距離継電器の眺める故障点インピーダンスについて

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Fault Impedance measured by Distance Relay

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Abstract

The impedance measured by the ground fault protective distance relay connected to provide phase voltage and phase current, and by the short circuit fault protective distance relay operating by line to line voltage and delta current varies with fault impedance chiefly the arc resistance. In this paper, the theoretical formulas estimating the performance of distance relays connected to faulted phase and also unfaulted phases of three phase line are introduced for one rute and parallel two rute three phase line, during one line grounding, two line short circuit, and two line grounding fault conditions.

And also it is mentioned that the loci of measured impedance value are circle, and is proved by instances for practical transmission line calculation.

I. 緒　　言

送電系統に於いて各種非対称故障の発生時，自相及び他相の距離継電器の測定するインピーダンスは，故障点に於けるインピーダンス，特にアーク抵抗によつて影響される[1]。本文は相電圧相電流を利用した地絡保護距離継電器，並びに線間電圧及びデルタ電流を用いた短絡保護距離継電器の眺める故障時インピーダンスに対する故障点インピーダンスの影響を示す計算式を，一回線並びに二回線送電線に於ける各種故障に就いて誘導し，アーク抵抗のみ考慮した場合の之等の円特性を計算例によつて図示したものである。

II. 一回線送電線に於ける計算

第1図(a)に示す回路に於いて[2]，Sは電源内部誘起電圧点，Rは継電器設置点，Pは故障発生箇所，Lは負荷点とすれば，同図(b), (c), (d)の如く，P点より負荷側のインピーダンスは之を等価アドミッタンスY_f'として故障点に結び，次でY_f'を含んだRP間の線路定数を求め，電源と継電器地点間の定数を直列に結んで，故障点を受電端と見做した等価回路を得る事が出来，今之を正相，逆相，零相の各回路に適用すれば，故障計算を容易にする事が出来る。

第２図 (a) の如き零相回路に於いては

$$\begin{bmatrix} A'_{\gamma 0} & B'_{\gamma 0} \\ C'_{\gamma 0} & D'_{\gamma 0} \end{bmatrix} = \begin{bmatrix} A''_{\gamma 0} & B''_{\gamma 0} \\ C''_{\gamma 0} & D''_{\gamma 0} \end{bmatrix} \begin{bmatrix} 1 & Z_{tB0} \\ 0 & 1 \end{bmatrix} \quad \cdots\cdots (1)$$

$$\begin{bmatrix} A_{\alpha 0} & B_{\alpha 0} \\ C_{\alpha 0} & D_{\alpha 0} \end{bmatrix} = \begin{bmatrix} 1 & Z_{tA0} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A'_{\alpha 0} & B'_{\alpha 0} \\ C'_{\alpha 0} & D'_{\alpha 0} \end{bmatrix} \quad \cdots\cdots (2)$$

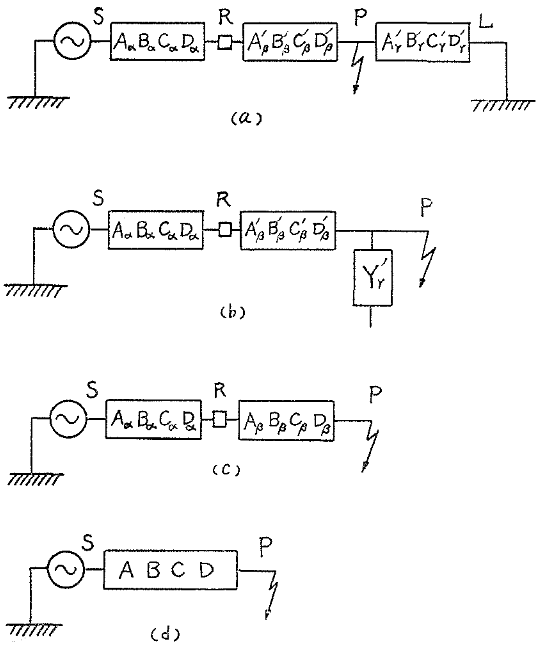
受端中性点直接接地として

$$Y'_{\gamma 0} = D'_{\gamma 0}/B'_{\gamma 0} \quad \cdots\cdots (3)$$

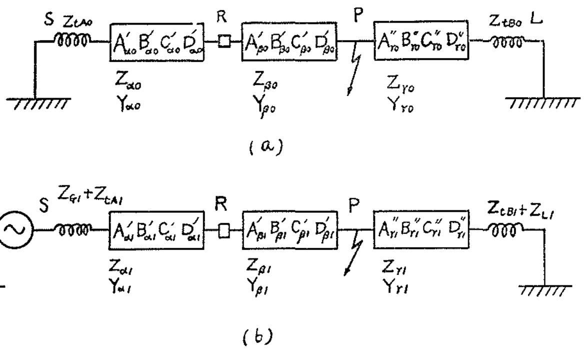
$$\begin{bmatrix} A_{\beta 0} & B_{\beta 0} \\ C_{\beta 0} & D_{\beta 0} \end{bmatrix} = \begin{bmatrix} A'_{\beta 0} & B'_{\beta 0} \\ C'_{\beta 0} & D'_{\beta 0} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ Y'_{\gamma 0} & 1 \end{bmatrix} \quad \cdots\cdots (4)$$

$$\begin{bmatrix} A_0 & B_0 \\ C_0 & D_0 \end{bmatrix} = \begin{bmatrix} A_{\alpha 0} & B_{\alpha 0} \\ C_{\alpha 0} & D_{\alpha 0} \end{bmatrix} \begin{bmatrix} A_{\beta 0} & B_{\beta 0} \\ C_{\beta 0} & D_{\beta 0} \end{bmatrix} \quad \cdots\cdots (5)$$

第２図 (b) の如き正相回路にては



第 1 図



第 2 図

$$\begin{bmatrix} A'_{\gamma 1} & B'_{\gamma 1} \\ C'_{\gamma 1} & D'_{\gamma 1} \end{bmatrix} = \begin{bmatrix} A''_{\gamma 1} & B''_{\gamma 1} \\ C''_{\gamma 1} & D''_{\gamma 1} \end{bmatrix} \begin{bmatrix} 1 & Z_{tB1}+Z_{L1} \\ 0 & 1 \end{bmatrix} \quad \cdots\cdots (6)$$

$$\begin{bmatrix} A_{\alpha 1} & B_{\alpha 1} \\ C_{\alpha 1} & D_{\alpha 1} \end{bmatrix} = \begin{bmatrix} 1 & Z_{G1}+Z_{tA1} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A'_{\alpha 1} & B'_{\alpha 1} \\ C'_{\alpha 1} & D'_{\alpha 1} \end{bmatrix} \quad \cdots\cdots (7)$$

$$Y'_{\gamma 1} = D'_{\gamma 1}/B'_{\gamma 1} \quad \cdots\cdots (8)$$

$$\begin{bmatrix} A_{\beta 1} & B_{\beta 1} \\ C_{\beta 1} & D_{\beta 1} \end{bmatrix} = \begin{bmatrix} A'_{\beta 1} & B'_{\beta 1} \\ C'_{\beta 1} & D'_{\beta 1} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ Y'_{\gamma 1} & 1 \end{bmatrix} \quad \cdots\cdots (9)$$

$$\begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} = \begin{bmatrix} A_{\alpha 1} & B_{\alpha 1} \\ C_{\alpha 1} & D_{\alpha 1} \end{bmatrix} \begin{bmatrix} A_{\beta 1} & B_{\beta 1} \\ C_{\beta 1} & D_{\beta 1} \end{bmatrix} \quad \cdots\cdots (10)$$

逆相回路に就いても逆相インピダンスを用いる事により前同様次式を得る。

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} A_{\alpha 2} & B_{\alpha 2} \\ C_{\alpha 2} & D_{\alpha 2} \end{bmatrix} \begin{bmatrix} A_{\beta 2} & B_{\beta 2} \\ C_{\beta 2} & D_{\beta 2} \end{bmatrix} \quad \cdots\cdots (11)$$

(5), (10) 及び (11) より，第1図 (d) の回路に対して，電源及び故障点の電圧電流間に次式が成立つ。

$$\left.\begin{aligned} \begin{bmatrix} E_{s0} \\ I_{s0} \end{bmatrix} &= \begin{bmatrix} A_0 & B_0 \\ C_0 & D_0 \end{bmatrix} \begin{bmatrix} E_{p0} \\ I_{p0} \end{bmatrix} \\ \begin{bmatrix} E_{s1} \\ I_{s1} \end{bmatrix} &= \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} E_{p1} \\ I_{p1} \end{bmatrix} \\ \begin{bmatrix} E_{s2} \\ I_{s2} \end{bmatrix} &= \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} E_{p2} \\ I_{p2} \end{bmatrix} \end{aligned}\right\} \quad \cdots\cdots (12)$$

[A] 一線接地故障

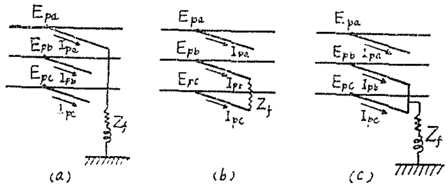
第3図 (a) の如く，P 点にて a 相一線地絡発生の場合，故障条件は

$$\left.\begin{aligned} E_{pa} &= Z_f I_{pa} \\ I_{pb} &= I_{pc} = 0 \end{aligned}\right\} \quad \cdots\cdots (13)$$

且つ一般には

$$E_{s0} = E_{s2} = 0 \quad \cdots\cdots (14)$$

故に
$$\left.\begin{aligned} I_{p0} &= I_{p1} = I_{p2} \\ E_{p0}+E_{p1}+E_{p2} &= 3Z_f I_{p1} \end{aligned}\right\} \quad \cdots\cdots (15)$$



第 3 図

(12), (14) 及び (15) より

$$I_{p0} = I_{p1} = I_{p2} = \frac{E_{s1}}{A_1\left(\dfrac{B_0}{A_0}+\dfrac{B_1}{A_1}+\dfrac{B_2}{A_2}+3Z_f\right)} = \frac{E_{s1}}{\varDelta} \quad \cdots\cdots (16)$$

$$\varDelta = A_1\left(\frac{B_0}{A_0}+\frac{B_1}{A_1}+\frac{B_2}{A_2}+3Z_f\right)$$

$$\left.\begin{aligned} E_{p0} &= -\frac{1}{\varDelta}\left(\frac{B_0}{A_0}\right)E_{s1} \\ E_{p1} &= \frac{1}{\varDelta}\left(\frac{B_0}{A_0}+\frac{B_2}{A_2}+3Z_f\right)E_{s1} \\ E_{p2} &= -\frac{1}{\varDelta}\left(\frac{B_2}{A_2}\right)E_{s1} \end{aligned}\right\} \quad \cdots\cdots (17)$$

継電器設置点 R に於ける電圧電流値を夫々 E_R, I_R にて示せば，各対称分は

$$\left.\begin{aligned} \begin{bmatrix} E_{R0} \\ I_{R0} \end{bmatrix} &= \begin{bmatrix} A_{\beta 0} & B_{\beta 0} \\ C_{\beta 0} & D_{\beta 0} \end{bmatrix} \begin{bmatrix} E_{p0} \\ I_{p0} \end{bmatrix} \\ \begin{bmatrix} E_{R1} \\ I_{R1} \end{bmatrix} &= \begin{bmatrix} A_{\beta 1} & B_{\beta 1} \\ C_{\beta 1} & D_{\beta 1} \end{bmatrix} \begin{bmatrix} E_{p1} \\ I_{p1} \end{bmatrix} \\ \begin{bmatrix} E_{R2} \\ I_{R2} \end{bmatrix} &= \begin{bmatrix} A_{\beta 2} & B_{\beta 2} \\ C_{\beta 2} & D_{\beta 2} \end{bmatrix} \begin{bmatrix} E_{p2} \\ I_{p2} \end{bmatrix} \end{aligned}\right\} \quad \cdots\cdots (18)$$

R 点各相電圧及び電流は，上式より

$$\left.\begin{aligned} &\begin{bmatrix} E_{Ra} \\ I_{Ra} \end{bmatrix} = [Z] \begin{bmatrix} E_{p0} \\ E_{p1} \\ E_{p2} \\ I_{p0} \\ I_{p1} \\ I_{p2} \end{bmatrix}, \quad \begin{bmatrix} E_{Rb} \\ I_{Rb} \end{bmatrix} = [Z] \begin{bmatrix} E_{p0} \\ a^2E_{p1} \\ aE_{p2} \\ I_{p0} \\ a^2I_{p1} \\ aI_{p2} \end{bmatrix} \\ &\begin{bmatrix} E_{Rc} \\ I_{Rc} \end{bmatrix} = [Z] \begin{bmatrix} E_{p0} \\ aE_{p1} \\ a^2E_{p2} \\ I_{p0} \\ aI_{p1} \\ a^2I_{p2} \end{bmatrix}, \quad [Z] = \begin{bmatrix} A_{\beta 0} & A_{\beta 1} & A_{\beta 2} & B_{\beta 0} & B_{\beta 1} & B_{\beta 2} \\ C_{\beta 0} & C_{\beta 1} & C_{\beta 2} & D_{\beta 0} & D_{\beta 1} & D_{\beta 2} \end{bmatrix} \end{aligned}\right\} \quad \cdots\cdots\cdots (19)$$

(16), (17) を (19) に代入する事により，相電圧，相電流を用いる接地距離継電器の測定するインピーダンスは，a 相に就いては線路値に換算した値として次の如く表わす事が出来る。

$$Z_a = \frac{E_{Ra}}{I_{Ra}} = \frac{\left\{\frac{B_0}{A_0}(A_{\beta 1}-A_{\beta 0})+\frac{B_2}{A_2}(A_{\beta 1}-A_{\beta 2})+B_{\beta 0}+B_{\beta 1}+B_{\beta 2}\right\}+3A_{\beta 1}Z_f}{\left\{\frac{B_0}{A_0}(C_{\beta 1}-C_{\beta 0})+\frac{B_2}{A_2}(C_{\beta 1}-C_{\beta 2})+D_{\beta 0}+D_{\beta 1}+D_{\beta 2}\right\}+3C_{\beta 1}Z_f} \quad (20)$$

即ち Z_a の値は故障点リアクタンス値 X_f を独立変数とせば，アーク抵抗 R_f の変化に対して円群を示す[3]。

今 $X_f = 0$ とし

$$a' = \left\{\frac{B_0}{A_0}(A_{\beta 1}-A_{\beta 0})+\frac{B_2}{A_2}(A_{\beta 1}-A_{\beta 2})+B_{\beta 0}+B_{\beta 1}+B_{\beta 2}\right\}$$

$$b' = 3A_{\beta 1}$$

$$c' = \left\{\frac{B_0}{A_0}(C_{\beta 1}-C_{\beta 0})+\frac{B_2}{A_2}(C_{\beta 1}-C_{\beta 2})+D_{\beta 0}+D_{\beta 1}+D_{\beta 2}\right\}$$

$$d' = 3C_{\beta 1}$$

とすれば，円の中心は，添字 k を共軛値を示すものとして

$$\frac{a'd'_k-b'c'_k}{c'd'_k-c'_kd'}$$

半径は

$$\left|\frac{a'd'-b'c'}{c'd'_k-c'_kd'}\right|$$

である。此の円周上，$Z_f=0$ とすれば金属接地状態を示し，$Z_f=\infty$ とすれば，故障発生なき時の値にて，正相インピーダンスを眺める事となる。

一般に距離継電器は過渡状態にて動作するもの故，系統正相インピーダンスと逆相インピーダンスは等しく置き得るので，過渡値のみを求めるならば，式の繁雑さは軽減されるので，

以降過渡値のみを示す事とする。b, c 相についても (16), (17), (19) 式より求められ，過渡値として

$$\left.\begin{aligned}
Z_a &= \frac{\left\{\dfrac{B_0}{A_0}(A_{\beta 1}-A_{\beta 0})+B_{\beta 0}+2B_{\beta 1}\right\}+3A_{\beta 1}Z_f}{\left\{\dfrac{B_0}{A_0}(C_{\beta 1}-C_{\beta 0})+D_{\beta 0}+2D_{\beta 1}\right\}+3C_{\beta 1}Z_f}\\
Z_b &= \frac{E_{Rb}}{I_{Rb}} = \frac{\left\{\dfrac{B_0}{A_0}(a^2A_{\beta 1}-A_{\beta 0})-j\sqrt{3}\,\dfrac{B_1}{A_1}A_{\beta 1}+B_{\beta 0}-B_{\beta 1}\right\}+3a^2A_{\beta 1}Z_f}{\left\{\dfrac{B_0}{A_0}(a^2C_{\beta 1}-C_{\beta 0})-j\sqrt{3}\,\dfrac{B_1}{A_1}C_{\beta 1}+D_{\beta 0}-D_{\beta 1}\right\}+3a^2C_{\beta 1}Z_f}\\
Z_c &= \frac{E_{Rc}}{I_{Rc}} = \frac{\left\{\dfrac{B_0}{A_0}(aA_{\beta 1}-A_{\beta 0})+j\sqrt{3}\,\dfrac{B_1}{A_1}A_{\beta 1}+B_{\beta 0}-B_{\beta 1}\right\}+3aA_{\beta 1}Z_f}{\left\{\dfrac{B_0}{A_0}(aC_{\beta 1}-C_{\beta 0})+j\sqrt{3}\,\dfrac{B_1}{A_1}C_{\beta 1}+D_{\beta 0}-D_{\beta 1}\right\}+3aC_{\beta 1}Z_f}
\end{aligned}\right\} \quad (21)$$

同様に線間電圧とデルタ電流を用いる短絡距離電器の測る a 相接地時のインピーダンスは

$$\left.\begin{aligned}
Z_{(a-b)} &= \frac{E_{Ra}-E_{Rb}}{I_{Ra}-I_{Rb}} = \frac{A_{\beta 1}\left(a^2\dfrac{B_0}{A_0}-a\dfrac{B_1}{A_1}\right)+(a^2-1)B_{\beta 1}+3a^2A_{\beta 1}Z_f}{C_{\beta 1}\left(a^2\dfrac{B_0}{A_0}-a\dfrac{B_1}{A_1}\right)+(a^2-1)D_{\beta 1}+3a^2C_{\beta 1}Z_f}\\
Z_{(b-c)} &= \frac{E_{Rb}-E_{Rc}}{I_{Rb}-I_{Rc}} = \frac{\left(\dfrac{B_0}{A_0}+2\dfrac{B_1}{A_1}\right)A_{\beta 1}+3A_{\beta 1}Z_f}{\left(\dfrac{B_0}{A_0}+2\dfrac{B_1}{A_1}\right)C_{\beta 1}+3C_{\beta 1}Z_f} = \frac{A_{\beta 1}}{C_{\beta 1}}\\
Z_{(c-a)} &= \frac{E_{Rc}-E_{Ra}}{I_{Rc}-I_{Ra}} = \frac{A_{\beta 1}\left(\dfrac{B_0}{A_0}-a\dfrac{B_1}{A_1}\right)+(1-a^2)B_{\beta 1}+3A_{\beta 1}Z_f}{C_{\beta 1}\left(\dfrac{B_0}{A_0}-a\dfrac{B_1}{A_1}\right)+(1-a^2)D_{\beta 1}+3C_{\beta 1}Z_f}
\end{aligned}\right\} \quad \cdots\cdots (22)$$

今第 2 図に於いて，RL 間の 80% の地点 P にて故障発生とし，線路定数を

$A'_{\alpha 0} = D'_{\alpha 0} = 1$ $\qquad$ $A'_{\beta 0} = D'_{\beta 0} = 1$

$B'_{\alpha 0} = 18.90+j\,62.41\,\Omega$ $\qquad$ $B'_{\beta 0} = 46.64+j\,154\,\Omega$

$C'_{\alpha 0} = j\,0.7470\times 10^{-4}\,\mho$ $\qquad$ $C'_{\beta 0} = j\,1.844\times 10^{-4}\,\mho$

$A''_{\gamma 0} = D''_{\gamma 0} = 1$ $\qquad$ $Z_{tA0} = j\,68.5\,\Omega$

$B''_{\gamma 0} = 11.66+j\,38.52\,\Omega$ $\qquad$ $Z_{tB0} = j\,91.7\,\Omega$

$C''_{\gamma 0} = j\,0.4611\times 10^{-4}\,\mho$

$A'_{\alpha 1} = D'_{\alpha 1} = 1$ $\qquad$ $A'_{\beta 1} = D'_{\beta 1} = 1$

$B'_{\alpha 1} = 5.636+j\,18.23\,\Omega$ $\qquad$ $B'_{\beta 1} = 13.91+j\,54.00\,\Omega$

$C'_{\alpha 1} = j\,1.233\times 10^{-4}\,\mho$ $\qquad$ $C'_{\beta 1} = j\,3.044\times 10^{-4}\,\mho$

$A''_{\gamma 1} = D''_{\gamma 1} = 1$ $\qquad$ $Z_{G1}+Z_{tA1} = j\,92.0\,\Omega$

$B''_{\gamma 1} = 3.478+j\,11.25\,\Omega$ $\qquad$ $Z_{tB1}+Z_{L1} = 8.351+j\,101.7\,\Omega$

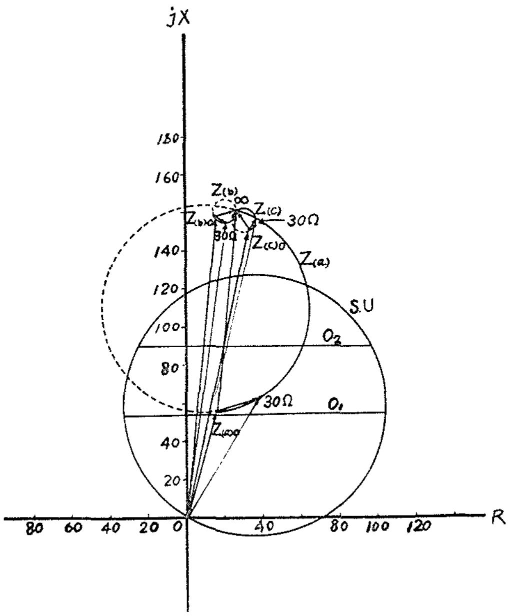
$C''_{\gamma 1} = j\,0.7611\times 10^{-4}\,\mho$

とした場合には，(21), (22) 式は

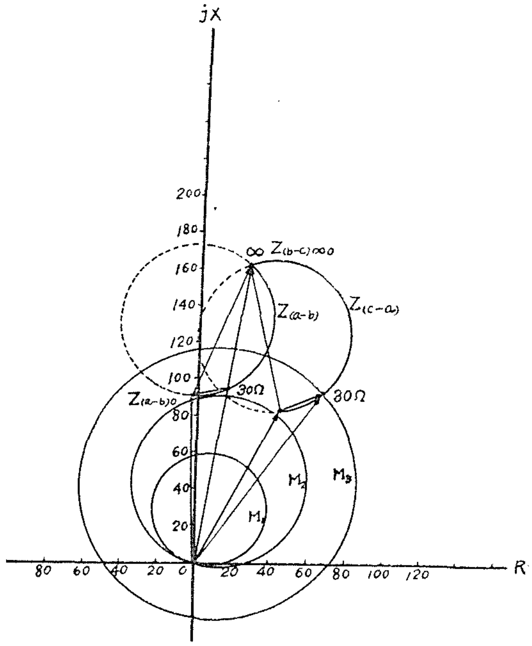
$$
\left.\begin{aligned}
Z_{Ra} &= \frac{(50.92+j\,178.2)+(4.230-j\,0.2427)Z_f}{(3.159+j\,0.007430)+(27.86-j\,255.6)\times 10^{-4}Z_f}\\
Z_{Rb} &= \frac{(184.5-j\,207.6)+(-2.325-j\,3.542)Z_f}{(-1.169-j\,1.293)+(-0.02353+j\,0.01037)Z_f}\\
Z_{Rc} &= \frac{(-243.3-j\,105.1)+(-1.905+j\,3.785)Z_f}{(-0.9833+j\,1.370)+(0.02074+j\,0.01519)Z_f}
\end{aligned}\right\} \quad \cdots\cdots\cdots\cdots (21')
$$

$$
\left.\begin{aligned}
Z_{(a-b)} &= \frac{(178.3-j\,154.5)+(-2.325-j\,3.542)Z_f}{(-1.788-j\,1.900)+(-0.02353+j\,0.01037)Z_f}\\
Z_{(b-c)} &= 27.27+j\,162.5\\
Z_{(c-a)} &= \frac{(65.35+j\,226.7)+(4.230-j\,0.2427)Z_f}{(2.464+j\,0.5141)+(0.002786-j\,0.02556)Z_f}
\end{aligned}\right\} \quad \cdots\cdots\cdots\cdots (22')
$$

となり，之等を図示したものが，第4図，第5図である。図上，Z_f はアーク抵抗 R_f のみとし，0 Ω，30 Ω 及び無限大の値が示してある。又比較の為，線路側に換算して，第1段 (O_1) 52.96 Ω，第2段 (O_2) 88.35 Ω，スターテング要素 (S. U.) 135.6 Ω に整定した接地保護リアクタンス継電器の特性が第4図に対して併記され，又第1段 (M_1) 60.59 Ω，第2段 (M_2) 88.35 Ω，第3段 (M_3) 前方 121.1 Ω，後方 26.48 Ω 整定の短絡保護モー距離継電器の特性円が第5図に記入してある。$R_f=\infty$ にて各相とも同一インピーダンスを測定する事が了解される。



第4図　a 相アーク接地を見る接地継電器インピーダンス測定値



第5図　a 相接地を見る短絡継電器

[B] 二線短絡故障

第3図(*b*)の如き線間短絡が発生した場合に就いては，故障条件として

$$\left.\begin{aligned} I_{pa} &= 0 \\ I_{pb} &= -I_{pc} \\ E_{pb}-E_{pc} &= I_{pb}Z_f \end{aligned}\right\} \qquad \cdots\cdots (23)$$

故に
$$\left.\begin{aligned} I_{p0} &= 0, \quad I_{p2} = -I_{p1} \\ E_{p1} &= E_{p2}+I_{p1}Z_f \end{aligned}\right\} \qquad \cdots\cdots (24)$$

(12), (14) 及び (24) より

$$\left.\begin{aligned} I_{p0} &= 0 \\ I_{p1} &= \frac{\frac{B_1}{A_1}E_{s1}}{B_1\left(\frac{B_1}{A_1}+\frac{B_2}{A_2}+Z_f\right)} = \frac{1}{\varDelta'}\left(\frac{B_1}{A_1}\right)E_{s1} \\ I_{p2} &= -\frac{1}{\varDelta'}\left(\frac{B_1}{A_1}\right)E_{s1} \\ \varDelta' &= B_1\left(\frac{B_1}{A_1}+\frac{B_2}{A_2}+Z_f\right) \end{aligned}\right\} \qquad \cdots\cdots (25)$$

$$\left.\begin{aligned} E_{p0} &= 0 \\ E_{p1} &= \frac{1}{\varDelta'}\,\frac{B_1}{A_1}\left(\frac{B_2}{A_2}+Z_f\right)E_{s1} \\ E_{p2} &= \frac{1}{\varDelta'}\,\frac{B_1}{A_1}\cdot\frac{B_2}{A_2}E_{s1} \end{aligned}\right\} \qquad \cdots\cdots (26)$$

(18), (19) に (25), (26) を代入計算すれば，各継電器の眺めるインピーダンスの線路側に換算した値を得る。過渡値として

$$\left.\begin{aligned} Z'_a &= \frac{2\frac{B_1}{A_1}A_{\beta1}+A_{\beta1}Z_f}{2\frac{B_1}{A_1}C_{\beta1}+C_{\beta1}Z_f} = \frac{A_{\beta1}}{C_{\beta1}} \\ Z'_b &= \frac{-\frac{B_1}{A_1}A_{\beta1}+(a^2-a)B_{\beta1}+a^2A_{\beta1}Z_f}{-\frac{B_1}{A_1}C_{\beta1}+(a^2-a)D_{\beta1}+a^2C_{\beta1}Z_f} \\ Z'_c &= \frac{-\frac{B_1}{A_1}A_{\beta1}+(a-a^2)B_{\beta1}+aA_{\beta1}Z_f}{-\frac{B_1}{A_1}C_{\beta1}+(a-a^2)D_{\beta1}+aC_{\beta1}Z_f} \end{aligned}\right\} \qquad \cdots\cdots (27)$$

$$\left.\begin{aligned} Z'_{(a-b)} &= \frac{3\frac{B_1}{A_1}A_{\beta1}+(a-a^2)B_{\beta1}+(1-a^2)A_{\beta1}Z_f}{3\frac{B_1}{A_1}C_{\beta1}+(a-a^2)D_{\beta1}+(1-a^2)C_{\beta1}Z_f} \\ Z'_{(b-c)} &= \frac{2B_{\beta1}+A_{\beta1}Z_f}{2D_{\beta1}+C_{\beta1}Z_f} \end{aligned}\right\} \qquad \cdots\cdots (28)$$

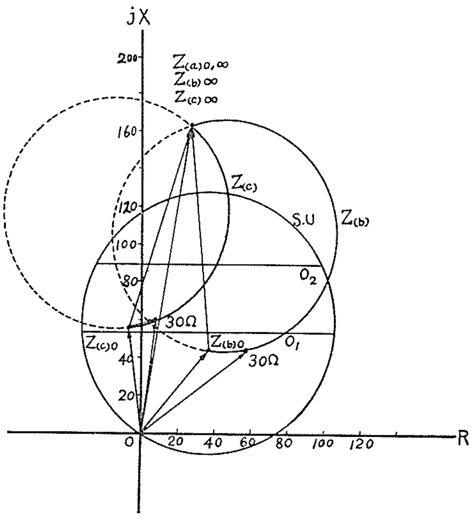
$$Z'_{(c-a)} = \frac{-3\dfrac{B_1}{A_1}A_{\beta 1}+(a-a^2)B_{\beta 1}+(a-1)A_{\beta 1}Z_f}{-3\dfrac{B_1}{A_1}C_{\beta 1}+(a-a^2)D_{\beta 1}+(a-1)C_{\beta 1}Z_f}$$

前例と同一回路とし，P 点にて線間短絡発生の場合の計算値は，(27), (28) 式より

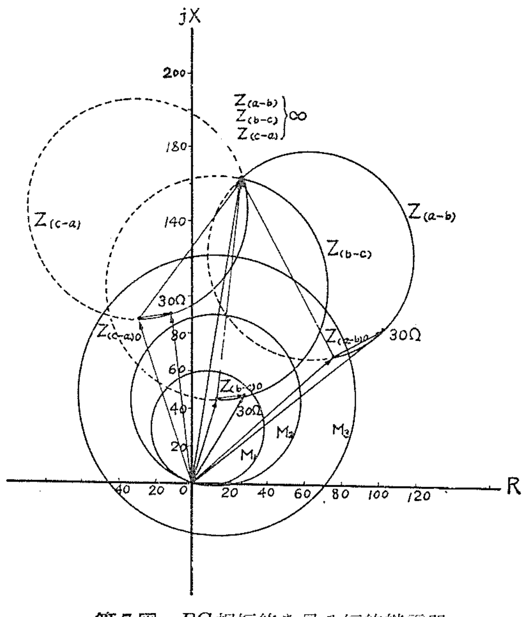
$$\left.\begin{aligned} Z'_a &= 27.27+j\,162.5 \\ Z'_b &= \frac{(61.21-j\,81.03)+(-0.775-j\,1.181)Z_f}{(-0.3576-j\,1.689)+(-0.007842+j\,0.003455)Z_f} \\ Z'_c &= \frac{(-94.68-j\,32.85)+(-0.6349+j\,1.262)Z_f}{(-0.3576+j\,1.775)+(0.006913+j\,0.005064)Z_f} \end{aligned}\right\} \quad \cdots\cdots (27')$$

$$\left.\begin{aligned} Z'_{(a-b)} &= \frac{(-27.71+j\,194.9)+(2.185+j\,1.100)Z_f}{(1.073+j\,1.603)+(0.008771-j\,0.01197)Z_f} \\ Z'_{(b-c)} &= \frac{(27.82+j\,90.00)+(1.410-j\,0.08091)Z_f}{2+(9.287-j\,85.19)\times 10^{-4}Z_f} \\ Z'_{(c-a)} &= \frac{(-128.2-j\,146.7)+(-2.045+j\,1.342)Z_f}{(-1.073+j\,1.861)+(0.005984+j\,0.01358)Z_f} \end{aligned}\right\} \quad \cdots\cdots (28')$$

第 6 図，第 7 図は $X_f=0$ として上式を図示したものである。



第 6 図　*BC* 相短絡を見る接地継電器



第 7 図　*BC* 相短絡を見る短絡継電器

[C]　二線短絡接地故障

第 3 図 (c) の故障が P 点にて発生した時の各継電器の測るインピーダンスに就いては

$$\left.\begin{aligned} I_{pa} &= 0 \\ E_{pb} &= E_{pc} = (I_{pb}+I_{pc})Z_f \end{aligned}\right\} \quad \cdots\cdots (29)$$

故に

$$\left.\begin{aligned} I_{p1}+I_{p2} &= -I_{p0} \\ E_{p1} &= E_{p2} = E_{p0}-3I_{p0}Z_f \end{aligned}\right\} \quad \cdots\cdots (30)$$

(12), (14) 及び (30) 式より

$$\left.\begin{aligned}
I_{p0} &= -\frac{\dfrac{B_2}{A_2}E_{s1}}{A_1\left\{\dfrac{B_1}{A_1}\dfrac{B_2}{A_2}+\left(\dfrac{B_1}{A_1}+\dfrac{B_2}{A_2}\right)\left(\dfrac{B_0}{A_0}+3Z_f\right)\right\}} = -\frac{1}{\Delta''}\frac{B_2}{A_2}E_{s1} \\
I_{p1} &= \frac{1}{\Delta''}\left(\frac{B_0}{A_0}+\frac{B_2}{A_2}+3Z_f\right)E_{s1} \\
I_{p2} &= -\frac{1}{\Delta''}\left(\frac{B_0}{A_0}+3Z_f\right)E_{s1} \\
\Delta'' &= A_1\left\{\frac{B_1}{A_1}\cdot\frac{B_2}{A_2}+\left(\frac{B_1}{A_1}+\frac{B_2}{A_2}\right)\left(\frac{B_0}{A_0}+3Z_f\right)\right\}
\end{aligned}\right\} \quad\cdots\cdots (31)$$

$$\left.\begin{aligned}
E_{p0} &= \frac{1}{\Delta''}\left(\frac{B_0}{A_0}\cdot\frac{B_2}{A_2}\right)E_{s1} \\
E_{p1} &= \frac{1}{\Delta''}\frac{B_2}{A_2}\left(\frac{B_0}{A_0}+3Z_f\right)E_{s1} \\
E_{p2} &= \frac{1}{\Delta''}\frac{B_2}{A_2}\left(\frac{B_0}{A_0}+3Z_f\right)E_{s1}
\end{aligned}\right\} \quad\cdots\cdots (32)$$

(18), (19) に (31), (32) を代入すれば，過渡値として

$$\left.\begin{aligned}
Z_a'' &= \frac{\dfrac{B_0}{A_0}\cdot\dfrac{B_1}{A_1}(A_{\beta0}+2A_{\beta1})+\dfrac{B_1}{A_1}(B_{\beta1}-B_{\beta0})+3\left(2\dfrac{B_1}{A_1}A_{\beta1}\right)Z_f}{\dfrac{B_0}{A_0}\cdot\dfrac{B_1}{A_1}(C_{\beta0}+2C_{\beta1})+\dfrac{B_1}{A_1}(D_{\beta1}-D_{\beta0})+3\left(2\dfrac{B_1}{A_1}C_{\beta1}\right)Z_f} \\
Z_b'' &= \frac{\dfrac{B_0}{A_0}\cdot\dfrac{B_1}{A_1}(A_{\beta0}-A_{\beta1})+\dfrac{B_1}{A_1}(a^2B_{\beta1}-B_{\beta0})+\dfrac{B_0}{A_0}(a^2-a)B_{\beta1}+3\left\{(a^2-a)B_{\beta1}-\dfrac{B_1}{A_1}A_{\beta1}\right\}Z_f}{\dfrac{B_0}{A_0}\cdot\dfrac{B_1}{A_1}(C_{\beta0}-C_{\beta1})+\dfrac{B_1}{A_1}(a^2D_{\beta1}-D_{\beta0})+\dfrac{B_0}{A_0}(a^2-a)D_{\beta1}+3\left\{(a^2-a)D_{\beta1}-\dfrac{B_1}{A_1}C_{\beta1}\right\}Z_f} \\
Z_c'' &= \frac{\dfrac{B_0}{A_0}\cdot\dfrac{B_1}{A_1}(A_{\beta0}-A_{\beta1})+\dfrac{B_1}{A_1}(aB_{\beta1}-B_{\beta0})+\dfrac{B_0}{A_0}(a-a^2)B_{\beta1}+3\left\{(a-a^2)B_{\beta1}-\dfrac{B_1}{A_1}A_{\beta1}\right\}Z_f}{\dfrac{B_0}{A_0}\cdot\dfrac{B_1}{A_1}(C_{\beta0}-C_{\beta1})+\dfrac{B_1}{A_1}(aD_{\beta1}-D_{\beta0})+\dfrac{B_0}{A_0}(a-a^2)D_{\beta1}+3\left\{(a-a^2)D_{\beta1}-\dfrac{B_1}{A_1}C_{\beta1}\right\}Z_f}
\end{aligned}\right\} \quad\cdots\cdots (33)$$

$$\left.\begin{aligned}
Z_{(a-b)}'' &= \frac{3\dfrac{B_0}{A_0}\cdot\dfrac{B_1}{A_1}A_{\beta1}+\dfrac{B_1}{A_1}(1-a^2)B_{\beta1}-\dfrac{B_0}{A_0}(a^2-a)B_{\beta1}+3\left\{3\dfrac{B_1}{A_1}A_{\beta1}-(a^2-a)B_{\beta1}\right\}Z_f}{3\dfrac{B_0}{A_0}\cdot\dfrac{B_1}{A_1}C_{\beta1}+\dfrac{B_1}{A_1}(1-a^2)D_{\beta1}-\dfrac{B_0}{A_0}(a^2-a)D_{\beta1}+3\left\{3\dfrac{B_1}{A_1}C_{\beta1}-(a^2-a)D_{\beta1}\right\}Z_f} \\
Z_{(b-c)}'' &= \frac{\dfrac{B_1}{A_1}B_{\beta1}+2\dfrac{B_0}{A_0}B_{\beta1}+6B_{\beta1}Z_f}{\dfrac{B_1}{A_1}D_{\beta1}+2\dfrac{B_0}{A_0}D_{\beta1}+6D_{\beta1}Z_f} = \frac{B_{\beta1}}{D_{\beta1}}
\end{aligned}\right\} \quad (34)$$

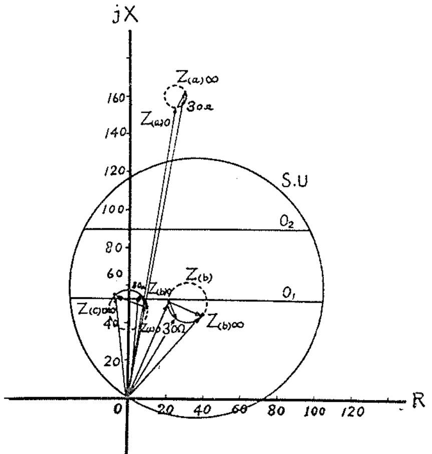
$$Z''_{(c-a)}=\frac{-3\frac{B_0}{A_0}\cdot\frac{B_1}{A_1}A_{\beta1}+\frac{B_1}{A_1}(a-1)B_{\beta1}+\frac{B_0}{A_0}(a-a^2)B_{\beta1}+3\left\{(a-a^2)B_{\beta1}-3\frac{B_1}{A_1}A_{\beta1}\right\}Z_f}{-3\frac{B_0}{A_0}\cdot\frac{B_1}{A_1}C_{\beta1}+\frac{B_1}{A_1}(a-1)D_{\beta1}+\frac{B_0}{A_0}(a-a^2)D_{\beta1}+3\left\{(a-a^2)D_{\beta1}-3\frac{B_1}{A_1}C_{\beta1}\right\}Z_f}$$

前例と同じ回路にて，P 点故障時の計算の結果は，(33), (34) より

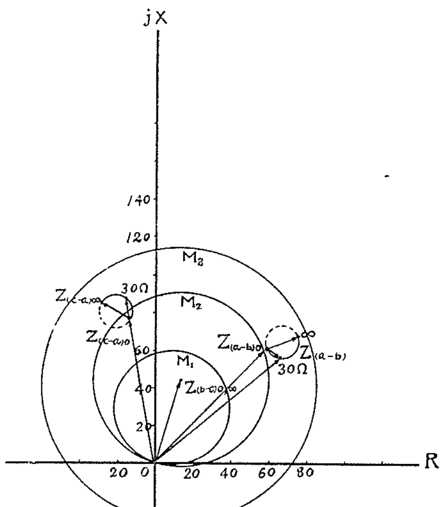
$$\left.\begin{aligned}Z''_a&=\frac{(-13900+j6169)+(100.5+j341.6)Z_f}{(24.85+j93.87)+(2.145-j0.2389)Z_f}\\Z''_b&=\frac{(8696+j7516)+(183.6-j243.1)Z_f}{(184.1-j95.78)+(-1.073-j5.067)Z_f}\\Z''_c&=\frac{(92.00-j10900)+(-28.41-j98.54)Z_f}{(-215.0-j40.14)+(-1.073+j5.325)Z_f}\end{aligned}\right\}\quad\cdots\cdots(33')$$

$$\left.\begin{aligned}Z''_{(a-b)}&=\frac{(-22340-j137.2)+(-83.11+j584.7)Z_f}{(-183.5+j189.7)+(3.218+j4.808)Z_f}\\Z''_{(b-c)}&=13.91+j45.00\\Z''_{(c-a)}&=\frac{(14020-j17070)+(-384.5-j440.2)Z_f}{(-240.7-j134.0)+(-3.218+j5.584)Z_f}\end{aligned}\right\}\quad\cdots\cdots(34')$$

上式を $X_f=0$ として図示すれば，第 8 図，第 9 図の如くなる。即ち本例にて $Z_f=\infty$ の場合は二線短絡の場合の $Z_f=0$ の点と一致する事は第 7 図，第 8 図と比較して明らかである。



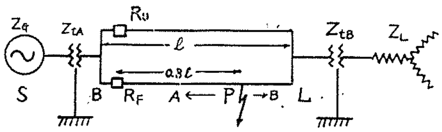
第 8 図　bc 相接地を見る接地継電器



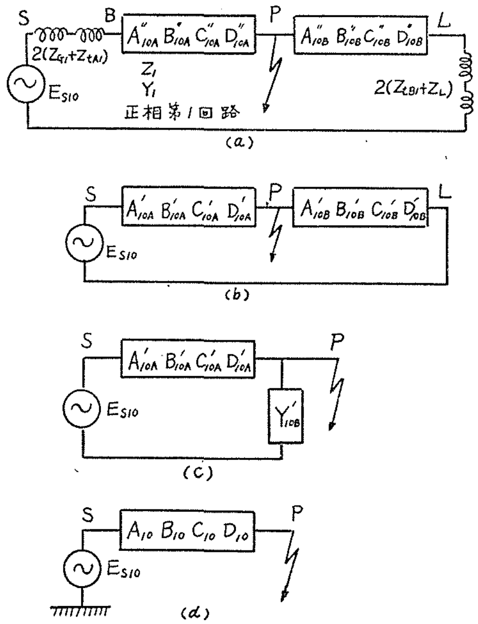
第 9 図　bc 相接地を見る短絡継電器

III. 並行二回線送電線に就いての計算

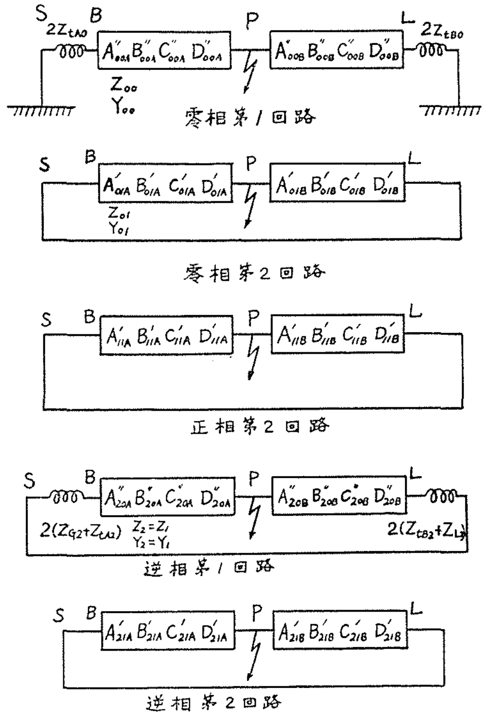
第 10 図に示す回路の P 点にて各種非対称故障発生せる場合，故障回線及び健全回線の各相距離継電器 R_F 及び R_U の測定するインピーダンスは，故障点インピーダンスの影響を考慮



第 10 図



第 11 図



第 12 図

するに当り，零相分相互誘導を含む必要があるが，今此の回路を対称二相回路に分解すれば，一回線の場合と同様にして計算式を得る事が出来る。

即ち第 11 図 (a) を正相第 1 回路とすれば，同図 (b), (c), (d) の順により，内部誘起電圧点 S を送電端，故障点 P を受電端とする等価回路とする事が出来る。

$$\left.\begin{aligned}\begin{bmatrix}A'_{10A} & B'_{10A}\\ C'_{10A} & D'_{10A}\end{bmatrix} &= \begin{bmatrix}1 & 2(Z_{tA1}+Z_{G1})\\ 0 & 1\end{bmatrix}\begin{bmatrix}A''_{10A} & B''_{10A}\\ C''_{10A} & D''_{10A}\end{bmatrix}\\ \begin{bmatrix}A'_{10B} & B'_{10B}\\ C'_{10B} & D'_{10B}\end{bmatrix} &= \begin{bmatrix}A''_{10B} & B''_{10B}\\ C''_{10B} & D''_{10B}\end{bmatrix}\begin{bmatrix}1 & 2(Z_{tB1}+Z_{L1})\\ 0 & 1\end{bmatrix}\end{aligned}\right\} \qquad \cdots\cdots\cdots (35)$$

正相第 1 回路の負荷中性点は $E_L=0$ として

$$Y'_{10B} = D'_{10B}/B'_{10B} \qquad \cdots\cdots\cdots (36)$$

$$\begin{bmatrix}A_{10} & B_{10}\\ C_{10} & D_{10}\end{bmatrix} = \begin{bmatrix}A'_{10A} & B'_{10A}\\ C'_{10A} & D'_{10A}\end{bmatrix}\begin{bmatrix}1 & 0\\ Y'_{10B} & 1\end{bmatrix} \qquad \cdots\cdots\cdots (37)$$

同様にして，第 12 図に示す各相分回路は，第 11 図と同じく，負荷側中性点は短絡されている故に次の如く置換し得る。

$$\left.\begin{aligned}\begin{bmatrix}A'_{00B} & B'_{00B}\\ C'_{00B} & D'_{00B}\end{bmatrix} &= \begin{bmatrix}A''_{00B} & B''_{00B}\\ C''_{00B} & D''_{00B}\end{bmatrix}\begin{bmatrix}1 & 2Z_{tB0}\\ 0 & 1\end{bmatrix}\\ Y'_{00B} &= D'_{00B}/B'_{00B}\end{aligned}\right\} \qquad \cdots\cdots\cdots (38)$$

$$\begin{bmatrix} A_{00} & B_{00} \\ C_{00} & D_{00} \end{bmatrix} = \begin{bmatrix} 1 & 2Z_{tA0} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A''_{00A} & B''_{00A} \\ C''_{00A} & D''_{00A} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ Y'_{00B} & 1 \end{bmatrix} \quad \Bigg\}$$

$$\left.\begin{aligned} & Y'_{01B} = D'_{01B}/B'_{01B} \\ & \begin{bmatrix} A_{01} & B_{01} \\ C_{01} & D_{01} \end{bmatrix} = \begin{bmatrix} A'_{01A} & B'_{01A} \\ C'_{01A} & D'_{01A} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ Y'_{01B} & 1 \end{bmatrix} \end{aligned}\right\} \quad \cdots\cdots\cdots (39)$$

$$\left.\begin{aligned} & Y'_{11B} = D'_{11B}/B'_{11B} \\ & \begin{bmatrix} A_{11} & B_{11} \\ C_{11} & D_{11} \end{bmatrix} = \begin{bmatrix} A'_{11A} & B'_{11A} \\ C'_{11A} & D'_{11A} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ Y'_{11B} & 1 \end{bmatrix} \end{aligned}\right\} \quad \cdots\cdots\cdots (40)$$

$$\left.\begin{aligned} & \begin{bmatrix} A'_{20B} & B'_{20B} \\ C'_{20B} & D'_{20B} \end{bmatrix} = \begin{bmatrix} A''_{20B} & B''_{20B} \\ C''_{20B} & D''_{20B} \end{bmatrix} \begin{bmatrix} 1 & 2(Z_{tB1}+Z_{L2}) \\ 0 & 1 \end{bmatrix} \\ & Y'_{20B} = D'_{20B}/B'_{20B} \\ & \begin{bmatrix} A_{20} & B_{20} \\ C_{20} & D_{20} \end{bmatrix} = \begin{bmatrix} 1 & 2(Z_{tA1}+Z_{G2}) \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A''_{20A} & B''_{20A} \\ C''_{20A} & D''_{20A} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ Y'_{20B} & 1 \end{bmatrix} \end{aligned}\right\} \quad \cdots\cdots\cdots (41)$$

$$\left.\begin{aligned} & Y'_{21B} = D'_{21B}/B'_{21B} \\ & \begin{bmatrix} A_{21} & B_{21} \\ C_{21} & D_{21} \end{bmatrix} = \begin{bmatrix} A'_{21A} & B'_{21A} \\ C'_{21A} & D'_{21A} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ Y'_{21B} & 1 \end{bmatrix} \end{aligned}\right\} \quad \cdots\cdots\cdots (42)$$

第10図を参照すれば，(37)〜(42) 式より，S 点 P 点間に次の関係式が成立つ

$$\left.\begin{aligned} \begin{bmatrix} E_{s00} \\ I_{s00} \end{bmatrix} &= \begin{bmatrix} A_{00} & B_{00} \\ C_{00} & D_{00} \end{bmatrix} \begin{bmatrix} E_{p00} \\ I_{p00} \end{bmatrix} \\ \begin{bmatrix} E_{s01} \\ I_{s01} \end{bmatrix} &= \begin{bmatrix} A_{01} & B_{01} \\ C_{01} & D_{01} \end{bmatrix} \begin{bmatrix} E_{p01} \\ I_{p01} \end{bmatrix} \\ \begin{bmatrix} E_{s10} \\ I_{s10} \end{bmatrix} &= \begin{bmatrix} A_{10} & B_{10} \\ C_{10} & D_{10} \end{bmatrix} \begin{bmatrix} E_{p10} \\ I_{p10} \end{bmatrix} \\ \begin{bmatrix} E_{s11} \\ I_{s11} \end{bmatrix} &= \begin{bmatrix} A_{11} & B_{11} \\ C_{11} & D_{11} \end{bmatrix} \begin{bmatrix} E_{p11} \\ I_{p11} \end{bmatrix} \\ \begin{bmatrix} E_{s20} \\ I_{s20} \end{bmatrix} &= \begin{bmatrix} A_{20} & B_{20} \\ C_{20} & D_{20} \end{bmatrix} \begin{bmatrix} E_{p20} \\ I_{p20} \end{bmatrix} \\ \begin{bmatrix} E_{s21} \\ I_{s21} \end{bmatrix} &= \begin{bmatrix} A_{21} & B_{21} \\ C_{21} & D_{21} \end{bmatrix} \begin{bmatrix} E_{p21} \\ I_{p21} \end{bmatrix} \end{aligned}\right\} \quad \cdots\cdots\cdots (43)$$

又故障回線を F，健全回線を U で表わせば両者間には

$$\left.\begin{aligned} E_{p0F} &= E_{p00}+E_{p01} & E_{p0U} &= E_{p00}-E_{p01} \\ E_{p1F} &= E_{p10}+E_{p11} & E_{p1U} &= E_{p10}-E_{p11} \\ E_{p2F} &= E_{p20}+E_{p21} & E_{p2U} &= E_{p20}-E_{p21} \\ I_{p0F} &= I_{p00}+I_{p01} & I_{p0U} &= I_{p00}-I_{p01} \\ I_{p1F} &= I_{p10}+I_{p11} & I_{p1U} &= I_{p10}-I_{p11} \\ I_{p2F} &= I_{p20}+I_{p21} & I_{p2U} &= I_{p20}-I_{p21} \end{aligned}\right\} \quad \cdots\cdots\cdots (44)$$

[A] 一線接地故障

a 相 P 点にて一線接地故障発生すれば，故障条件は

$$\left.\begin{aligned} &E_{paF}=Z_f I_{paF} \\ &I_{pbF}=I_{pcF}=0 \\ &I_{paU}=I_{pbU}=I_{pcU}=0 \end{aligned}\right\} \qquad \cdots\cdots (45)$$

又一般に

$$E_{s00}=E_{s01}=E_{s11}=E_{s20}=E_{s21}=0 \qquad \cdots\cdots (46)$$

(45) 第1式より

$$E_{paF}=Z_f I_{paF}=E_{p00}+E_{p01}+E_{p10}+E_{p11}+E_{p20}+E_{p21}$$

第2式より

$$I_{p10}+I_{p11}=I_{p20}+I_{p21}=I_{p00}+I_{p01} \qquad \cdots\cdots (47)$$

第3式より

$$I_{p00}=I_{p01}\,,\quad I_{p10}=I_{p11}\,,\quad I_{p20}=I_{p21}$$

故に　$I_{p00}=I_{p01}=I_{p10}=I_{p11}=I_{p20}=I_{p21}$

(43) 式に於いて S 点各対称分電圧式の和を求めて，(46) 及び (47) を代入すれば

$$\frac{E_{s10}}{A_{10}}=Z_f I_{paF}+\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+\frac{B_{10}}{A_{10}}+\frac{B_{11}}{A_{11}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)I_{p10}$$

$$\left.\begin{aligned} I_{p10}&=\frac{E_{s10}}{A_{10}\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+\frac{B_{10}}{A_{10}}+\frac{B_{11}}{A_{11}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}+6Z_f\right)} \\ &=\frac{E_{s10}}{A_{10}(\varDelta+6Z_f)}=\frac{E_{s10}}{\sum}=I_{p00}=I_{p01}=I_{p11}=I_{p20}=I_{p21} \\ \varDelta&=\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+\frac{B_{10}}{A_{10}}+\frac{B_{11}}{A_{11}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}} \\ \sum&=A_{10}(\varDelta+6Z_f) \end{aligned}\right\} \qquad \cdots\cdots (48)$$

(43), (46) 及び (48) 式より

$$\left.\begin{aligned} E_{p00}&=-\frac{1}{\sum}\frac{B_{00}}{A_{00}}E_{s10} \\ E_{p01}&=-\frac{1}{\sum}\frac{B_{01}}{A_{01}}E_{s10} \\ E_{p10}&=\frac{1}{\sum}\left(\varDelta-\frac{B_{10}}{A_{10}}+6Z_f\right)E_{s10} \\ E_{p11}&=-\frac{1}{\sum}\frac{B_{11}}{A_{11}}E_{s10} \\ E_{p20}&=-\frac{1}{\sum}\frac{B_{20}}{A_{20}}E_{s10} \\ E_{p21}&=-\frac{1}{\sum}\frac{B_{21}}{A_{21}}E_{s10} \end{aligned}\right\} \qquad \cdots\cdots (49)$$

S 点に於ける電圧，電流各対称分については，(48), (49) を (43) に代入して

$$\left.\begin{aligned} &E_{s00}=E_{s01}=E_{s11}=E_{s20}=E_{s21}=0\\ &I_{s00}=\frac{1}{\sum}\frac{H_{00}}{A_{00}}E_{s10}\\ &I_{s01}=\frac{1}{\sum}\frac{H_{01}}{A_{01}}E_{s10}\\ &I_{s10}=\frac{1}{\sum}\left\{\frac{H_{10}+A_{10}C_{10}(\varDelta+6Z_f)}{A_{10}}\right\}E_{s10}\\ &I_{s11}=\frac{1}{\sum}\frac{H_{11}}{A_{11}}E_{s10}\\ &I_{s20}=\frac{1}{\sum}\frac{H_{20}}{A_{20}}E_{s10}\\ &I_{s21}=\frac{1}{\sum}\frac{H_{21}}{A_{21}}E_{s10} \end{aligned}\right\} \quad \cdots\cdots (50)$$

但し

$$\left.\begin{aligned} &H_{00}=A_{00}D_{00}-B_{00}C_{00}\\ &H_{01}=A_{01}D_{01}-B_{01}C_{01}\\ &H_{10}=A_{10}D_{10}-B_{10}C_{10}\\ &H_{11}=A_{11}D_{11}-B_{11}C_{11}\\ &H_{20}=A_{20}D_{20}-B_{20}C_{20}\\ &H_{21}=A_{21}D_{21}-B_{21}C_{21} \end{aligned}\right\} \quad \cdots\cdots (51)$$

母線 B 点に於ける電圧電流値は，次式に (50), (51) を代入して得られる。

$$\left.\begin{aligned} &\begin{bmatrix}E_{B00}\\ I_{B00}\end{bmatrix}=\begin{bmatrix}1 & -2Z_{tA0}\\ 0 & 1\end{bmatrix}\begin{bmatrix}E_{s00}\\ I_{s00}\end{bmatrix}\\ &\begin{bmatrix}E_{B01}\\ I_{B01}\end{bmatrix}=\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}E_{s01}\\ I_{s01}\end{bmatrix}\\ &\begin{bmatrix}E_{B10}\\ I_{B10}\end{bmatrix}=\begin{bmatrix}1 & -2(Z_{tA}+Z_{G1})\\ 0 & 1\end{bmatrix}\begin{bmatrix}E_{s10}\\ I_{s10}\end{bmatrix}\\ &\begin{bmatrix}E_{B11}\\ I_{B11}\end{bmatrix}=\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}E_{s11}\\ I_{s11}\end{bmatrix}\\ &\begin{bmatrix}E_{B20}\\ I_{B20}\end{bmatrix}=\begin{bmatrix}1 & -2(Z_{tA}+Z_{G2})\\ 0 & 1\end{bmatrix}\begin{bmatrix}E_{s20}\\ I_{s20}\end{bmatrix}\\ &\begin{bmatrix}E_{B21}\\ I_{B21}\end{bmatrix}=\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}E_{s21}\\ I_{s21}\end{bmatrix} \end{aligned}\right\} \quad \cdots\cdots (52)$$

(51) 式の各 H 値は，ほぼ 1 に近い値を示す故，式の繁雑を防ぐ為

$$H_{00}=H_{01}=H_{10}=H_{11}=H_{20}=H_{21}=1 \quad \cdots\cdots (53)$$

とすれば，母線に連る故障回線 F 及び健全回線 U の距離継電器 R_F 及び R_U 点に於ける各対称分電圧電流は，(44) 式を参照し，(50), (51), (52), (53) 式より次の如く計算される。

$$\left.\begin{aligned}
E_{R0F} &= E_{R0U} = -\frac{1}{\Sigma}\frac{2Z_{tA0}}{A_{00}}E_{s10} \\
E_{R1F} &= E_{R1U} = \frac{1}{\Sigma}\left\{\Sigma-\frac{2(Z_{tA}+Z_{G1})(1+C_{10}\Sigma)}{A_{10}}\right\}E_{s10} \\
E_{R2F} &= E_{R2U} = -\frac{1}{\Sigma}\frac{2(Z_{tA}+Z_{G2})}{A_{20}}E_{s10}
\end{aligned}\right\} \quad \cdots\cdots\cdots\cdots (54)$$

$$\left.\begin{aligned}
I_{R0F} &= \frac{1}{\Sigma}\left(\frac{1}{A_{00}}+\frac{1}{A_{01}}\right)E_{s10} \\
I_{R0U} &= \frac{1}{\Sigma}\left(\frac{1}{A_{00}}-\frac{1}{A_{01}}\right)E_{s10} \\
I_{R1F} &= \frac{1}{\Sigma}\left(\frac{1+C_{10}\Sigma}{A_{10}}+\frac{1}{A_{11}}\right)E_{s10} \\
I_{R1U} &= \frac{1}{\Sigma}\left(\frac{1+C_{10}\Sigma}{A_{10}}-\frac{1}{A_{11}}\right)E_{s10} \\
I_{R2F} &= \frac{1}{\Sigma}\left(\frac{1}{A_{20}}+\frac{1}{A_{21}}\right)E_{s10} \\
I_{R2U} &= \frac{1}{\Sigma}\left(\frac{1}{A_{20}}-\frac{1}{A_{21}}\right)E_{s21}
\end{aligned}\right\} \quad \cdots\cdots\cdots\cdots (55)$$

R_F 及び R_U の測定するインピーダンスは，(54)，(55) 式より各回線各相電圧電流を求めて計算出来る故，a 相故障回線に於いては

$$\begin{aligned}
Z_{aF} &= \frac{E_{RaF}}{I_{RaF}} = \frac{E_{R0F}+E_{R1F}+E_{R2F}}{I_{R0F}+I_{R1F}+I_{R2F}} \\
&= \frac{\Sigma-\dfrac{2(Z_{tA}+Z_{G1})(1+C_{10}\Sigma)}{A_{10}}-\dfrac{2Z_{tA0}}{A_{00}}-\dfrac{2(Z_{tA}+Z_{G2})}{A_{20}}}{\dfrac{1}{A_{00}}+\dfrac{1}{A_{01}}+\dfrac{1}{A_{10}}+\dfrac{1}{A_{11}}+\dfrac{1}{A_{20}}+\dfrac{1}{A_{21}}+\dfrac{C_{10}}{A_{10}}\Sigma}
\end{aligned}$$

他も同様に求め得るが，今過渡状態のみを必要とするならば

$$2(Z_{tA}+Z_{G1}) = 2(Z_{tA}+Z_{G2}) = Z_s \quad \cdots\cdots\cdots\cdots (56)$$

として，接地継電器に対しては

$$\left.\begin{aligned}
Z_{aF} &= \frac{\left\{A_{10}\Delta-\dfrac{2Z_{tA0}}{A_{00}}-\dfrac{Z_s}{A_{10}}(2+A_{10}C_{10}\Delta)\right\}+6(A_{10}-C_{10}Z_s)Z_f}{\left(\dfrac{1}{A_{00}}+\dfrac{1}{A_{01}}+\dfrac{2}{A_{10}}+\dfrac{2}{A_{11}}+C_{10}\Delta\right)+6C_{10}Z_f} \\
Z_{bF} &= \frac{\left\{a^2A_{10}\Delta-\dfrac{2Z_{tA0}}{A_{00}}-\dfrac{Z_s}{A_{10}}(a^2C_{10}A_{10}\Delta-1)\right\}+6a^2(A_{10}-C_{10}Z_s)Z_f}{\left\{\dfrac{1}{A_{00}}+\dfrac{1}{A_{01}}-\dfrac{1}{A_{10}}-\dfrac{1}{A_{11}}+a^2C_{10}\Delta\right)+6a^2C_{10}Z_f} \\
Z_{cF} &= \frac{\left\{aA_{10}\Delta-\dfrac{2Z_{tA0}}{A_{00}}-\dfrac{Z_s}{A_{10}}(aC_{10}C_{10}\Delta-1)\right\}+6a(A_{10}-C_{10}Z_s)Z_f}{\left(\dfrac{1}{A_{00}}+\dfrac{1}{A_{01}}-\dfrac{1}{A_{10}}-\dfrac{1}{A_{11}}+aC_{10}\Delta\right)+6aC_{10}Z_f}
\end{aligned}\right\} \quad (57)$$

$$
\left.\begin{aligned}
Z_{aU} &= \frac{E_{R0U}+E_{R1U}+E_{R2U}}{I_{R0U}+I_{R1U}+I_{R2U}} \\
&= \frac{\left\{A_{10}\varDelta-\dfrac{2Z_{tA0}}{A_{00}}-\dfrac{Z_s}{A_{10}}(2+A_{10}C_{10}\varDelta)\right\}+6(A_{10}-C_{10}Z_s)Z_f}{\left(\dfrac{1}{A_{00}}-\dfrac{1}{A_{01}}+\dfrac{2}{A_{10}}-\dfrac{2}{A_{11}}+C_{10}\varDelta\right)+6C_{10}Z_f} \\
Z_{bU} &= \frac{\left\{a^2A_{10}\varDelta-\dfrac{2Z_{tA0}}{A_{00}}-\dfrac{Z_s}{A_{10}}(a^2A_{10}C_{10}\varDelta-1)\right\}+6a^2(A_{10}-C_{10}Z_s)Z_f}{\left(\dfrac{1}{A_{00}}-\dfrac{1}{A_{01}}-\dfrac{1}{A_{10}}+\dfrac{1}{A_{11}}+a^2C_{10}\varDelta\right)+6a^2C_{10}Z_f} \\
Z_{cU} &= \frac{\left\{aA_{10}\varDelta-\dfrac{2Z_{tA0}}{A_{00}}-\dfrac{Z_s}{A_{10}}(aA_{10}C_{10}\varDelta-1)\right\}+6a(A_{10}-C_{10}Z_s)Z_f}{\left(\dfrac{1}{A_{00}}-\dfrac{1}{A_{01}}-\dfrac{1}{A_{10}}+\dfrac{1}{A_{11}}+aC_{10}\varDelta\right)+6aC_{10}Z_f}
\end{aligned}\right\} \qquad (58)
$$

短絡距離継電器に対しては

$$
\left.\begin{aligned}
Z_{(a-b)F} &= \frac{(1-a^2)A_{10}\varDelta-\dfrac{Z_s}{A_{10}}\left\{(1-a^2)A_{10}C_{10}\varDelta+3\right\}+6(1-a^2)(A_{10}-C_{10}Z_s)Z_f}{3\left(\dfrac{1}{A_{10}}+\dfrac{1}{A_{11}}\right)+(1-a^2)C_{10}\varDelta+6(1-a^2)C_{10}Z_f} \\
Z_{(b-c)F} &= \frac{A_{10}\varDelta-\dfrac{Z_s}{A_{10}}C_{10}A_{10}\varDelta+6(A_{10}-C_{10}Z_s)Z_f}{C_{10}\varDelta+6C_{10}Z_f} \\
Z_{(c-a)F} &= \frac{(a-1)A_{10}\varDelta-\dfrac{Z_s}{A_{10}}\left\{(a-1)A_{10}C_{10}\varDelta-3\right\}+6(a-1)(A_{10}-C_{10}Z_s)Z_f}{-3\left(\dfrac{1}{A_{10}}+\dfrac{1}{A_{11}}\right)+(a-1)C_{10}\varDelta+6(a-1)C_{10}Z_f}
\end{aligned}\right\} \qquad (59)
$$

$$
\left.\begin{aligned}
Z_{(a-b)U} &= \frac{(1-a^2)A_{10}\varDelta-\dfrac{Z_s}{A_{10}}\left\{(1-a^2)A_{10}C_{10}\varDelta+3\right\}+6(1-a^2)(A_{10}-C_{10}Z_s)Z_f}{3\left(\dfrac{1}{A_{10}}-\dfrac{1}{A_{11}}\right)+(1-a^2)C_{10}\varDelta+6(1-a^2)C_{10}Z_f} \\
Z_{(b-c)U} &= \frac{A_{10}\varDelta-\dfrac{Z_s}{A_{10}}A_{10}C_{10}\varDelta+6(A_{10}-C_{10}Z_s)Z_f}{C_{10}\varDelta+6C_{10}Z_f} = Z_{(b-c)F} \\
Z_{(c-a)U} &= \frac{(a-1)A_{10}\varDelta-\dfrac{Z_s}{A_{10}}\left\{(a-1)A_{10}C_{10}\varDelta-3\right\}+6(a-1)(A_{10}-C_{10}Z_s)Z_f}{-3\left(\dfrac{1}{A_{10}}-\dfrac{1}{A_{11}}\right)+(a-1)C_{10}\varDelta+6(a-1)C_{10}Z_f}
\end{aligned}\right\} \qquad (60)
$$

実例計算として，第 11 図，第 12 図の如く各対称分で示される，第 10 図の P 点にて故障発生せる場合

$BP=109.1\,\mathrm{km}$， $PL=27.28\,\mathrm{km}$.

$Z_s=2(Z_{tA}+Z_{G1})=2(Z_{tA}+Z_{G2})=j\,184.0\,\Omega$

$2(Z_{tB}+Z_{L1})=2(Z_{tB}+Z_{L2})=16.72+j\,20.34\,\Omega$

$Z_1=0.1275+j\,0.4125\,\Omega/\mathrm{km}$

$$Y_1 = j\,2.790\times10^{-6}\,\mho/\text{km}$$

$$Z_{tA0} = j\,68.50\,\Omega \qquad Z_{tB0} = j\,91.70\,\Omega$$

$$Z_{00} = 0.6227+j\,2.353\,\Omega/\text{km}$$

$$Y_{00} = j\,1.334\times10^{-6}\,\mho/\text{km}$$

$$Z_{01} = 0.1275+j\,0.4713\,\Omega/\text{km}$$

$$Y_{01} = j\,2.045\times10^{-6}\,\mho/\text{km}$$

と仮定し，線路部分については

$$A=D=1.\quad B=Zl,\quad C=Yl,$$

として計算すれば

$$H_{00} = 1.036-j\,0.0098$$

$$H_{01} = 1.011-j\,0.003$$

$$H_{10} = 1.044-j\,0.00602$$

$$H_{11} = 1.014-j\,0.005$$

であり，各インピーダンス値は

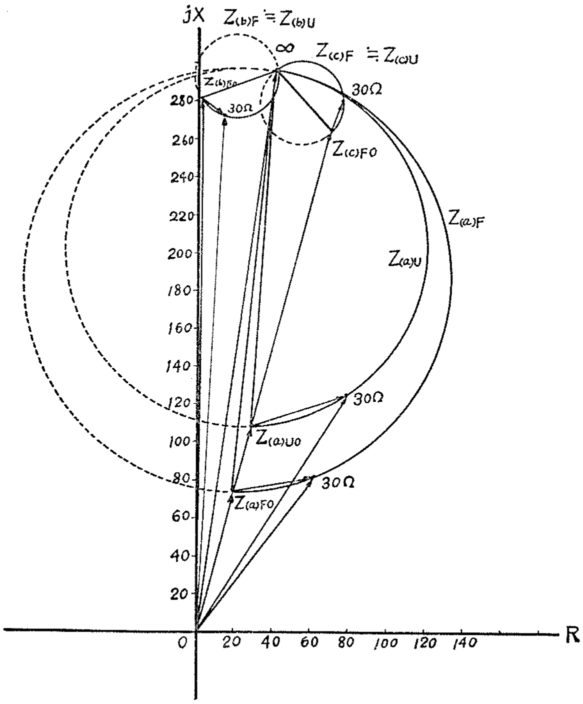
$$\left.\begin{aligned} Z_{aF} &= \frac{(71.33+j\,268.8)+(7.409-j\,0.2625)\,Z_f}{(3.706+j\,0.007780)+(0.002601-j\,0.02469)\,Z_f} \\ Z_{bF} &= \frac{(408.2-j\,275.8)+(-3.932-j\,6.285)\,Z_f}{(-0.9708-j\,1.452)+(-0.02268+j\,0.0101)\,Z_f} \\ Z_{cF} &= \frac{(-469.3-j\,152.3)+(-3.477+j\,6.547)\,Z_f}{(-0.973+j\,1.518)+(0.02008+j\,0.0146)\,Z_f} \end{aligned}\right\} \quad\cdots\cdots\cdots\cdots\cdots\cdots (57')$$

$$\left.\begin{aligned} Z_{aU} &= \frac{(70.93+j\,268.8)+(7.408-j\,0.2625)\,Z_f}{(2.506+j\,0.00778)+(0.002601-j\,0.02469)\,Z_f} \\ &\text{本例では}\ \frac{1}{A_{01}} \doteqdot \frac{1}{A_{11}} = 0.200\ \text{の為} \\ Z_{bU} &\doteqdot Z_{bF},\quad Z_{cU} \doteqdot Z_{cF}\ \text{となつている。} \end{aligned}\right\} \quad\cdots\cdots\cdots\cdots\cdots\cdots (58')$$

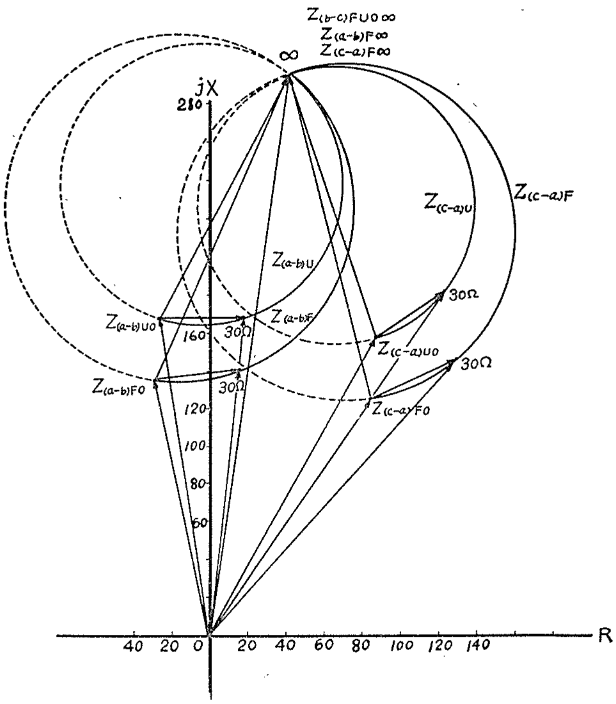
$$\left.\begin{aligned} Z_{(a-b)F} &= \frac{(-336.7+j\,544.7)+(11.34+j\,6.022)\,Z_f}{(4.334+j\,1.561)+(0.02528-j\,0.03478)\,Z_f} \\ Z_{(b-c)F} &= \frac{(71.30+j\,506.6)+(7.409-j\,0.2625)\,Z_f}{(1.715+j\,0.0013)+(0.002601-j\,0.6247)\,Z_f} \\ Z_{(c-a)F} &= \frac{(-540.7-j\,421.2)+(-10.89+j\,6.810)\,Z_f}{(-4.337+j\,1.409)+(0.01748+j\,0.0393)\,Z_f} \end{aligned}\right\} \quad\cdots\cdots\cdots\cdots\cdots\cdots (59')$$

$$\left.\begin{aligned} Z_{(a-b)U} &= \frac{(-337.3+j\,544.4)+(11.34+j\,6.022)\,Z_f}{(3.477+j\,1.460)+(0.02528-j\,0.03478)\,Z_f} \\ Z_{(b-c)U} &= Z_{(b-c)F} \\ Z_{(c-a)U} &= \frac{(-540.1-j\,421.5)+(-10.89+j\,6.810)\,Z_f}{(-3.480+j\,1.510)+(0.01748+j\,0.0393)\,Z_s} \end{aligned}\right\} \quad\cdots\cdots\cdots\cdots\cdots\cdots (60')$$

(57′), (58′) 及び (59′), (60′) を $X_f=0$ として図示すれば，夫々第 13 図及び第 14 図となり，一回線の場合の実例と同一の負荷を仮定しているので，$Z_f=\infty$ の場合継電器の眺めるインピ



第13図 *a* 相接地を見る両回線各接地継電器



第14図 *a* 相接地を見る両回線各短絡継電器

ーダンスは，ほぼ2倍値に近くなつている。

[B] 二線短絡故障

BC 相に二線短絡故障が発生した場合の故障条件は

$$\left.\begin{aligned} &I_{paF}=0\\ &I_{pbF}=-I_{pcF}\\ &E_{pbF}-E_{pcF}=I_{pbF}Z_f\\ &I_{paU}=I_{pbU}=I_{pcU}=0 \end{aligned}\right\} \quad \cdots\cdots (61)$$

(44) 及び (61) 式より

$$\left.\begin{aligned} &I_{p00}=I_{p01}=0\\ &I_{p10}=I_{p11},\quad I_{p20}=I_{p21}\\ &I_{p20}=-I_{p10}\\ &\text{(61)の第3式より}\\ &E_{p10}+E_{p11}=E_{p20}+E_{p21}+2I_{p10}Z_f \end{aligned}\right\} \quad \cdots\cdots (62)$$

(43), (46) 及び (62) 式より

$$\left.\begin{aligned} &E_{p00}=E_{p01}=0\\ &E_{p10}=\frac{1}{A_{10}}E_{s10}-\frac{B_{10}}{A_{10}}I_{p10}\\ &E_{p11}=-\frac{B_{11}}{A_{11}}I_{p10}\\ &E_{p20}=\frac{B_{20}}{A_{20}}I_{p10}\\ &E_{p21}=\frac{B_{21}}{A_{21}}I_{p10} \end{aligned}\right\} \quad \cdots\cdots (63)$$

(63) 式を (62) の最後の式に代入して

$$\left.\begin{aligned} &I_{p10}=\frac{E_{s10}}{A_{10}\left(\dfrac{B_{10}}{A_{10}}+\dfrac{B_{11}}{A_{11}}+\dfrac{B_{20}}{A_{20}}+\dfrac{B_{21}}{A_{21}}+2Z_f\right)}=\frac{E_{s10}}{\Sigma'}\\ &\Sigma'=A_{10}\left(\frac{B_{10}}{A_{10}}+\frac{B_{11}}{A_{11}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}+2Z_f\right) \end{aligned}\right\} \quad \cdots\cdots (64)$$

(62), (63) 及び (64) より

$$\left.\begin{aligned} &I_{p00}=I_{p01}=0\\ &I_{p10}=I_{p11}=\frac{1}{\Sigma'}E_{s10}\\ &I_{p20}=I_{p21}=-\frac{1}{\Sigma'}E_{s10} \end{aligned}\right\} \quad \cdots\cdots (65)$$

$$\left.\begin{aligned} &E_{p00}=E_{p01}=0\\ &E_{p10}=\frac{1}{\Sigma'}\left(\frac{\Sigma'}{A_{10}}-\frac{B_{10}}{A_{10}}\right)E_{s10} \end{aligned}\right\} \quad \cdots\cdots (66)$$

$$\left.\begin{aligned}
E_{p11} &= -\frac{1}{\sum'}\frac{B_{11}}{A_{11}}E_{s10}\\
E_{p20} &= \frac{1}{\sum'}\cdot\frac{B_{20}}{A_{20}}E_{s10}\\
E_{p21} &= \frac{1}{\sum'}\frac{B_{21}}{A_{21}}E_{s10}
\end{aligned}\right\}$$

(46), (53), (65), (66) を (43) 式に代入すれば，S 点の値として

$$\left.\begin{aligned}
&E_{s00} = E_{s01} = E_{s11} = E_{s20} = E_{s21} = 0\\
&I_{s00} = I_{s01} = 0\\
&I_{s10} = \frac{1}{\sum'}\frac{(C_{10}\sum'+1)}{A_{10}}E_{s10}\\
&I_{s11} = \frac{1}{\sum'}\frac{1}{A_{11}}E_{s10}\\
&I_{s20} = -\frac{1}{\sum'}\frac{1}{A_{20}}E_{s10}\\
&I_{s21} = -\frac{1}{\sum'}\frac{1}{A_{21}}E_{s10}
\end{aligned}\right\} \quad \cdots\cdots (67)$$

(52), (67) 式より母線 B に於ける値を求めれば

$$\left.\begin{aligned}
&E_{B00} = E_{B01} = E_{B11} = E_{B21} = 0\\
&E_{B10} = \frac{1}{\sum'}\left\{\sum' - \frac{2(Z_{tA}+Z_{G1})(C_{10}\sum'+1)}{A_{10}}\right\}E_{s10}\\
&E_{B20} = \frac{1}{\sum'}\left\{\frac{2(Z_{tA}+Z_{G2})}{A_{20}}\right\}E_{s10}
\end{aligned}\right\} \quad \cdots\cdots (68)$$

$$\left.\begin{aligned}
&I_{B00} = I_{B01} = 0\\
&I_{B10} = \frac{1}{\sum'}\left(\frac{C_{10}\sum'+1}{A_{10}}\right)E_{s10}\\
&I_{B11} = \frac{1}{\sum'}\frac{1}{A_{11}}E_{s10}\\
&I_{B20} = -\frac{1}{\sum'}\frac{1}{A_{20}}E_{s10}\\
&I_{B21} = -\frac{1}{\sum'}\frac{1}{A_{21}}E_{s10}
\end{aligned}\right\} \quad \cdots\cdots (69)$$

(68), (69) 式より故障回線，健全回線の継電器点の各対照分電圧電流を求め得る。即ち

$$\left.\begin{aligned}
&E_{R0F} = E_{R0U} = 0\\
&E_{R1F} = E_{R1U} = \frac{1}{\sum'}\left\{\Delta'(A_{10}-C_{10}Z_{s1}) - \frac{Z_{s1}}{A_{10}} + 2(A_{10}-C_{10}Z_{s1})Z_f\right\}E_{s10}\\
&E_{R2F} = E_{R2U} = \frac{1}{\sum'}\frac{Z_{s2}}{A_{20}}E_{s10}\\
\text{但し}\quad &\textstyle\sum' = A_{10}(\Delta'+2Z_f)\\
&\Delta' = \frac{B_{10}}{A_{10}} + \frac{B_{11}}{A_{11}} + \frac{B_{20}}{A_{20}} + \frac{B_{21}}{A_{21}}\\
&Z_{s1} = 2(Z_{tA}+Z_{G1}), \quad Z_{s2} = 2(Z_{tA}+Z_{G2})
\end{aligned}\right\} \quad (70)$$

$$\left.\begin{aligned}
I_{R0F} &= I_{R0U} = 0 \\
I_{R1F} &= \frac{1}{\sum'}\left(\frac{1}{A_{10}}+\frac{1}{A_{11}}+C_{10}\Delta'+2C_{10}Z_f\right)E_{s10} \\
I_{R2F} &= -\frac{1}{\sum'}\left(\frac{1}{A_{20}}+\frac{1}{A_{21}}\right)E_{s10} \\
I_{R1U} &= \frac{1}{\sum'}\left(\frac{1}{A_{10}}-\frac{1}{A_{11}}+C_{10}\Delta'+2C_{10}Z_f\right)E_{s10} \\
I_{R2U} &= -\frac{1}{\sum'}\left(\frac{1}{A_{20}}-\frac{1}{A_{21}}\right)E_{s10}
\end{aligned}\right\} \quad \cdots\cdots (71)$$

(70), (71) 式より前と同様各回線各距離継電器の測定するインピーダンスとして次の如く誘導される。今過渡値のみ示すものとせば $Z_{s1}=Z_{s2}$ となり

$$\left.\begin{aligned}
Z'_{aF} &= \frac{\Delta'(A_{10}-C_{10}Z_s)+2(A_{10}-C_{10}Z_s)Z_f}{C_{10}\Delta'+2C_{10}Z_f} = \frac{A_{10}-C_{10}Z_s}{C_{10}} \\
Z'_{bF} &= \frac{a^2\Delta'(A_{10}-C_{10}Z_s)-(a^2-a)\dfrac{Z_s}{A_{10}}+2a^2(A_{10}-C_{10}Z_s)Z_f}{(a^2-a)\left(\dfrac{1}{A_{10}}+\dfrac{1}{A_{11}}\right)+a^2C_{10}\Delta'+2a^2C_{10}Z_f} \\
Z'_{cF} &= \frac{a\Delta'(A_{10}-C_{10}Z_s)-(a-a^2)\dfrac{Z_s}{A_{10}}+2a(A_{10}-C_{10}Z_s)Z_f}{(a-a^2)\left(\dfrac{1}{A_{10}}+\dfrac{1}{A_{11}}\right)+aC_{10}\Delta'+2aC_{10}Z_f}
\end{aligned}\right\} \quad \cdots\cdots (72)$$

$$\left.\begin{aligned}
Z'_{aU} &= Z'_{aF} \\
Z'_{bU} &= \frac{a^2\Delta'(A_{10}-C_{10}Z_s)-(a^2-a)\dfrac{Z_s}{A_{10}}+2a^2(A_{10}-C_{10}Z_s)Z_f}{(a^2-a)\left(\dfrac{1}{A_{10}}-\dfrac{1}{A_{11}}\right)+a^2C_{10}\Delta'+2a^2C_{10}Z_f} \\
Z'_{cU} &= \frac{a\Delta'(A_{10}-C_{10}Z_s)-(a-a^2)\dfrac{Z_s}{A_{10}}+2a(A_{10}-C_{10}Z_s)Z_f}{(a-a^2)\left(\dfrac{1}{A_{10}}-\dfrac{1}{A_{11}}\right)+aC_{10}\Delta'+2aC_{10}Z_f}
\end{aligned}\right\} \quad \cdots\cdots (73)$$

$$\left.\begin{aligned}
Z'_{(a-b)F} &= \frac{(1-a^2)\Delta'(A_{10}-C_{10}Z_s)+(a^2-a)\dfrac{Z_s}{A_{10}}+2(1-a^2)(A_{10}-C_{10}Z_s)Z_f}{(a-a^2)\left(\dfrac{1}{A_{10}}+\dfrac{1}{A_{11}}\right)+(1-a^2)C_{10}\Delta'+2(1-a^2)C_{10}Z_f} \\
Z'_{(b-c)F} &= \frac{\Delta'(A_{10}-C_{10}Z_s)-\dfrac{2Z_s}{A_{10}}+2(A_{10}-C_{10}Z_s)Z_f}{2\left(\dfrac{1}{A_{10}}+\dfrac{1}{A_{11}}\right)+C_{10}\Delta'+2C_{10}Z_f} \\
Z'_{(c-a)F} &= \frac{(a-1)\Delta'(A_{10}-C_{10}Z_s)-(a-a^2)\dfrac{Z_s}{A_{10}}+2(a-1)(A_{10}-C_{10}Z_s)Z_f}{(a-a^2)\left(\dfrac{1}{A_{10}}+\dfrac{1}{A_{11}}\right)+(a-1)C_{10}\Delta'+2(a-1)C_{10}Z_f}
\end{aligned}\right\} \quad (74)$$

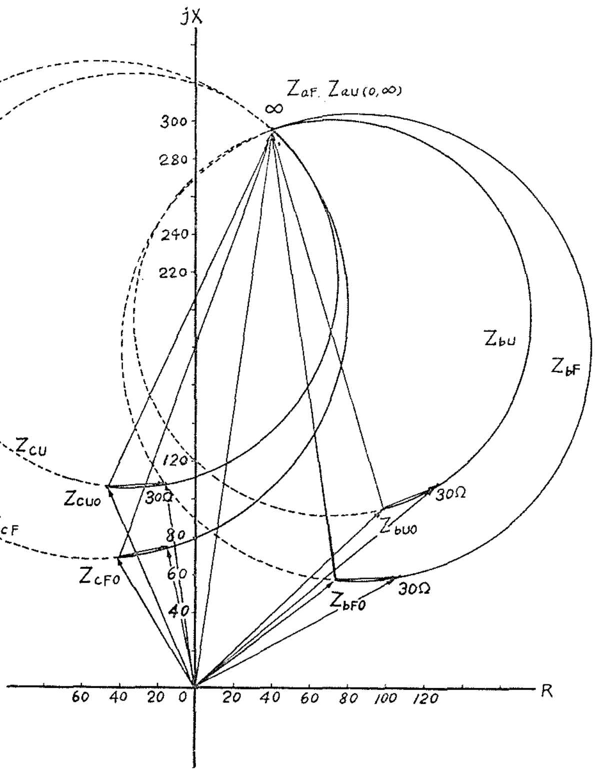
$$\left.Z'_{(a-b)U} = \frac{(1-a^2)\Delta'(A_{10}-C_{10}Z_s)+(a^2-a)\dfrac{Z_s}{A_{10}}+2(1-a^2)(A_{10}-C_{10}Z_s)Z_f}{(a-a^2)\left(\dfrac{1}{A_{10}}-\dfrac{1}{A_{11}}\right)+(1-a^2)C_{10}\Delta'+2(1-a^2)C_{10}Z_f}\right\} \quad (75)$$

$$\left.\begin{aligned}
Z'_{(b-c)U} &= \frac{\varDelta'(A_{10}-C_{10}Z_s)-\dfrac{2Z_s}{A_{10}}+2(A_{10}-C_{10}Z_s)Z_f}{2\left(\dfrac{1}{A_{10}}-\dfrac{1}{A_{11}}\right)+C_{10}\varDelta'+2C_{10}Z_f} \\
Z'_{(c-a)U} &= \frac{(a-1)\varDelta'(A_{10}-C_{10}Z_s)-(a-a^2)\dfrac{Z_s}{A_{10}}+2(a-1)(A_{10}-C_{10}Z_s)Z_f}{(a-a^2)\left(\dfrac{1}{A_{10}}-\dfrac{1}{A_{11}}\right)+(a-1)C_{10}\varDelta'+2(a-1)C_{10}Z_f}
\end{aligned}\right\}$$

第11図，第12図の回路に就いて前例の如く計算を行えば

$$\left.\begin{aligned}
Z'_{aF} &= \frac{(40.08+j\,304.8)+(2.470-j\,0.08752)\,Z_f}{(1.027+j\,0.009895)+(8.670-j\,82.30)\times10^{-4}\,Z_f} \\
Z'_{bF} &= \frac{(83.94-j\,184.2)+(-1.311-j\,2.095)\,Z_f}{(-0.5216-j\,2.112)+(-75.61+j\,33.64)\times10^{-4}\,Z_f} \\
Z'_{cF} &= \frac{(-124.0-j\,120.6)+(-1.159+j\,2.183)\,Z_f}{(-0.5074+j\,2.102)+(66.94+j\,48.66)\times10^{-4}\,Z_f}
\end{aligned}\right\}\quad\cdots\cdots\cdots(72')$$

$$\left.\begin{aligned}
Z'_{aU} &= Z'_{aF} \\
Z'_{bU} &= \frac{(83.94-j\,184.2)+(-1.311-j\,2.095)\,Z_f}{(-0.5216-j\,1.419)+(-75.61+j\,33.64)\times10^{-4}\,Z_f} \\
Z'_{cU} &= \frac{(-124.0-j\,120.6)+(-1.159+j\,2.183)\,Z_f}{(-0.50774+j\,1.409)+(66.94+j\,48.66)\times10^{-4}\,Z_f}
\end{aligned}\right\}\quad\cdots\cdots\cdots(73')$$

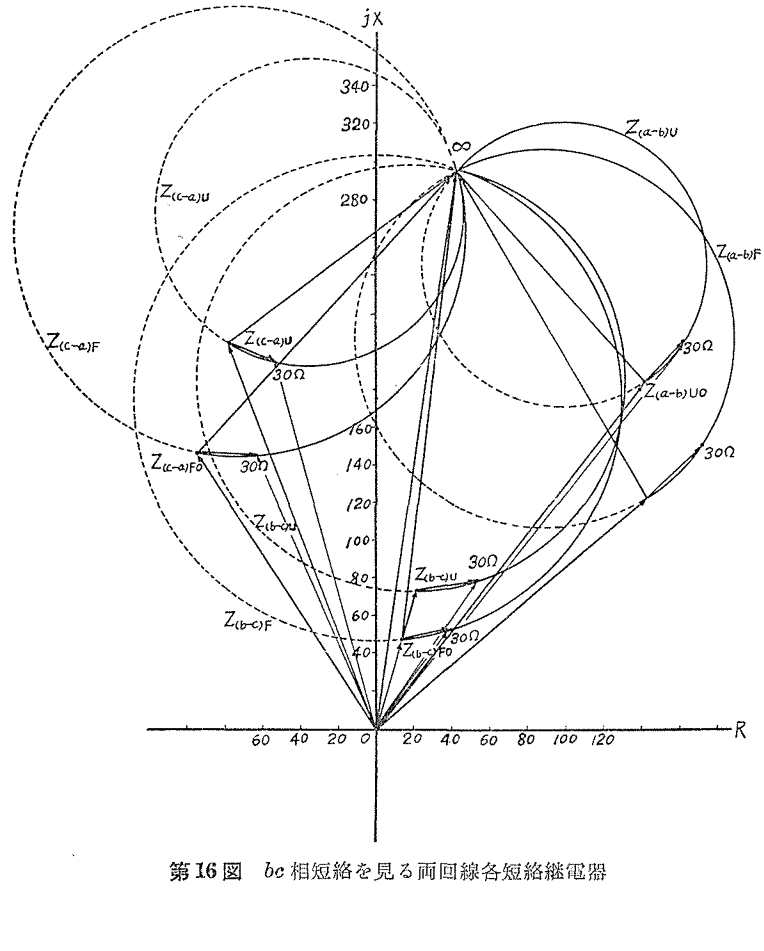


第15図 *bc* 相短絡を見る両回線各接地継電器

$$
\left.\begin{aligned}
Z'_{(a-b)F} &= \frac{(-43.88+j\,489.0)+(3.781+j\,2.008)\,Z_f}{(1.551+j\,2.122)+(0.008428-j\,0.01159)\,Z_f}\\
Z'_{(b-c)F} &= \frac{(36.74+j\,120.0)+(2.470-j\,0.08752)\,Z_f}{(2.433-j\,0.008249)+(8.670-j\,82.30)\times 10^{-4}\,Z_f}\\
Z'_{(c-a)F} &= \frac{(-164.1-j\,425.3)+(-3.697+j\,2.270)\,Z_f}{(-1.536+j\,2.092)+(58.27+j\,131.0)\times 10^{-4}\,Z_f}
\end{aligned}\right\}\quad\cdots\cdots\cdots\cdots\cdots(74')
$$

$$
\left.\begin{aligned}
Z'_{(a-b)U} &= \frac{(-43.88+j\,489.0)+(3.781+j\,2.008)\,Z_f}{(1.551+j\,1.429)+(0.008428-j\,0.01159)\,Z_f}\\
Z'_{(b-c)U} &= \frac{(36.74+j\,120.0)+(2.470-j\,0.08752)\,Z_f}{(1.633-j\,0.008245)+(8.670-j\,82.30)\times 10^{-4}\,Z_f}\\
Z'_{(c-a)U} &= \frac{(-164.1-j\,425.3)+(-3.697+j\,2.270)\,Z_f}{(-1.536+j\,1.399)+(58.27+j\,131.0)\times 10^{-4}\,Z_f}
\end{aligned}\right\}\quad\cdots\cdots\cdots\cdots\cdots(75')
$$

(72′), (73′) 及び (74′), (75′) を $X_f=0$ として図示すれば，第 15 図及び第 16 図の如くなる。一回線の計算例と同じ正相及び逆相分インピーダンスを用いている故，P 点にて発生せる二線短絡故障を眺める故障回線 bc 相短絡保護距離継電器の測定インピーダンス値は，第 16 図及び第 7 図を比較すれば，$Z_f=0$ に対して同一値を示す事が明らかである。



第 16 図　bc 相短絡を見る両回線各短絡継電器

[C] 二線短絡接地故障

第3図(c)の如き二線短絡接地故障が発生する場合の故障条件

$$\left.\begin{aligned} &I_{paF}=0\\ &E_{pbF}=E_{pcF}=(I_{pbF}+I_{pcF})Z_f\\ &I_{paU}=I_{pbU}=I_{pcU}=0 \end{aligned}\right\} \quad\cdots\cdots(76)$$

之より (44) 式を参照して

$$\left.\begin{aligned} &I_{p10}+I_{p11}+I_{p20}+I_{p21}=-I_{p00}-I_{p01}\\ &E_{p10}+E_{p11}=E_{p20}+E_{p21}\\ &E_{p10}+E_{p11}\fallingdotseq E_{p00}+E_{p01}-3(I_{p00}+I_{p01})Z_f\\ &I_{p00}=I_{p01},\quad I_{p10}=I_{p11},\quad I_{p20}=I_{p21}\\ \therefore\ &I_{p20}+I_{p00}=-I_{p10} \end{aligned}\right\} \quad\cdots\cdots(77)$$

(43), (46) 及び (77) 式より

$$\left.\begin{aligned} &E_{p00}=-\frac{B_{00}}{A_{00}}I_{p00},\quad E_{p01}=-\frac{B_{01}}{A_{01}}I_{p01}\\ &E_{p10}=\frac{1}{A_{10}}E_{s10}-\frac{B_{10}}{A_{10}}I_{p10},\quad E_{p11}=-\frac{B_{11}}{A_{11}}I_{p11}\\ &E_{p20}=-\frac{B_{20}}{A_{20}}I_{p20},\quad E_{p21}=-\frac{B_{21}}{A_{21}}I_{p21} \end{aligned}\right\} \quad\cdots\cdots(78)$$

(78) 式を (77) の第2, 第3式に代入し, (77) 式の第4, 第5式の関係を利用して整理すれば

$$\left.\begin{aligned} I_{p10}=I_{p11}&=\frac{\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}+6Z_f\right)E_{s10}}{A_{10}\left\{\left(\frac{B_{10}}{A_{10}}+\frac{B_{11}}{A_{11}}\right)\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)+\left(\frac{B_{10}}{A_{10}}+\frac{B_{11}}{A_{11}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)\times\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+6Z_f\right)\right\}}\\ &=\frac{\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}+6Z_f\right)}{\Delta''}E_{s10}\\ \Delta''=A_{10}&\left\{\left(\frac{B_{10}}{A_{10}}+\frac{B_{11}}{A_{11}}\right)\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)+\left(\frac{B_{10}}{A_{10}}+\frac{B_{11}}{A_{11}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+6Z_f\right)\right\} \end{aligned}\right\} \quad(79)$$

$$\left.\begin{aligned} &I_{p00}=I_{p01}=-\frac{1}{\Delta''}\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)E_{s10}\\ &I_{p20}=I_{p21}=-\frac{1}{\Delta''}\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+6Z_f\right)E_{s10} \end{aligned}\right\} \quad\cdots\cdots(80)$$

(78), (79) 及び (80) 式より

$$\left.\begin{aligned} &E_{p00}=\frac{1}{\Delta''}\frac{B_{00}}{A_{00}}\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)E_{s10}\\ &E_{p01}=\frac{1}{\Delta''}\frac{B_{01}}{A_{01}}\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)E_{s10} \end{aligned}\right. \quad\cdots\cdots(81)$$

$$
\left.
\begin{aligned}
E_{p10} &= \frac{1}{\varDelta''}\left\{\frac{B_{11}}{A_{11}}\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)\right. \\
&\qquad \left. +\left(\frac{B_{11}}{A_{11}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+6Z_f\right)\right\}E_{s10} \\
E_{p11} &= -\frac{1}{\varDelta''}\frac{B_{11}}{A_{11}}\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}+6Z_f\right)E_{s10} \\
E_{p20} &= \frac{1}{\varDelta''}\frac{B_{20}}{A_{20}}\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+6Z_f\right)E_{s10} \\
E_{p21} &= \frac{1}{\varDelta''}\frac{B_{21}}{A_{21}}\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+6Z_f\right)E_{s10}
\end{aligned}
\right\}
$$

(43), (52) 両式より，母線 B に於ける各対称分の値として次式を得る

$$
\left.
\begin{aligned}
\begin{bmatrix} E_{B00} \\ I_{B00} \end{bmatrix} &= \begin{bmatrix} 1 & -2Z_{tA0} \\ 0 & 1 \end{bmatrix}\begin{bmatrix} A_{00} & B_{00} \\ C_{00} & D_{00} \end{bmatrix}\begin{bmatrix} E_{p00} \\ I_{p00} \end{bmatrix} \\
\begin{bmatrix} E_{B01} \\ I_{B01} \end{bmatrix} &= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} A_{01} & B_{01} \\ C_{01} & D_{01} \end{bmatrix}\begin{bmatrix} E_{p01} \\ I_{p01} \end{bmatrix} \\
\begin{bmatrix} E_{B10} \\ I_{B10} \end{bmatrix} &= \begin{bmatrix} 1 & -2(Z_{tA}+Z_{G1}) \\ 0 & 1 \end{bmatrix}\begin{bmatrix} A_{10} & B_{10} \\ C_{10} & D_{10} \end{bmatrix}\begin{bmatrix} E_{p10} \\ I_{p10} \end{bmatrix} \\
\begin{bmatrix} E_{B11} \\ I_{B11} \end{bmatrix} &= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} A_{11} & B_{11} \\ C_{11} & D_{11} \end{bmatrix}\begin{bmatrix} E_{p11} \\ I_{p11} \end{bmatrix} \\
\begin{bmatrix} E_{B20} \\ I_{B20} \end{bmatrix} &= \begin{bmatrix} 1 & -2(Z_{tA}+Z_{G2}) \\ 0 & 1 \end{bmatrix}\begin{bmatrix} A_{20} & B_{20} \\ C_{20} & D_{20} \end{bmatrix}\begin{bmatrix} E_{p20} \\ I_{p20} \end{bmatrix} \\
\begin{bmatrix} E_{B21} \\ I_{B21} \end{bmatrix} &= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} A_{21} & B_{21} \\ C_{21} & D_{21} \end{bmatrix}\begin{bmatrix} E_{p21} \\ I_{p21} \end{bmatrix}
\end{aligned}
\right\} \quad \cdots\cdots\cdots\cdots (82)
$$

(82) 式に (79), (80) 及び (81) 式を代入し整理すれば，(53) 式を考慮した場合として

$$
\left.
\begin{aligned}
E_{B01} &= E_{B11} = E_{B21} = 0 \\
E_{B00} &= \frac{1}{\varDelta''}\frac{2Z_{tA0}}{A_{00}}\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)E_{s10} \\
E_{B10} &= \frac{1}{\varDelta''}\left[\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)\left(\frac{B_{11}}{A_{11}}(A_{10}-Z_{s1}C_{10})+(B_{10}-Z_{s1}D_{10})\right)+\left(\frac{B_{00}}{A_{00}}\right.\right. \\
&\qquad \left.\left. +\frac{B_{01}}{A_{01}}+6Z_f\right)\left\{\left(\frac{B_{11}}{A_{11}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)(A_{10}-Z_{s1}C_{10})+(B_{10}-Z_{s1}C_{10})\right\}\right]E_{s10} \\
E_{B20} &= \frac{1}{\varDelta''}\frac{Z_{s2}}{A_{20}}\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+6Z_f\right)E_{s10}
\end{aligned}
\right\} \quad (83)
$$

$$
\left.
\begin{aligned}
I_{B00} &= -\frac{1}{\varDelta''}\frac{1}{A_{00}}\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)E_{s10} \\
I_{B01} &= -\frac{1}{\varDelta''}\frac{1}{A_{01}}\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)E_{s10} \\
I_{B10} &= \frac{1}{\varDelta''}\left[\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)\left(C_{10}\frac{B_{11}}{A_{11}}+D_{10}\right)+\left(\frac{B_{00}}{A_{00}}\right.\right. \\
&\qquad \left.\left. +\frac{B_{01}}{A_{01}}+6Z_f\right)\left\{C_{10}\left(\frac{B_{11}}{A_{11}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)+D_{10}\right\}\right]E_{s10} \\
I_{B11} &= \frac{1}{\varDelta''}\frac{1}{A_{11}}\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}+6Z_f\right)E_{s10}
\end{aligned}
\right\} \quad \cdots\cdots\cdots\cdots (84)
$$

$$
\left.\begin{aligned}
I_{B20} &= -\frac{1}{\Delta''}\frac{1}{A_{20}}\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+6Z_f\right)E_{s10}\\
I_{B21} &= -\frac{1}{\Delta''}\frac{1}{A_{21}}\left(\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}+6Z_f\right)E_{s10}
\end{aligned}\right\}
$$

次に

$$
\left.\begin{aligned}
&\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}=\beta\\
&\frac{B_{00}}{A_{00}}+\frac{B_{01}}{A_{01}}=\gamma\\
&\frac{B_{11}}{A_{11}}(A_{10}-Z_{s1}C_{10})+(B_{10}-Z_{s1}D_{10})=\delta\\
&\left(\frac{B_{20}}{A_{20}}+\frac{B_{21}}{A_{21}}\right)(A_{10}-Z_{s1}C_{10})=\kappa\\
&C_{10}\frac{B_{11}}{A_{11}}+D_{10}+\frac{1}{A_{11}}=\rho\\
&C_{10}\frac{B_{11}}{A_{11}}+D_{10}-\frac{1}{A_{11}}=\rho'
\end{aligned}\right\}\quad\cdots\cdots(85)
$$

と置けば，(83), (84) 式より

$$
\left.\begin{aligned}
E_{R0F} &= \frac{1}{\Delta''}\frac{2Z_{tA0}}{A_{00}}\beta E_{s10}\\
E_{R1F} &= \frac{1}{\Delta''}\left\{\beta\delta+(\gamma+6Z_f)(\delta+\kappa)\right\}E_{s10}\\
E_{R2F} &= \frac{1}{\Delta''}\frac{Z_{s2}}{A_{20}}(\gamma+6Z_f)E_{s10}\\
E_{R0U} &= E_{R0F},\quad E_{R1U}=E_{R1F},\quad E_{R2U}=E_{R2F}
\end{aligned}\right\}\quad\cdots\cdots(86)
$$

$$
\left.\begin{aligned}
I_{R0F} &= -\frac{1}{\Delta''}\beta\left(\frac{1}{A_{00}}+\frac{1}{A_{01}}\right)E_{s10}\\
I_{R1F} &= \frac{1}{\Delta''}\left\{(\gamma+6Z_f)(C_{10}\beta+\rho)+\beta\rho\right\}E_{s10}\\
I_{R2F} &= -\frac{1}{\Delta''}(\gamma+6Z_f)\left(\frac{1}{A_{20}}+\frac{1}{A_{21}}\right)E_{s10}\\
I_{R0U} &= -\frac{1}{\Delta''}\beta\left(\frac{1}{A_{00}}-\frac{1}{A_{01}}\right)E_{s10}\\
I_{R1U} &= \frac{1}{\Delta''}\left\{(\gamma+6Z_f)(C_{10}\beta+\rho')+\beta\rho'\right\}E_{s10}\\
I_{R2U} &= -\frac{1}{\Delta''}(\gamma+6Z_f)\left(\frac{1}{A_{20}}-\frac{1}{A_{21}}\right)E_{s10}
\end{aligned}\right\}\quad\cdots\cdots(87)
$$

(86), (87) 式より各距離継電器の測定するインピーダンス値は

$$
Z''_{aF}=\frac{\beta\left(\frac{2Z_{tA0}}{A_{00}}+\delta\right)+\gamma\left(\frac{Z_{s2}}{A_{20}}+\gamma+\kappa\right)+6\left(\frac{Z_{s2}}{A_{20}}+\delta+\kappa\right)Z_f}{\beta\left(\rho-\frac{1}{A_{00}}-\frac{1}{A_{01}}\right)+\gamma\left(\rho+C_{10}\beta-\frac{1}{A_{20}}-\frac{1}{A_{21}}\right)+6\left\{\rho+C_{10}\beta-\left(\frac{1}{A_{20}}+\frac{1}{A_{21}}\right)\right\}Z_f}\quad(88)
$$

$$
\left.\begin{aligned}
Z''_{bF} &= \frac{\beta\left(\dfrac{2Z_{tA0}}{A_{00}}+a^2\delta\right)+(\gamma+6Z_f)\left\{\dfrac{aZ_{s2}}{A_{20}}+a^2(\delta+\kappa)\right\}}{\beta\left(a^2\rho-\dfrac{1}{A_{00}}-\dfrac{1}{A_{01}}\right)+(\gamma+6Z_f)\left\{a^2(C_{10}\beta+\rho)-a\left(\dfrac{1}{A_{20}}+\dfrac{1}{A_{21}}\right)\right\}}\\
Z''_{cF} &= \frac{\beta\left(\dfrac{2Z_{tA0}}{A_{00}}+a\delta\right)+(\gamma+6Z_f)\left\{a^2\dfrac{Z_{s2}}{A_{20}}+a(\delta+\kappa)\right\}}{\beta\left(a\rho-\dfrac{1}{A_{00}}-\dfrac{1}{A_{01}}\right)+(\gamma+6Z_f)\left\{a(\rho+C_{10}\beta)-a^2\left(\dfrac{1}{A_{20}}+\dfrac{1}{A_{21}}\right)\right\}}
\end{aligned}\right\}
$$

$$
\left.\begin{aligned}
Z''_{aU} &= \frac{\beta\left(\dfrac{2Z_{tA0}}{A_{00}}+\delta\right)+(\gamma+6Z_f)\left(\delta+\kappa+\dfrac{Z_{s2}}{A_{20}}\right)}{\beta\left(\rho'-\dfrac{1}{A_{00}}+\dfrac{1}{A_{01}}\right)+(\gamma+6Z_f)\left\{\rho'+C_{10}\beta-\left(\dfrac{1}{A_{20}}-\dfrac{1}{A_{21}}\right)\right\}}\\
Z''_{bU} &= \frac{\beta\left(\dfrac{2Z_{tA0}}{A_{00}}+a^2\delta\right)+(\gamma+6Z_f)\left\{\dfrac{aZ_{s2}}{A_{\ 0}}+a^2(\delta+\kappa)\right\}}{\beta\left(a^2\rho'-\dfrac{1}{A_{00}}+\dfrac{1}{A_{01}}\right)+(\gamma+6Z_f)\left\{a^2(C_{10}\beta+\rho')-a\left(\dfrac{1}{A_{20}}-\dfrac{1}{A_{21}}\right)\right\}}\\
Z''_{cU} &= \frac{\beta\left(\dfrac{2Z_{tA0}}{A_{00}}+a\delta\right)+(\gamma+6Z_f)\left\{\dfrac{a^2Z_{s2}}{A_{20}}+a(\delta+\kappa)\right\}}{\beta\left(a\rho'-\dfrac{1}{A_{00}}+\dfrac{1}{A_{01}}\right)+(\gamma+6Z_f)\left\{a(C_{10}\beta+\rho')-a^2\left(\dfrac{1}{A_{20}}-\dfrac{1}{A_{21}}\right)\right\}}
\end{aligned}\right\} \tag{89}
$$

$$
\left.\begin{aligned}
Z''_{(a-b)F} &= \frac{\beta(1-a^2)\delta+(\gamma+6Z_f)\left\{(1-a)\dfrac{Z_{s2}}{A_{20}}+(1-a^2)(\delta+\kappa)\right\}}{\beta(1-a^2)\rho+(\gamma+6Z_f)\left\{(1-a^2)(\rho+C_{10}\beta)-(1-a)\left(\dfrac{1}{A_{20}}+\dfrac{1}{A_{21}}\right)\right\}}\\
Z''_{(b-c)F} &= \frac{\beta\delta+(\gamma+6Z_f)\left\{-\dfrac{Z_{s2}}{A_{20}}+(\delta+\kappa)\right\}}{\beta\rho+(\gamma+6Z_f)\left\{\rho+C_{10}\beta+\left(\dfrac{1}{A_{20}}+\dfrac{1}{A_{21}}\right)\right\}}\\
Z''_{(c-a)F} &= \frac{\beta(a-1)\delta+(\gamma+6Z_f)\left\{(a^2-1)\dfrac{Z_{s2}}{A_{20}}+(a-1)(\delta+\kappa)\right\}}{\beta(a-1)\rho+(\gamma+6Z_f)\left\{(a-1)(\rho+C_{10}\beta)-(a^2-1)\left(\dfrac{1}{A_{20}}+\dfrac{1}{A_{21}}\right)\right\}}
\end{aligned}\right\} \tag{90}
$$

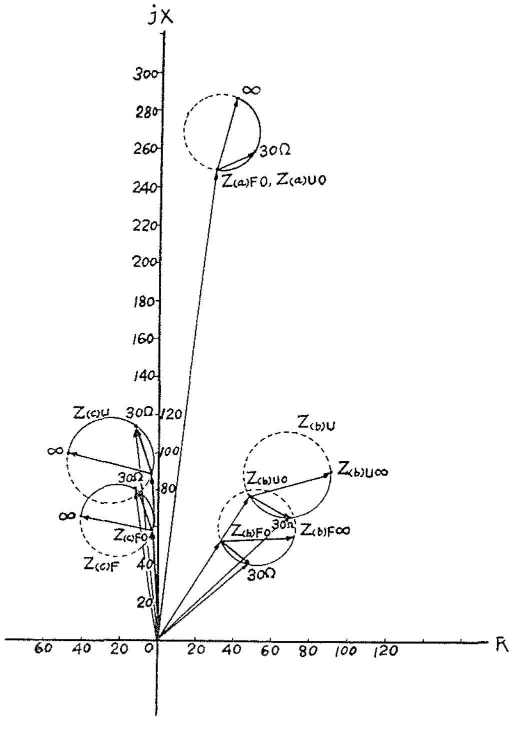
$$
\left.\begin{aligned}
Z''_{(a-b)U} &= \frac{\beta(1-a^2)\delta+(\gamma+6Z_f)\left\{(1-a^2)(\delta+\kappa)+(1-a)\dfrac{Z_{s2}}{A_{20}}\right\}}{\beta(1-a^2)\rho'+(\gamma+6Z_f)\left\{(1-a^2)(\rho'+C_{10}\beta)-(1-a)\left(\dfrac{1}{A_{20}}-\dfrac{1}{A_{21}}\right)\right\}}\\
Z''_{(b-c)U} &= \frac{\beta\delta+(\gamma+6Z_f)\left\{-\dfrac{Z_{s2}}{A_{20}}+(\delta+\kappa)\right\}}{\beta\rho'+(\gamma+6Z_f)\left\{\rho'+C_{10}\beta+\left(\dfrac{1}{A_{20}}-\dfrac{1}{A_{21}}\right)\right\}}\\
Z''_{(c-a)U} &= \frac{\beta(a-1)\delta+(\gamma+6Z_f)\left\{(a^2-1)\dfrac{Z_{s2}}{A_{20}}+(a-1)(\delta+\kappa)\right\}}{\beta(a-1)\rho'+(\gamma+6Z_f)\left\{(a-1)(\rho'+C_{10}\beta)-(a^2-1)\left(\dfrac{1}{A_{20}}-\dfrac{1}{A_{21}}\right)\right\}}
\end{aligned}\right\} \tag{91}
$$

(88)～(91) に於いて過渡値は正相分と逆相分のインピーダンスを等しく置く事によつて得られる。前例と同様の回路に於ける実例計算は下記の如くになる。

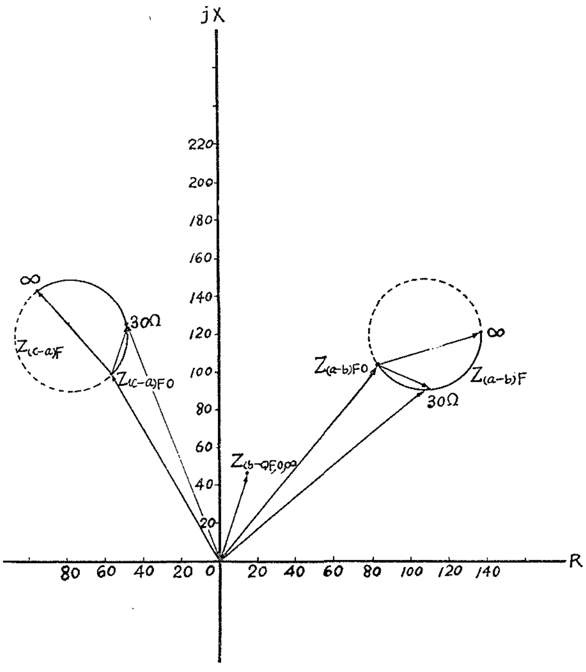
$$\left.\begin{aligned}
Z''_{aF} &= \frac{(-62080+j\,15300)+(234.7+j\,1805)Z_f}{(31.02+j\,253.2)+(6.304+j\,0.03887)\,Z_f}\\
Z''_{bF} &= \frac{(30610+j\,14430)+(485.6-j\,1088)\,Z_f}{(460.9-j\,293.1)+(-3.128-j\,12.77)\,Z_f}\\
Z''_{cF} &= \frac{(11630-j\,29100)+(-720.4-j\,716.4)\,Z_f}{(-503.6-j\,179.8)+(-3.092+j\,12.73)\,Z_f}
\end{aligned}\right\}\quad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\ (88')$$

$$\left.\begin{aligned}
Z''_{aU} &= \frac{(-62080+j\,15300)+(234.7+j\,1805)Z_f}{(30.74+j\,253.3)+(6.306+j\,0.03885)\,Z_f}\\
Z''_{bU} &= \frac{(30610+j\,14430)+(485.6-j\,1088)\,Z_f}{(331.2-j\,200.8)+(-3.213-j\,8.618)\,Z_f}\\
Z''_{cU} &= \frac{(11630-j\,29100)+(-720.4-j\,716.4)\,Z_f}{(-339.8-j\,123.0)+(-3.092+j\,8.580)\,Z_f}
\end{aligned}\right\}\quad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\ (89')$$

$$\left.\begin{aligned}
Z''_{(a-b)F} &= \frac{(-92700+j\,875.6)+(-250.9+j\,2893)\,Z_f}{(-429.9+j\,545.9)+(9.522+j\,12.81)\,Z_f}\\
Z''_{(b-c)F} &= \frac{(-25140+j\,10960)+(214.6+j\,696.6)\,Z_f}{(65.16+j\,557.2)+(14.73-j\,0.07002)\,Z_f}\\
Z''_{(c-a)F} &= \frac{(73710-j\,28100)+(-955.2-j\,2521)\,Z_f}{(-534.8-j\,431.6)+(-9.396+j\,12.70)\,Z_f}
\end{aligned}\right\}\quad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\ (90')$$



第17図　*bc* 相接地を見る両回線各接地継電器



第18図　*bc* 相接地を見る故障回線短絡継電器

(88′), (89′) 及び (90′) 式は $X_f=0$ とした時夫々第17図，第18図に示される如くである。$Z_f=\infty$ の場合の値は夫々第15図，第16図の夫々の継電器の測定する $Z_f=0$ の場合の値と一致している。

IV. 結　言

系統故障時，故障相，健全相に設置されている距離継電器の測定するインピーダンスに就いての本文の計算式により，故障点アーク抵抗変化の影響は，円特性を示す事が判明した，リアクタンス継電器設置の場合アーク抵抗によるリアクタンス誤差も図式的に明瞭であり，又非故障インピーダンス値との関係も明らかである。線路アドミッタンス，負荷等の回路定数を考慮すれば，特に他相故障を眺めるインピーダンス値は，相互に可成の相違を生ずる。本例と異なる電流電圧要素を導入する構成の距離続電器の動作に対しても同様に解析は容易であり，又連繋系統に対しての適用も可能である。終りに本研究に終始御指導御鞭撻を賜つた小串孝治教授に深く感謝の意を表する。

参 考 文 献

1) A.R. Warrington: T.A.I.E.E., vol. 68, p.608 (1949).
2) 小串孝治： 送電配電理論及び計算.
3) 小串孝治： 電気工学円線図.
4) 小串・三浦： 北大工学部紀要. 第九冊，第三号，. 第十冊，第一号.