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COMPARISON BETWEEN THE CHARACTERISTICS OF DISTANCE RELAYS AND CHOOSING THE IDEAL ONE TO USE IN THE JORDANIAN SYSTEM

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Abstract:-
This paper compares among the impedance, mho, elliptical characteristics …etc. that are used in the distance relays, as well as in the third zone using MATLAB /SIMULINK tool box. The aim of this comparison is to determine the best characteristic that must be used in third zone to detect the faults which may occur on the transmission lines in the Jordanian system.

Keywords:- *Distance Relay, Characteristics, Impedance Relay, MAT Lab, Power System*

1 INTRODUCTION

Usually, distance relays are used to protect long transmission lines, the selection of the characteristic is very important to validate the best performance of the relay; this selection depends on the protected zone. For example, for the first zone, the reactance characteristic is used because it is the least affected characteristic by the arc [1]. For the second zone, the mho characteristic is best suited because it is the least affected by the power surges in comparison with the impedance and reactance characteristics. For the third zone, and in case of very long distances, multiple characteristics are used. However, throughout research it has been found that the elliptical characteristic is the best to use in the third zone. [2]
The characteristics of the distance relays have geometrical shapes [3]. The desired characteristic could be drawn from its equation.. MATLAB/SIMULINK tool box is utilized to produce an effective method and editing of the plots.

2 CHARACTERISTICS' EQUATIONS

The equation describes the impedance characteristic could be found using the circle equation.
As shown in figure (1), the circle is centered at the origin and has a radius of Z, so the equation of the impedance characteristic is

$X^2 + Y^2 = Z^2$……………………………………………………………………………….…………(1)

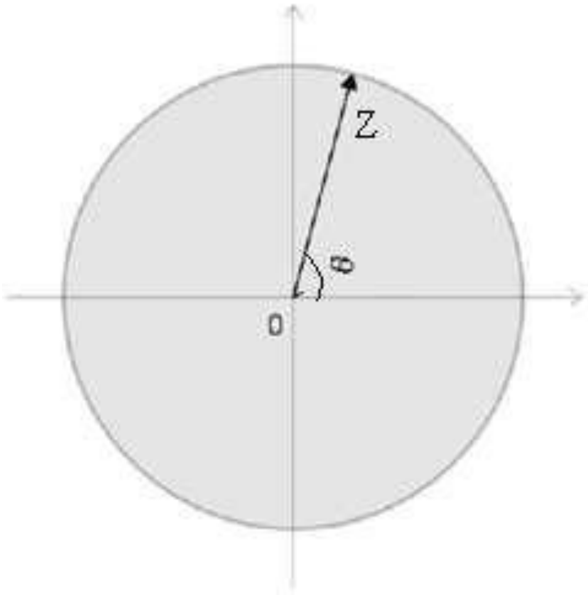

Figure 1 Impedance characteristic

Figure (2) shows the mho characteristic; using this figure and basic calculus we can determine its equation.

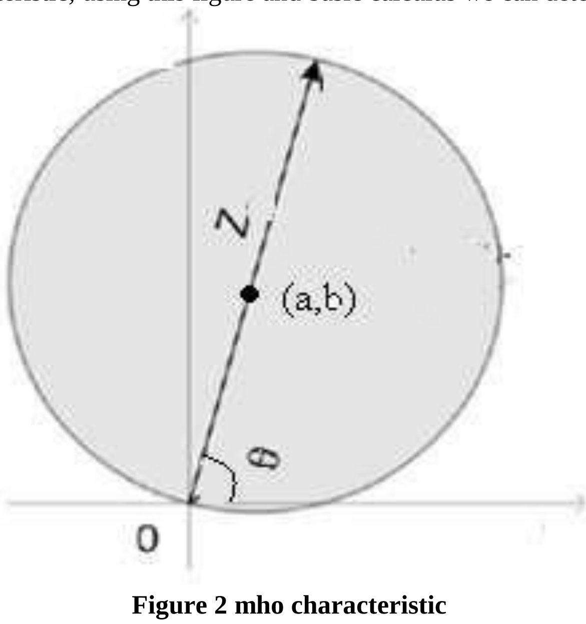

Figure 2 mho characteristic

$S = b/a = \tan\theta$……………………………………………………………………………… (2)

$B = a \operatorname{Tan}\theta$…………………………………………………………………………………….. (3)

Where equation (2) determines the slope, which equals tan(Θ).

Using the equation for finding the distance between two points where the radius is $Z/2$

$a^2 + b^2 = Z^2/4$……………………………………………………………………………. (4)

Substitute equation (3) in equation (4) we can find a and b as follow;

$a=\sqrt{\frac{Z^2/4}{1+(\tan(\theta))^2}}$………………………………………………………………..……...……… (5)

$b=\sqrt{\frac{Z^2/4}{1+(\tan(\theta))^2}}\tan\theta$………………………………….……………………………………. (6)

The equation describes the mho characteristic is:

$(x-a)^2+(y-b)^2=Z^2/4$ …………………………….………………….(7) For the elliptical characteristic shown in figure (3), its equation from the definition of the ellipse could be derived; the definition states that the locus of points (x,y) , the sum of whose distance from two points –called foci- is constant.

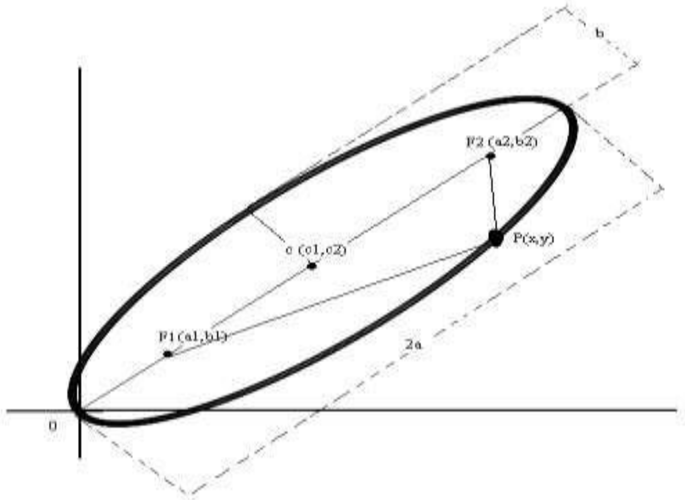

Figure 3 Ellipse

$PF_1 + PF_1 = \mathbf{2}\,a$ ……………………………..……………………………….……...(8)

$\sqrt{(x-a_1)^2+(y-b_1)^2}+\sqrt{(x-a_2)^2+(y-b_2)^2}=2a$………………………………..…….(9)

$CF_1 = CF_2 = d$ …………………………………………………….…………..(10)

$d^2= a^2- b^2$……………………………………………………………………...……..(11)

For the protection zones, the reach impedance is 2a. The distance $OF_1 = KZ_r$while OF2=Z_r.

$OF_2 = Z_r$. WhereZ_r is the replica impedance.[3].

3 PROTECTION ZONES

In this paper we will use only three zones. Consider a line AB followed the line BC, then

$Z_1 = 0.85\ Z_{AB}$……………………………………..……….…………………(12) [4]

$Z_2 = Z_{AB} + 0.25\ Z_{BC}$……………………………………...……...(13) [4]

Z3=ZAB+1.1ZBC$Z_3 = Z_{AB} + 1.1\ Z_{BC}$……………………………..……………...(14) [4]

The reach impedance of each zone could be found by knowing the line impedances.

4 DETECTING FAULTS

For the shown system in figure (4) which describes a line in Jordanian grid, and by dividing the system into three lines, assume a three-phase solid fault occurs at point F

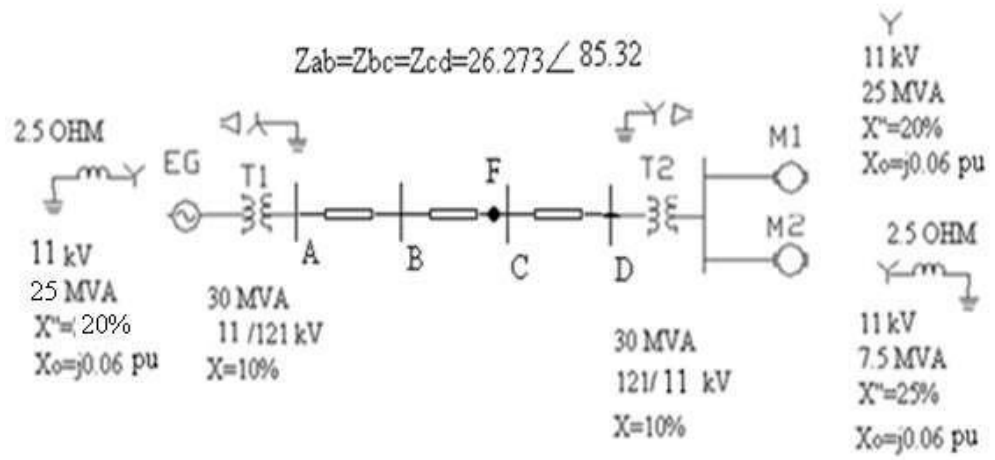

Figure 4 Power system

Assuming that the relay is located in front of the transformer directly, and using the equivalent circuit of the system in per unit values as shown in figure (5) the seen impedance by the relay is found to be the equivalent impedance from the fault point to the relay [5] so Z_{seen} = 52.55 Ω.

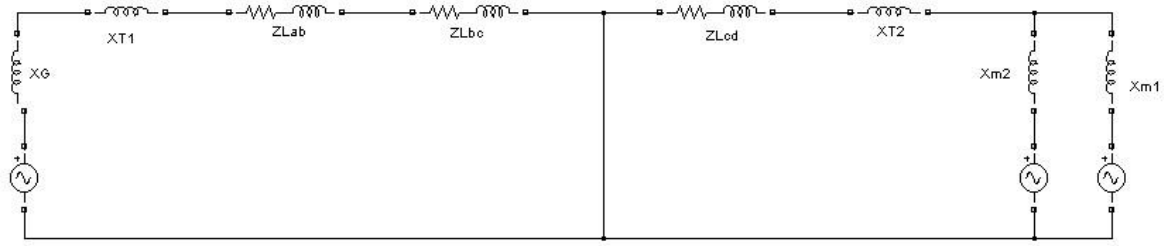

Figure 5 Equivalent circuit

The wave form of the fault current in per unit is shown in figure (6). This wave form is obtained using MATLAB Simulink.

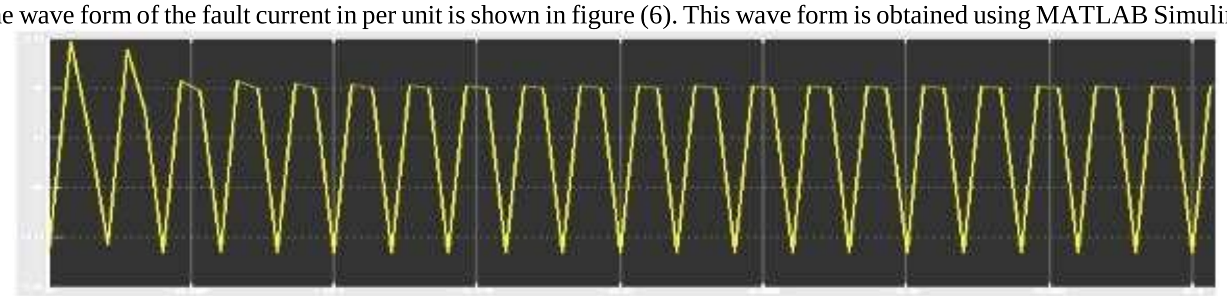

Figure 6 Fault current

Figure (7) shows the calculations of this system by using MATLAB/ SIMULINK tool box.

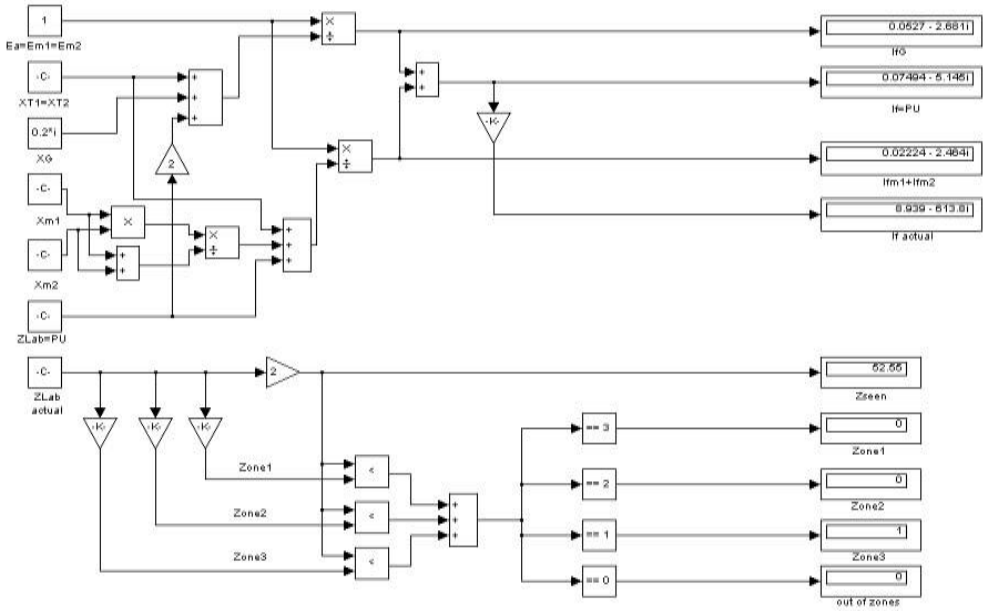

Figure 7 MATLAB/SIMULINK blocks

Finding the reach impedance of each zone, a comparison will be made using the graphical plotting on MATLAB/SIMULINK. Using the values shown in figure (4) we can find that;

$Zone1 = Z_1 = 0.85\ Z_{AB} = 0.85 * 26.273\angle 85.32 = 22.33205\angle 85.32\ \Omega$.

$Zone2 = Z_2 = Z_{AB} + 0.25\ Z_{BC} = 1.25 * 26.273\angle 85.32 = 32.84125\angle 85.32\ \Omega$.

$Zone3 = Z_3 = Z_{AB} + 1.1\ \ Z_{BC} = 2.1 * 26.273\angle 85.32\ \ = 55.1733\angle 85.32\ \Omega$.

From these values the fault locates in the third zone could be concluded. If this fault associated with arc (5–8) Ω [8][6] the impedance on the R-X diagram can be shown in figure (8).

Assuming another fault occurs on the second zone has an impedance of 31∠85.32 Ω and associated with $R_{arc} = 8\ \Omega$, then this fault on R-X diagram can be shown as in figure (8).

Figure (8) shows the faults discussed before and compares among impedance, mho, and elliptic characteristics of the distance relay. As obvious from figure (8), for the fault locates in the third zone, if there is an arc or not, it will be inside both the ellipse and the mho. Although the mho characteristic covers more area, but the ellipse can detect the fault even associated with arc.

For the fault which has a magnitude of 31∠85.32 Ω and associated with $R_{arc} = 8\ \Omega$, according to its magnitude it must locate in the second zone, but the arc moves it to the third zone where moth ellipse and mho relays cover whole the second zone only covered by the mho relay.

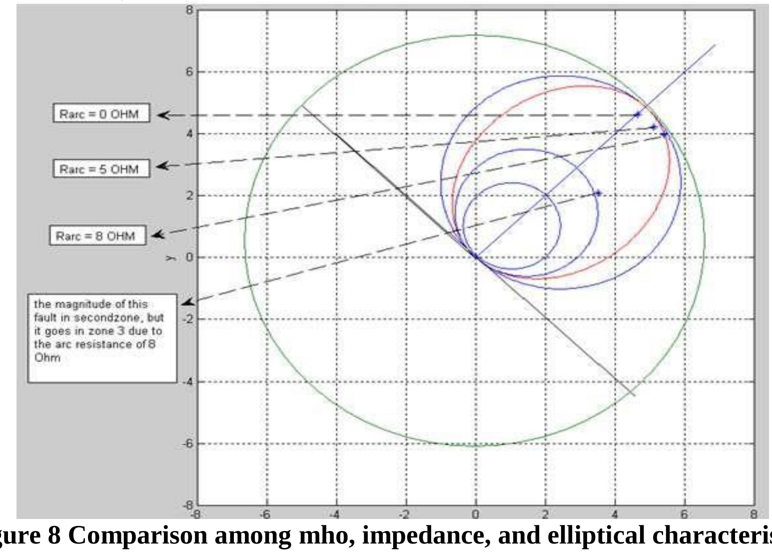

Figure 8 Comparison among mho, impedance, and elliptical characteristics

Figures (9), (10), and (11) show more faults on the same system if it is associated with arc or not and how it will appear on the R-X diagram.

For easy comparison, all values are reduced to be scaled by 8 and rotated by 40.32°counter clockwise, to obtain the actual value on the R-X diagram.

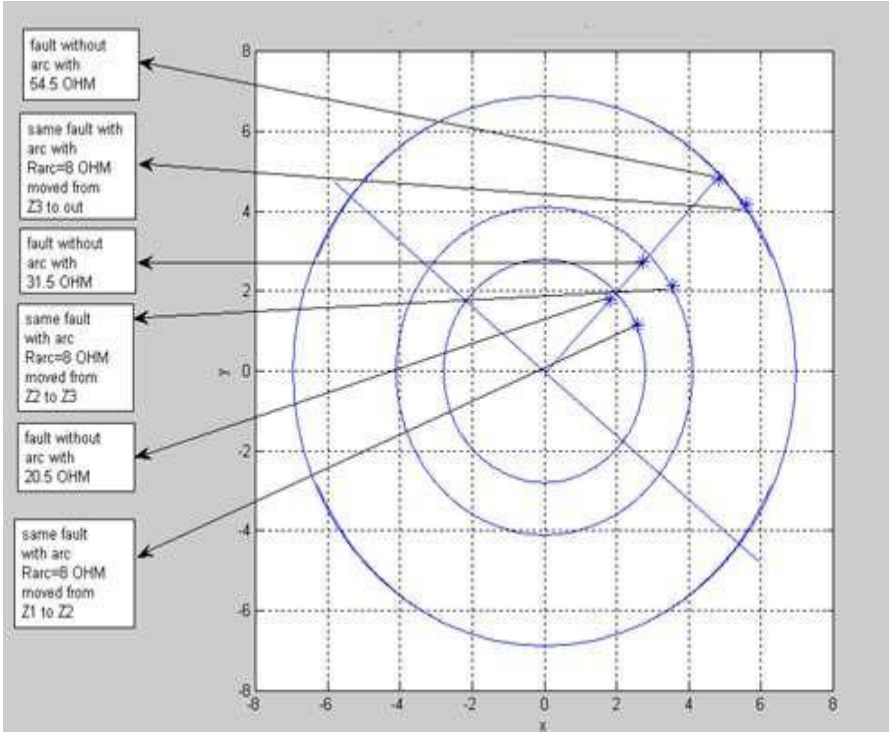

Figure 9 Impedance characteristic

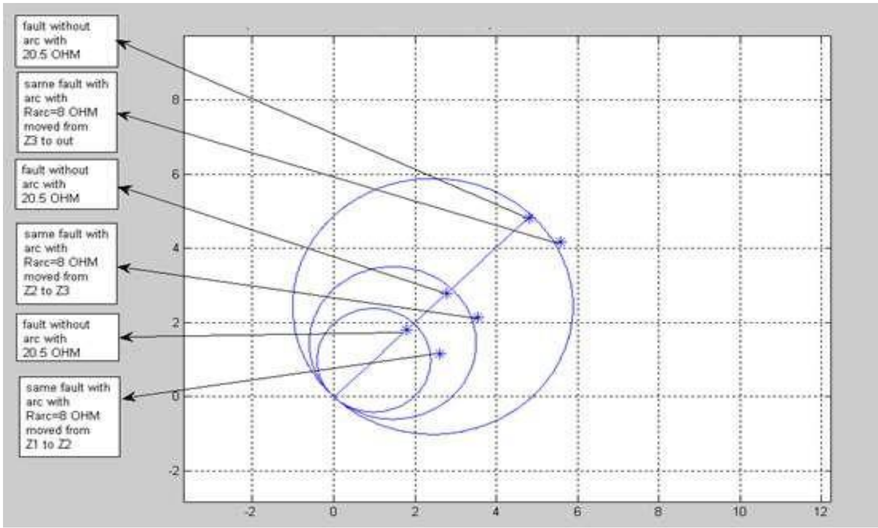

Figure 10 mho characteristic

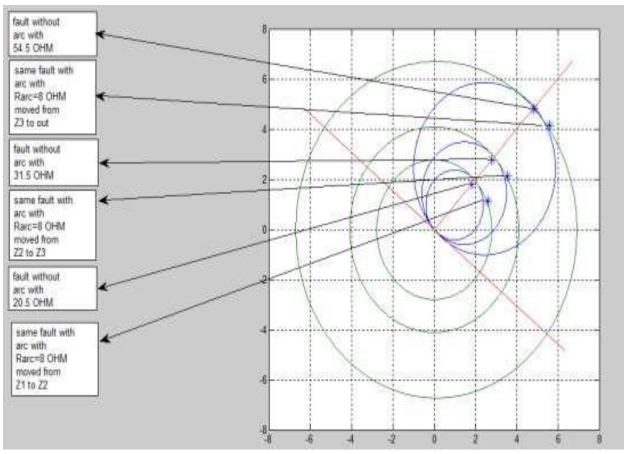

Figure 11 Full comparison among impedance and mho characteristics

If the fault of $Z_{seen} = 52.55\ \Omega$associated with a high value of arc resistance, then the fault will go out of the protected zone from both the ellipse and the mho, so a modification is done on the ellipse by increasing the reach impedance and reducing the sub axis. Define the third zone again to be:

$$Zone3 = Z_3 = Z_{AB} + 1.5\ Z_{BC}$$

According to this and by taking more values for the fault, the protection third zone can be shown in figure (12) with full comparison among impedance, mho, and elliptical characteristics.

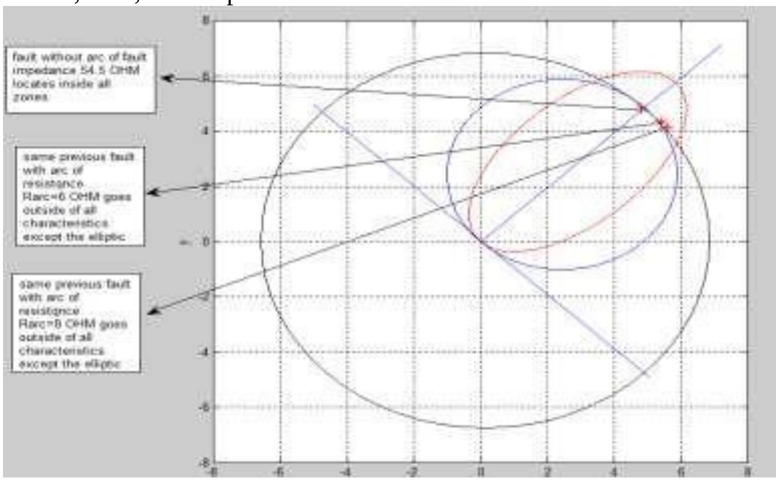

Figure 12 Comparison among impedance, mho, and elliptical characteristics after the elliptical characteristic is modified

5 CONCLUSION

According to the obtained results we can conclude that for the third zone the elliptical characteristic is the best distance relay can be used in order to detect the faults especially if the fault associated with arc.

If the reach impedance for the mho and elliptical relays are the same, then the coverage area using the elliptical relay less than the coverage area using the mho characteristic, both relays give the same performance, so the elliptical relay better than the mho relay.

If the fault occurs at the end of the line or near to end and associated with arc, both relays cannot detect the fault, so a modification n the elliptical relay can be done by increasing the reach impedance, and hence it can detect the fault even associated with arc. If this modification is done on the mho relay, then the coverage area is very large and this is not economical method on the mho relay. If a change in the power angle occurs, and hence a power swing occurs in the grid, the elliptical relay can detect this disturbance and take action, while the other characteristics cannot especially if the current increase highly.

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