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Apparent impedance error calculation for L-G fault in transmission line with change in power system conditions

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ABSTRACT

EHV/UHV long transmission lines have large distributed capacitance which has significant effect on the operation of a distance relay. To set the distance relay without considering the distributed capacitance will cause serious over reaching or under reaching. This paper analyzes the effect of distributed capacitance on the relay tripping characteristics and the setting principal of distance relay for EHV/UHV long transmission line is discussed.

Key words: EHV/UHV long transmission line, distance relay, distributed capacitance, relay tripping characteristics.

INTRODUCTION:

Distance relays are widely used as primary or backup protection for UHV/EHV lines, as they are independent of communication channels, and their reaches are insensitive to system condition[1]. A distance relay operates by measuring the electrical circuit distance between the relay location and the point of fault (apparent impedance, (ZAPP)) to determine if a fault is in its protection zone. It is apparent that the protection zones need to be set accurately to avoid overreaching or under reaching, and ensure the reliability and selectivity. Normally the protection zones can be set without considering the distributed capacitance, as the impedance of the distributed capacitance is too big compared with the line impedance. With the transmission distance increasing, however, the distributed capacitance of the whole line increases correspondingly. Meanwhile, to improve the economical and transmission efficiency over long distance, higher voltage levels are adopted, which brings higher distributed capacitance per unit of transmission lines[8]. The impedance of the distributed capacitance is comparable with the line impedance, thus its effects on the distance relay need to be considered, to ensure the distance relay's reliable operation [2].

1. CALCULATION OF APPARENT IMPEDANCE WITHOUT CAPACITANCE FOR L-G FAULT:

In the case of zero fault resistance, the measured impedance by distance relay is the exact impedance of the line section between the fault and the relaying points. From Fig.1., this impedance is equal to dZ1L, where d is per unit length of the line section between the fault and the relaying points and Z1L is the line positive sequence impedance in ohms. For a non-zero fault resistance, the measured impedance at the relaying point is not equal to the mentioned magnitude. In this case, the structural and operational conditions of the power system affect the measured impedance. The operational conditions prior to the fault instances can be represented by the load angle of the line 'δ' and the voltage magnitude ratio at the line ends 'h' or in general EN / EM= he-jδ. The structural conditions are evaluated by the short circuit levels at the line ends. The measured impedance at the relaying point can be expressed by the following equations.

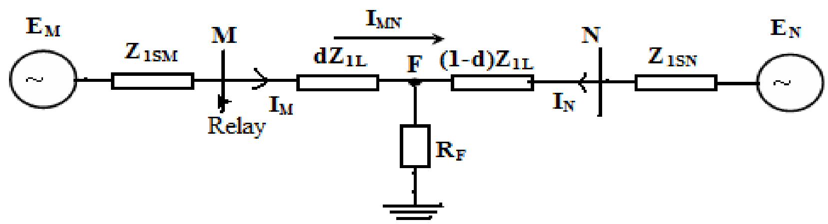

Figure 1: phase -to-ground fault without consideration of line capacitance

The measured impedance at the relaying point can be expressed by the following equations[3].

Z1LM=d*Z1L; (1)

Z1LN=(1-d)*Z1L; (2)

Z1M=Z1SM+Z1LM; (3)

Z1N=Z1SN+Z1LN; (4)

K1=(1-(h*pa))/(Z1N+h*Z1M*pa); (5)

C1=Z1N/(Z1N+Z1M); (6)

C0=Z0N/(Z0N+Z0M); (7)

K0=(Z0L-Z1L)/(Z1L); (8)

Zeq=2*Z1M*Z1N/(Z1M+Z1N)+Z0N*Z0M/(Z0M+Z0N); (9)

ZAPP=Z1LM+3*RF/((Zeq+3*RF)*K1+2*C1+C0*(1+K0)); (10)

For zero fault resistance, the apparent impedance at the relaying point is equal to the impedance of the line section located between the relaying point and the fault point. From equation (10) it is observed that, in the presence of fault resistance the apparent impedance is affected by power system conditions only.

Calculation of apparent impedance without capacitance for various fault resistance(RF) and line length(p) p=300,h=0.96;delta('δ')=5 is as follows.

RF=0, Z_{APP} = 0.0092 + 0.0953i

RF=0.1, Z_{APP} = 0.0897 + 0.1052i

RF=0.5, Z_{APP} = 0.4118 + 0.1449i

RF=0.9, Z_{APP} = 0.7337 + 0.1847i

RF=1, Z_{APP} = 0.8141 + 0.1946i

The apparent impedance without capacitance for various h and p=300 , RF=0.1 ;delta=5 is as follows.

h=0.96, Z_{APP} = 0.0897 + 0.1052i

h=0.9, Z_{APP} = 0.0890 + 0.1051i

h=0.5, Z_{APP} = 0.0845 + 0.1044i

h=0.2, Z_{APP} = 0.0809 + 0.1038i

h=0.1, Z_{APP} = 0.0797 + 0.1036i

The apparent impedance without capacitance for various delta and p=300 ,RF=0.1 ;h=0.96 is as follows.

Delta=5, Z_{APP} = 0.0897 + 0.1052i

Delta=9, Z_{APP} = 0.0898 + 0.1045i

Delta=12, Z_{APP} = 0.0899 + 0.1039i

Delta=15, Z_{APP} = 0.0899 + 0.1033i

Delta=20, Z_{APP} = 0.0899 + 0.1024i

2. APPARENT IMPEDANCE WITH CONSIDERATION OF LINE CAPACITANCE FOR L-G FAULT:

Long EHV/UHV transmission lines are highly affected by the line capacitance. If the effect of line capacitance for a fault with considerable value of fault resistance is ignored, then there is a substantial error in the impedance seen by a relay. Transmission line model including the line capacitance is shown in fig.2. In this proposed method double π model is utilized for considering the transmission line capacitance with fault resistance as shown in fig.3. The system of fig.3 includes four additional shunt branches. Compared to fig .3 the fault point divides the line into two π sections. Each line section is modeled by a π model[8],[5].

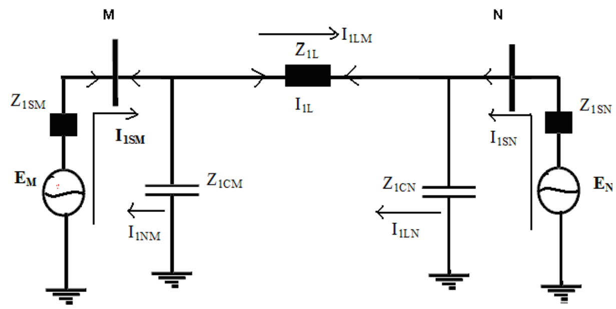

Figure 2: Transmission line model including shunt capacitance

Z1CM=1/(j*W*P*C1/2); (11)
Z0CM=1/(j*W*P*C0/2); (12)
Z1CN=1/(j*W*P*C1/2); (13)
Z0CN=1/(j*W*P*C0/2); (14)
Z1C=1/(j*W*P*C1/2); (15)
Z0C=1/(j*W*P*C0/2); (16)
Y1C=1/Z1C; (17)
Y0C=1/Z0C; (18)
W=100*pi; (19)
Y1CM1=(1/2)*d*Y1C; (20)
Y0CM1=(1/2)*d*Y0C; (21)
Y1CN1=(1/2)*(1-d)*Y1C; (22)
Y0CN1=(1/2)*(1-d)*Y0C; (23)

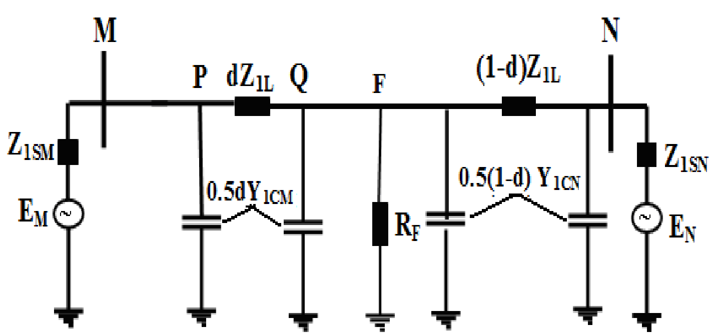

Figure 3: Line diagram for phase-to-ground fault with consideration of line capacitance

IPREL1=(ZT2*(Zeq+3*RF))/ (1-Z1SM*ZT1-d*Z1L*ZT2); (24)
IPREL2=(ZT1*(Zeq+3*RF))/ (1-Z1SM*ZT1-d*Z1L*ZT2); (25)
ZAPP=(3*RF+KC1)/KC2; (26)

It can be seen from equation (26) that the fault resistance is not only the factor causing the measured impedance deviation, but also the line capacitance. The ZAPP is also dependent on power system conditions and line length.

Calculation of apparent impedance with capacitance for various fault resistance and p=300,h=0.96,delta=5 is as follows.

RF=0, Z_{APP} = 0.0093 + 0.0961i

RF=0.1, Z_{APP} = 0.0901 + 0.1049i

RF=0.5, Z_{APP} = 0.4130 + 0.1401i

RF=0.9, Z_{APP} = 0.7358 + 0.1752i

RF=1, Z_{APP} = 0.8165 + 0.1839i

Calculation of apparent impedance with capacitance for various h and p=300, RF=0.1 ,delta=5 is as follows.

h=0.96, Z_{APP} = 0.0901 + 0.1049i

h=0.9, Z_{APP} = 0.0894 + 0.1049i

h=0.5, Z_{APP} = 0.0848 + 0.1046i

h=0.2, Z_{APP} = 0.0812 + 0.1044i

h=0.1, Z_{APP} = 0.0800 + 0.1043i

Calculation of apparent impedance with capacitance for various delta and p=300 , RF=0.1 ,h=0.96 is as follows.

Delta=5, Z_{APP} = 0.0901 + 0.1049i

Delta=9, Z_{APP} = 0.0901 + 0.1042i

Delta=12, Z_{APP} = 0.0901 + 0.1036i

Delta=15, Z_{APP} = 0.0901 + 0.1030i

Delta=20, Z_{APP} = 0.0899 + 0.1021i

Error or difference in impedance value with and without considering Capacitance for various fault resistance and p=300,h=0.96,delta=5 is as follows.

RF =0, Z_{APP} = 0.0001+0.0008i

RF =0.1, Z_{APP} = 0.0004 -0.0003i

RF =0.5, Z_{APP} = 0.0012-0.0048i

RF =0.9, Z_{APP} = 0.0021-0.0095i

RF =1, Z_{APP} = 0.0024-0.0107i

Error or difference in impedance value with and without considering Capacitance for various h and p=300,delta=5 is as follows.

h=0.96, Z_{APP} = 0.0004-0.0003i

h=0.9, Z_{APP} = 0.0004-0.0002i

h=0.5, Z_{APP} = 0.0003-0.0002i

h=0.2, Z_{APP} = 0.0003-0.0006i

h=0.1, Z_{APP} = 0.0003-0.0007i

Error or difference in impedance value with and without considering Capacitance for various delta and p=300,h=0.96 is as follows.

Delta=5, Z_{APP} = 0.0004-0.0003i

Delta=9,, Z_{APP} = 0.0003-0.0003i

Delta=12 Z_{APP} = 0.0002-0.0003i

Delta=15, Z_{APP} = 0.0002-0.0003i

Delta=20, Z_{APP} = 0.0000-0.0002i

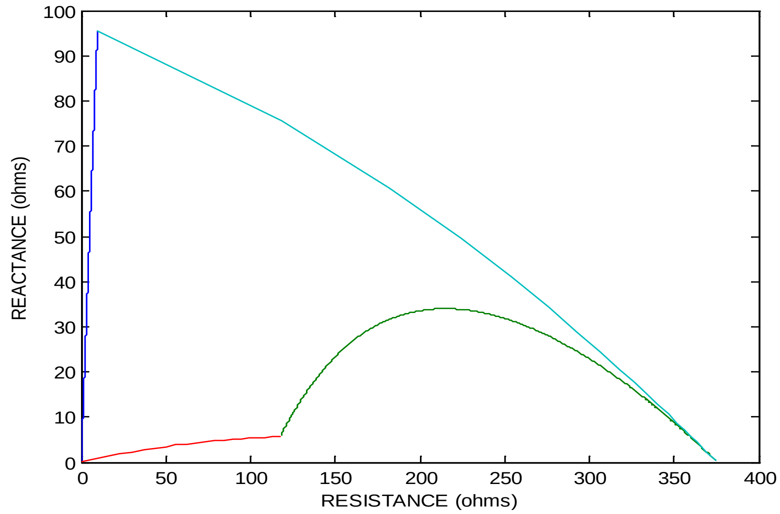

Figure 4: Distance relay tripping characteristic zone without capacitance (or) RX plot without capacitance

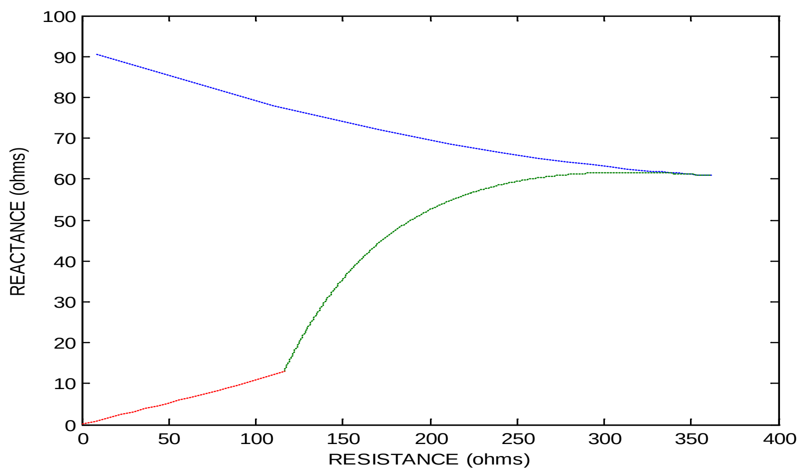

Figure 5: Distance relay tripping characteristic zone with capacitance (or) RX plot with capacitance

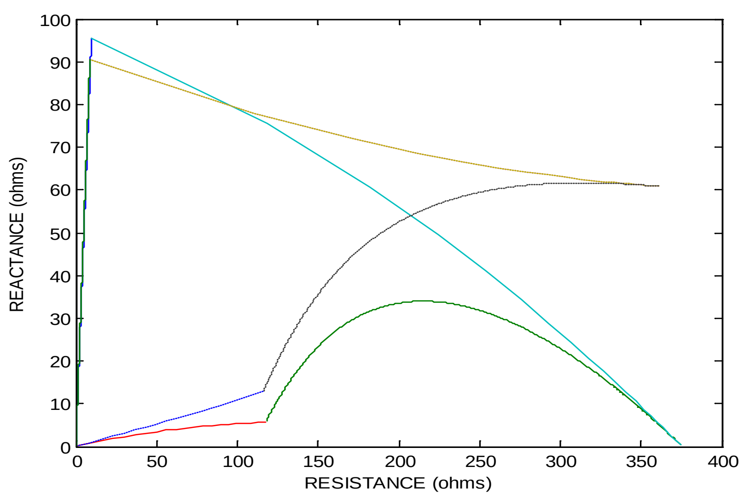

Figure 6: Distance relay tripping characteristic zone (or) comparision of RX plot with and without capacitance

The Fig 7 represents the apparent impedance measured at the relay point with and without considering capacitance. By observing the Fig 7 there is difference in impedance ,with and without capacitance .Because of the above reason the relay may mal operate.

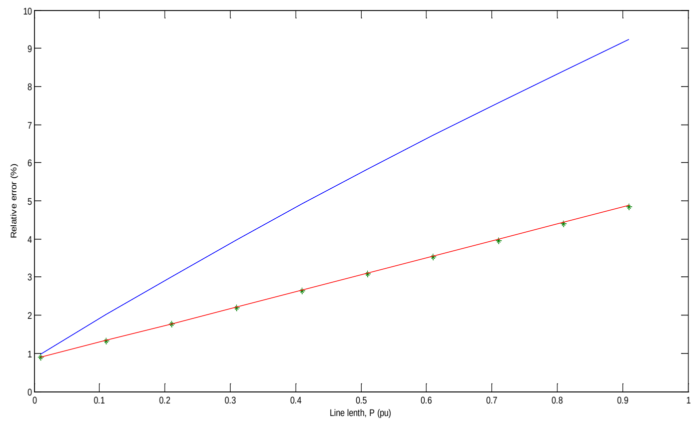

Figure 7: Apparent impedance with and without capacitance

In the Fig.7 the bottom line represents the apparent impedance without capacitance and the another line showing the apparent impedance with capacitance .The Fig.7 also shows the change in apparent impedance seen by the relay. If the capacitance effect doesn't considered the relay may mal operate because there is a substantial change in impedance seen by relay .It is very important to consider the capacitance effect in long transmission line for accurate operation of relay .Fig.7 shows the amount of increase in the measured impedance for the various fault points, in the case of zero fault resistance. Here, the increase in the measured resistance, reactance, and impedance magnitude are shown by dotted, dashed, and full curves, respectively. It can be seen that the impedance deviation is a function of fault location. Because of different deviation of the measured resistance and reactance, the angle of the measured impedance varies as well as its magnitude.

3. TRIPPING CHARACTERISTICS:

Knowing the structural and operational conditions, i.e. the short circuit levels, the load angle, and the voltage magnitude ratio, the distance relay ideal tripping characteristic can be defined. This characteristic has four boundaries. First boundary is the measured impedance for zero fault resistance; fault location varies from near end up to the far end of the line. In the second boundary, the fault point is at the far end; fault resistance varies between 0 and 200 ohms. Third boundary is the result of the fault point variation along the line for the fault resistance of 200 ohms. Forth is achieved by variation of the fault resistance between 0 and 200 ohms for the faults on the near end of the line[6],[7].

4. CONCLUSIONS:

An adaptive relay setting scheme for stand-alone digital distance protection has been proposed [4]. The distance relay tripping characteristics changes with change in fault resistance , change in h ,change in line length p, change in angle delta . It is also seen that significant change in relay tripping characteristics with and without considering capacitance. The change in tripping characteristics, change in apparent impedance and error in impedance also seen. It is very important to consider the capacitance effect for ideal tripping characteristics

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