconnected	0.7121	6.9677	0.4732	4.6301	4.6164:6.9375
SEMOHA-GLEEM	4.95	0.1124	0.1022	0.7319	7.1625	——	"	0.4659	4.5587	——	"	0.7351	7.1927	0.4672	4.5714	4.5587:7.1625
MENSH.-SEMOHA	7.20	0.1124	0.1548	0.7625	4.9250	2.1626	13.9700	0.4499	2.9063	0.7124	4.6020	0.7655	4.9450	0.4509	2.9120	2.9063:13.970
SEMOHA-MENSH.	7.20	0.1124	0.1548	0.7319	4.7250	2.2500	14.5930	0.4659	3.0096	0.8084	5.2227	0.7351	4.7487	0.4687	3.0180	3.0096:14.593
MENSH.-M.B	6.00	0.1240	0.1365	0.7625	5.5836	2.1626	15.8432	0.4499	3.2959	0.7124	5.2190	0.7655	5.6080	0.4509	3.3032	3.2959:15.843
M.B-MENSH.	6.00	0.1240	0.1365	0.7884	5.7725	2.0776	15.2200	0.4254	3.1164	0.8084	5.9223	0.7911	5.7956	0.4262	3.1223	3.1164 :15.22
WARDIAN-M.B	5.00	0.3490	0.3204	0.4685	1.4622	0.5227	1.6313	0.3789	1.1825	0.4839	1.5103	0.4957	1.5471	0.3793	1.1838	1.1825:1.6313
M.B-WARDIAN	5.00	0.3490	0.3204	0.6685	2.0864	0.7232	2.2571	0.4254	1.3277	0.6274	1.9581	0.6959	2.1719	0.4262	1.3302	1.3277: 2.2571
WARDIAN-MEX TL	5.00	0.3490	0.3204	0.4685	1.4622	0.5227	1.6313	0.3789	1.1825	0.4839	1.5102	0.4957	1.5471	0.3793	1.1838	1.1825:1.6313
MEX TL-WARDIAN	5.00	0.3490	0.3204	0.2954	0.9218	0.3225	1.0062	0.2687	0.8386	0.3048	0.9513	0.2955	0.9222	0.2689	0.8392	0.8386:1.0062
M.B-ABIS	7.50 +3.80	0.3490 +0.1240	0.5864	0.7884	1.3443	2.0776	3.5429	0.4254	0.7254	0.6274	1.0699	0.7911	1.3491	0.4262	0.7268	0.7254:3.5429
ABIS-M.B	7.50 +3.80	0.3490 +0.1240	0.5864	0.8457	1.4421	1.7116	2.9187	0.6602	1.1258	0.8124	1.3854	0.8474	1.4450	0.6608	1.1268	1.1258:2.9187

0.7254:15.8432

Table(2) 66 KV Lines, Values of Zs/ZLI.
3-phase short circuit.

NAME	LENGTH IN Km	SIZE Ω/Km	Z_{LI} 0.8 Z_L%	CASE A Zs%	CASE A Zs/ZLI	CASE B Zs%	CASE B Zs/ZLI	CASE C Zs%	CASE C Zs/ZLI	CASE D Zs%	CASE D Zs/ZLI	CASE E Zs%	CASE E Zs/ZLI	CASE F Zs%	CASE F Zs/ZLI	LIMIT OF Zs/ZLI
SIOUF-SOUK 2	2.225	0.1704	0.336	0.8034	2.391	0.8998	2.677	0.7275	2.165	0.8998	2.677	1.1239	3.344	1.0333	3.075	2.165: 3.344
SOUK 2/3 - SIOUF	2.225	0.1704	0.336	0.8474	2.522	0.94336	2.807	0.7716	2.296	0.94336	2.807	1.1679	3.475	1.0773	3.206	2.296 :3.475
SIOUF-SOUK 5/14	2.425	0.204	0.439	0.8034	1.830	0.8998	2.049	0.7275	1.657	0.8998	2.049	1.6202	3.690	1.5674	3.570	1.657:3.690
SOUK5-SIOUF	2.425	0.204	0.439	0.8367	1.905	0.9301	2.118	0.7592	1.657	0.9301	2.118	1.6519	3.762	1.5991	3.642	1.657:3.762
SIOUF-NOZHA 1	7.300	0.1704	1.104	0.8034	0.727	0.8998	0.815	0.7275	0.658	0.8998	0.815	1.1239	1.018	1.5674	1.419	0.658:1.419
NOZHA 1-SIOUF	7.300	0.1704	1.104	1.1585	1.049	1.2646	1.145	1.075	0.973	1.2646	1.145	1.7184	1.556	1.9931	1.805	0.973 : 1.805
SIOUF-NOZHA 3	7.650	0.204	1.385	0.834	0.580	0.8998	0.649	0.7275	0.525	0.8998	0.649	1.6202	1.169	1.0333	0.746	0.525:1.169
NOZHA 3-SIOUF	7.650	0.204	1.385	1.1585	0.836	1.2646	0.913	1.075	0.776	1.2646	0.913	2.0459	1.477	1.6279	1.175	0.776 : 1.477
NOZHA-KARMOZ	5.000	0.1704	0.756	1.1585	1.530	1.2646	1.672	1.075	1.421	1.2646	1.672	1.7184	2.273	1.6279	2.153	1.421 : 2.273
KARMOZ-NOZHA	5.000	0.1704	0.756	1.8615	2.462	1.9675	2.602	1.778	2.352	1.6975	2.245	2.2202	2.936	2.1303	2.8178	2.245:2.936
NEHAS-NOZHA	3.758	0.1533	0.511	1.0961	2.145	1.8083	2.352	1.0126	1.981	1.2023	2.352	1.967	3.849	1.9142	3.745	1.981 : 3.849
SIOUF-RAS SODA1	8.700	0.2085	1.611	0.8034	0.498	0.8998	0.558	0.7275	0.451	0.8998	0.558	1.6202	1.005	1.5674	0.972	0.451:1.005
RAS SODA1-SIOUF	8.700	0.2085	1.611	0.8927	0.554	0.990	0.614	0.8196	0.508	0.990	0.614	1.7111	1.062	1.6583	1.029	0.508:1.062
SIOUF-RAS SODA3	9.000	0.1704	1.361	0.8034	0.590	0.8998	0.661	0.7275	0.534	0.8998	0.661	1.6202	1.190	1.5674	1.151	0.534:1.6202
RAS SODA3-SIOUF	9.000	0.1704	1.361	0.8927	0.655	0.990	1.108	0.8196	0.602	0.990	1.108	1.7111	1.257	1.6583	1.218	0.602: 1.257
SIOUF-RAS SODA4	5.096 +2.800	0.1704 +0.1533	1.151	0.8034	0.698	0.8998	0.781	0.7275	0.632	0.8998	0.781	1.6202	1.407	1.5674	1.361	0.632 : 1.407
RAS SODA4-SIOUF	5.096 +2.800	0.1704 +0.1533	1.151	0.8927	0.775	0.990	0.860	0.8196	0.712	0.990	0.860	1.7111	1.486	1.6583	1.440	0.712 : 1.486
SIOUF-NEHASS 1	4.05	0.2085	0.749	0.8034	1.072	0.8998	1.201	0.7275	0.971	0.8998	1.201	1.1239	1.500	1.0333	1.379	0.971 : 1.500
NEHASS1-SIOUF	4.05	0.2085	0.749	1.0961	1.460	1.2023	1.605	1.0126	1.352	1.2023	1.605	1.2208	1.629	1.0933	1.459	1.352:1.629
SIOUF-NEHASS 3	6.80	0.1305	0.768	0.8034	1.019	0.8998	1.142	0.7275	0.923	0.8998	1.142	1.6202	2.056	1.5674	1.989	0.923 : 2.056
NEHASS 3-SIOUF	6.800	0.1305	0.788	1.0961	1.390	1.2023	1.525	1.0126	1.285	1.2023	1.525	1.967	2.496	1.9142	2.429	1.285 : 2.496

0.451: 3.849

Table(3) 30 KV Lines, Values of Zs/ZLI,
3-Phase Short-Circuit.

$Z_{LI} = 0.8\, Z_{L\Lambda} \left(\frac{10.000}{(30)^2 \times 10} \right)$

NAME	LENGTH In Km.	SIZE Ω/Km	Z_L	CASE A		CASE B		CASE C		CASE D		CASE E		CASE F		LIMIT OF
				Zs%	Zs/ZL	Zs%	Zs/ZL	Zs%	Zs/ZL	Zs%	Zs/ZL	Zs%	Zs/ZL	Zs%	Zs/ZL	Zs/ZL
SIOUF-GLEEM	7.5	0.2350	1.335	1.6949	1.269	2.050	1.565	1.388	1.039	2.090	1.565	1.7031	1.275	1.392	1.042	1.039: 1.565
GLEEM-SIOUF	7.5	0.2350	1.335	2.2900	1.715	2.757	2.065	1.809	1.355	2.757	2.065	2.296	1.719	1.812	1.357	1.357: 2.065
GLEEM-SEMOHA	4.95	0.1124	0.658	2.2900	3.480	—	DISCONNECT	1.809	2.749	—	DISCONNECT	2.295	3.489	1.812	2.753	2.749: 3.480
SEMOHA-GLEEM	4.95	0.1124	0.658	2.596	3.940	—	"	2.054	3.121	—	"	2.603	3.955	2.056	3.124	3.124 : 3.955
MENSH.-SEMOHA	7.20	0.1124	0.958	3.029	3.162	31.837	33.230	2.385	2.480	6.748	7.040	3.035	3.168	2.386	2.450	2.480:31.837
SEMOHA-MENSH.	7.20	0.1124	0.958	2.596	2.709	32.316	33.730	2.054	2.144	7.227	7.540	2.603	2.717	2.056	2.146	2.144:32.316
MENSH.-M.B	6.00	0.124	0.823	3.029	3.680	31.837	38.680	2.385	2.897	6.748	8.199	3.035	3.687	2.386	2.899	2.897:38.837
M.B-MENSH.	6.00	0.124	0.823	3.389	4.117	31.426	38.180	2.635	3.201	6.3371	7.700	3.395	4.125	2.637	3.204	3.201:31.426
WARDIAN-M.B	5.00	0.349	1.762	7.548	4.283	22.830	12.956	3.012	1.709	5.571	3.161	7.549	4.284	3.013	1.709	1.709:22.830
M.B-WARDIAN	5.00	0.349	1.762	8.429	4.783	23.710	13.456	2.635	1.495	6.3371	3.596	8.430	4.784	2.637	1.496	1.495:23.710
WARDIAN-HEX TL	5.00	0.349	1.762	7.548	4.283	22.830	12.956	3.012	1.709	5.571	3.161	7.549	4.284	3.013	1.709	1.709:12.956
HEX TL-WARDIAN	5.00	0.349	1.762	6.667	3.784	21.950	12.457	3.095	1.756	4.732	2.685	6.668	3.784	3.095	1.756	1.756:12.457
M.B-ABIS	7.50 + 3.80	0.349 + 0.124	3.164	3.3899	1.071	31.426	9.930	2.635	0.832	6.3371	2.002	3.395	1.073	2.637	0.833	0.833: 9.930
ABIS-M.B	7.50 + 3.80	0.349 + 0.124	3.164	4.530	1.431	29.844	9.432	4.110	1.298	7.373	2.330	4.533	1.432	4.112	1.299	1.298: 9.432

0.833:38.837

Table(4) 66 KV lines, Values of Zs/ZL.
1-phase short circuit

$Zs = 2Z_{s1} + Z_{s0}$

$Z_L\% = 0.8(2Z_{L1} + Z_{L0})_\Omega \left(\frac{10,000}{66^2 \times 10}\right)$

NAME	LENGTH IN Km	SIZE Ω/Km	$Z_L\%$	CASE A		CASE B		CASE C		CASE D		CASE E		CASE F		LIMIT OF
				Zs%	Zs/ZL	Zs%	Zs/ZL	Zs%	Zs/ZL	Zs%	Zs/ZL	Zs%	Zs/ZL	Zs%	Zs/ZL	Zs/ZL
SIOUF-SOUK 2	2.225	0.1704	1.661	2.772	1.668	2.970	1.788	2.618	1.576	2.970	1.788	3.847	2.316	3.664	2.205	1.576:2.316
SOUK 2/3 - SIOUF	2.225	0.1704	1.661	3.602	2.168	3.800	2.287	3.448	2.075	3.800	2.287	4.677	2.815	4.494	2.705	2.075:2.815
SIOUF-SOUK 5/14	2.425	0.204	1.955	2.772	1.417	2.970	1.519	2.618	1.839	2.970	1.519	5.767	2.949	5.660	2.895	1.417:2.949
SOUK 5-SIOUF	2.425	0.204	1.955	3.420	1.749	3.620	1.852	3.269	1.672	3.620	1.852	6.418	3.282	6.311	3.228	1.672:3.282
SIOUF-NOZHA 1	7.300	0.1704	5.450	2.772	0.508	2.970	0.544	2.618	0.480	2.970	0.544	5.767	1.058	5.660	1.038	0.480:1.058
NOZHA 1-SIOUF	7.300	0.1704	5.450	3.966	0.727	4.165	0.764	3.813	0.699	4.165	0.764	7.898	1.449	7.791	1.429	0.699:1.449
SIOUF-NOZHA 3	7.650	0.204	6.168	2.772	0.449	2.970	0.481	2.618	0.424	2.970	0.481	3.847	0.623	3.664	0.594	0.424:0.623
NOZHA 3-SIOUF	7.650	0.204	6.168	3.966	0.642	4.165	0.675	3.813	0.618	4.165	0.675	6.736	1.092	6.553	1.062	0.618:1.092
NOZHA-KARMOZ	5.00	0.1704	3.733	3.966	1.062	4.165	1.115	3.813	1.021	4.165	1.115	6.736	1.804	6.553	1.755	1.021 : 1.804
KARMOZ NOZHA	5.00	0.1704	3.733	6.847	1.834	7.046	1.887	6.693	1.792	7.046	1.887	8.833	2.366	8.652	2.317	1.792:2.366
NEHAS NOZHA	3.758	0.1533	2.691	3.665	1.361	3.864	1.435	3.512	1.305	3.864	1.435	7.349	2.730	7.242	2.691	1.305:2.730
SIOUF-RAS SODA 1	8.700	0.2085	7.084	2.772	0.391	2.970	0.419	2.618	0.369	2.970	0.419	5.767	0.814	5.660	0.798	0.369:0.814
RAS SODA 1/2-SIOUF	8.700	0.2085	7.084	4.430	0.625	4.628	0.653	4.276	0.603	4.628	0.653	7.425	1.048	7.318	1.033	0.603:1.048
SIOUF-RAS SODA 3	9.00	0.1704	6.719	2.772	0.412	2.970	0.442	2.618	0.389	2.970	0.442	5.767	0.858	5.660	0.842	0.389:0.858
RAS SODA 3-SIOUF	9.00	0.1704	6.719	4.430	0.659	4.628	0.688	4.276	0.636	4.628	0.686	7.425	1.105	7.318	1.089	0.636: 1.105
SIOUF RAS SODA 4	5.095 + 2.80	0.1704 + 0.1533	5.809	2.772	0.477	2.970	0.511	2.618	0.450	2.970	0.511	5.767	0.992	5.660	0.974	0.450:0.992
RAS SODA 4-SIOUF	5.095 + 2.80	0.1704 + 0.1533	5.809	4.430	0.762	4.628	0.796	4.276	0.736	4.628	0.796	7.425	1.278	7.318	1.259	0.736:1.278
SIOUF-NEHASS 1	4.05	0.2085	3.297	2.772	0.840	2.970	0.900	2.618	0.794	2.970	0.900	5.767	1.749	5.660	1.716	0.794:1.749
NEHASS 1-SIOUF	4.05	0.2085	3.297	3.665	1.112	3.864	1.171	3.512	1.065	3.864	1.171	7.349	2.228	7.242	2.196	1.065:2.228
SIOUF-NEHASS 3	6.80	0.1305	4.595	2.772	0.603	2.970	0.646	2.618	0.569	2.970	0.646	3.847	0.837	3.664	0.797	0.569:0.837
NEHASS 3-SIOUF	6.80	0.1305	4.595	3.665	0.797	3.864	0.846	3.512	0.764	3.864	0.840	5.145	1.337	5.961	1.297	0.764:1.337

0.369:3.282

Table (5) 30 KV Lines, values of Zs/ZL,
1-phase short circuit

(2-phase short circuit):

minimum ratio 0.5207 to 1 and maximum ratio 4.4445 to 1

(1-phase short circuit :

minimum ratio 0.369 to 1 and maximum ratio 3.282 to 1

The Mho relay can operate with source to line impedance ratio of up to100 to 1 for phase faults and 60 to 1 for earth faults. The reactance relay can operate with source to line impedance ratio near infinity.

Then from the results of Z_s/Z_L of Alexandria Zone (66 kV - 30 kV); the Mho characteristic can be chosen for the given network

7. Relationship Between Source to Line Impedance Ratio and Relay Voltages

Since for any protection scheme, it is essential to calculate the ratio of Z_s/Z_L at the relaying point, in order to obtain the value of the voltage at the relaying point; it is necessary to calculate the value of Z_s/Z_{L1} at different relaying points.

Take some values of Z_s/Z_{L1} from Tables 2 and 3 and calculate the corresponding relay voltage from the relation;

$$V_R = V/(Z_s/Z_{L1} + 1)$$

Where V_R is the relay voltage

V is the line to line voltage for phase faults and equals to 100 volts for voltage transformer 66000/100 and 30000/100

The results are plotted in Fig. (7).

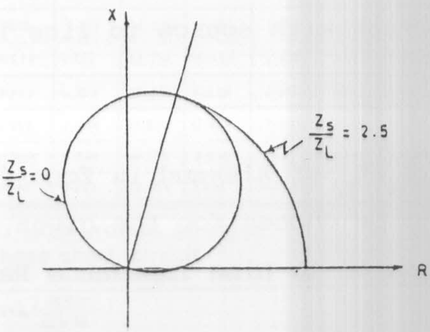

Fig.(6) Comparison between different values of $\frac{Z_S}{Z_L}$

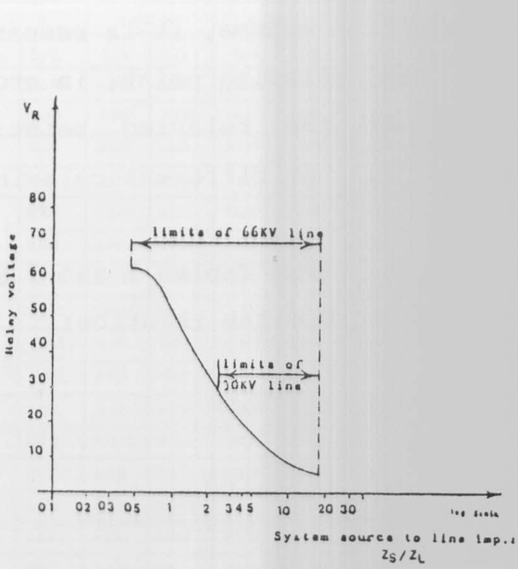

Fig.(7) Variation of relay voltage with system sourc line impedance ratio.

Conclusion

The distance relay has characteristics that depend upon the actual values of the input voltage and current. A practical distance relay consists of starting element, measuring element, directional element and timer, the heart of the distance relay is the measuring element which compares the current and voltage at the relaying point. The factors affecting the choice of the measuring element are Z_s/Z_{L1} ratio, fault resistance, power swing and loads.

For the practical example considered in this paper, Alexandria Zone 66 kV-30 kV) network, short circuit calculations have been carried out for 3-phase and single-phase to ground faults in order to calculate the ratio of Z_s/Z_{L1} at different locations and therefore determine the limits of operation of any distance relay for different short circuit points.

From the values of Z_s/Z_{L1}, the minimum voltage at different relaying points were calculated as given in Fig. (7). From the results obtained relays having Mho characteristics are recommended for the protection scheme in the Alexandria Zone (66 kV - 30 kV) for the following reasons:

1. The range of ratio Z_s/Z_L is within the range of the best operation of a Mho relay (ratio Z_s/Z_{L1} of up 100 to 1 for phase faults and 60 to 1 for earth faults [3].
2. Since in Alexandria Zone most of the transmission line network (66 KV - 30 kV) consists of under ground cables, the arc resistance is usually small. The Mho relay can operate satisfactorily since it can accomodate the arc resistance, Also, adjustment of the

characteristic angle is easly achieved to meet higher arc resistances.

3. The Mho characteristic is ideally suited for protecting long or heavily loaded transmission lines because it is less likely to trip on power swings than the conventional reactance or impedance relays

References

[1] Minimum Impedance Relay Discription 26/110 E-2b/ph 8-12-63 BBC
[2] BBC Brown Boveri Technical Fundamentals H.V Distance relay and protection Schemes
[3] GEC Measurement 1982 Protective Relays Application Guide
[4] Power System Protection and switchear C.S. JHA
[5] The Brown Boveri Review vol. 49. No. 5, Circle Digrams of Directional Impedance Relay.
[6] Protective Relay: Their Theory and practic, vol. (1-2). By: A.R. Van C. Warrington.