USE

Z = impedance   R = resistance   X = reactance

$Z = R + jX$

FAULT CALCULATION FORMULAS

PER UNIT

Choose your utility Transformer KVA & secondary kV value

BASE kVA = 450 kVA

BASE kV = 1 kV

$$\text{BASE A} = I_{BASE} = \frac{\text{BASE kVA}}{\sqrt{3}\ \text{BASE kV}}$$

$$R_{PU} = \frac{R \times \text{BASE kVA}}{(\text{BASE kV})^2\,(1000)}$$

$$X_{PU} = \frac{X \times \text{BASE kVA}}{(\text{BASE kV})^2\,(1000)}$$

$$|Z_{PU}| = \sqrt{R_{PU}^2 + X_{PU}^2}$$

$$I_{PU} = \frac{E_{PU}}{|Z_{PU}|} = \frac{1}{\sqrt{R_{PU}^2 + X_{PU}^2}}$$

$$E_{PU} = 1V_{PU}$$

$|Z|^2 = |R|^2 + |X|^2$

IMPEDANCES

CABLES – USE CABLE LENGTHES & TABLES

TRANSFORMERS – USE Z% & X% SUPPLIED BY UTILITY OR NAMEPLATE DATA

% aka PU

$$R_{PU} = \sqrt{Z_{PU}^2 - X_{PU}^2}$$

MOTORS – MOTORS SERVED BY MCC'S ARE CONSIDERED TO HAVE A GROUP REACTANCE OF 25% ON A kVA RATING EQUAL TO THE CONNECTED MOTOR HP.

$$Z_{PU} = \left(\frac{25}{100}\right)\frac{\text{BASE kVA}}{(\text{TOTAL MOTOR kVA})}$$

$$R_{PU} = \sqrt{\frac{(Z_{PU})^2}{1 + (X/R)^2}}$$

$X/R = 4$

PARALLELING (THEVININ EQUIVALENT)

$1/Z = G + jB$

$$G = \frac{R}{R^2 + X^2}$$

$$-B = \frac{X}{R^2 + X^2}$$

$$R = \frac{G}{G^2 + B^2}$$

$$X = \frac{-B}{G^2 + B^2}$$

TWO EQUAL Z's -> Z/2

THREE EQUAL Z's -> Z/3

$$\frac{1}{Z_{TOT}} = \frac{1}{Z_1} + \frac{1}{Z_2}$$

FAULT CURRENT

As per Panel Prop SHORT CCT RATING SPECIFY when Range

SYMMETRICAL

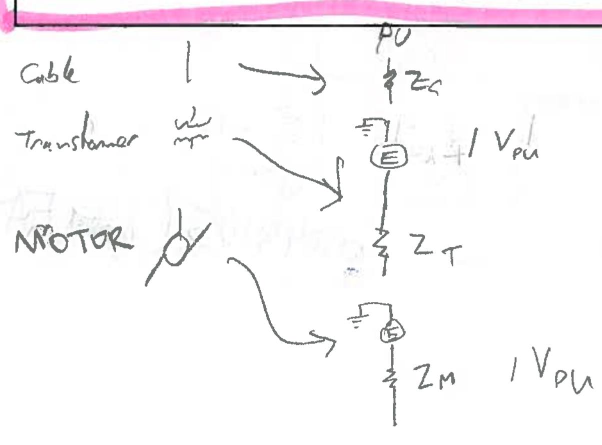
$I_{FC} = I_{BASE} \times I_{PU}$

ASYMMETRICAL

$I_{FC\text{-}ASYM} = I_{FC} \times (\text{ASYM FACTOR})$

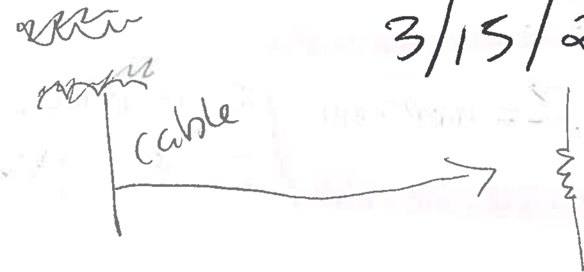
ASYM FACTOR

$$= \frac{\sqrt{1 + 2e^{-2\pi/(X/R)}} + 2\sqrt{1 + 0.5e^{-2\pi/(X/R)}}}{3}$$



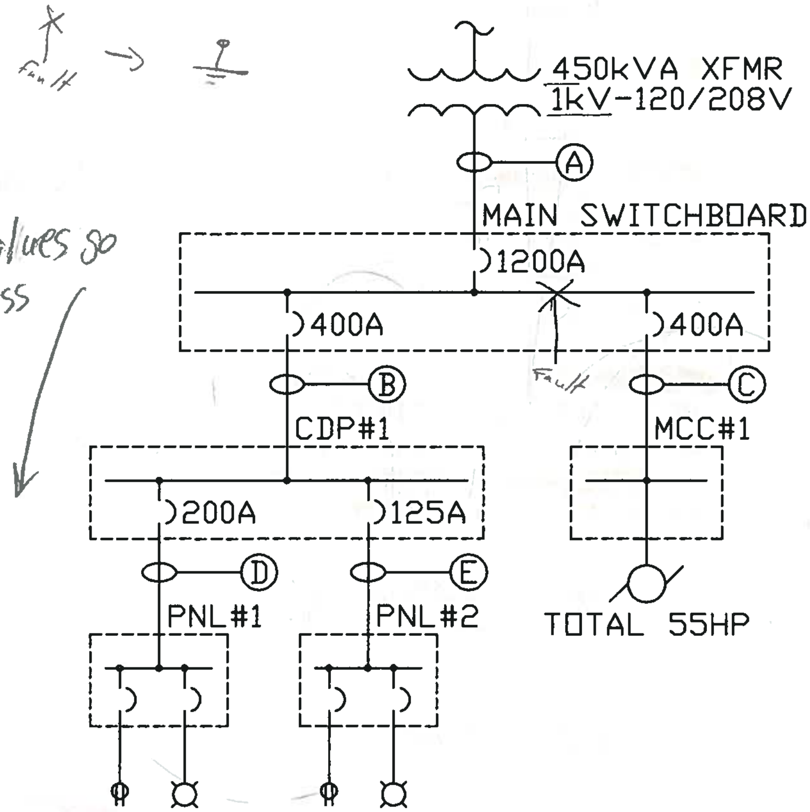
★ The only thing you consider DOWNSTREAM is MOTORS ★

3/15/2012

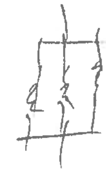


FAULT CALCULATION - EXAMPLE

SINGLE LINE DIAGRAM



Z=6.19%
X=6.15%



STEEL CONDUIT (MAGNETIC DUCT)

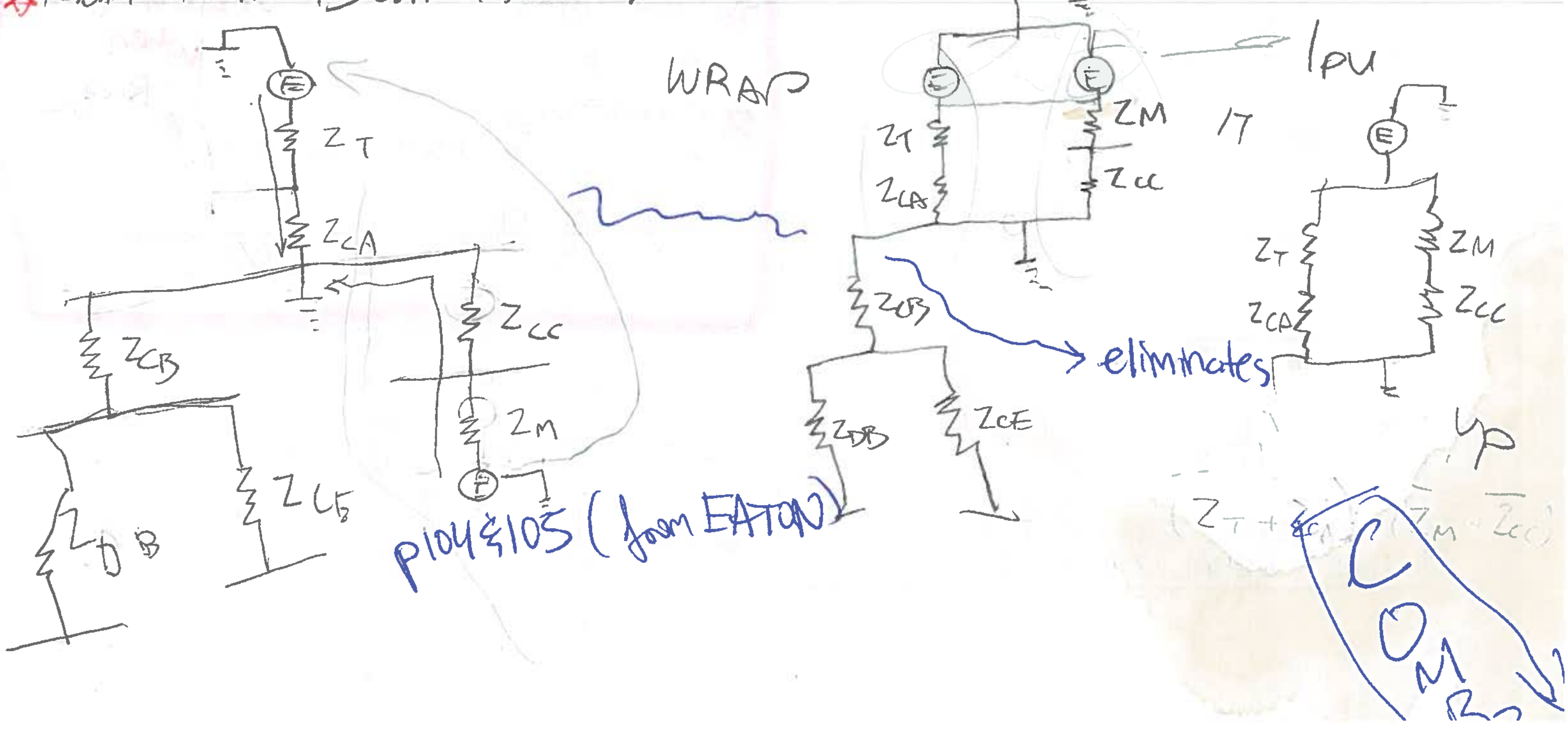
- (A) 3 RUNS OF 3 1/2"C-4#500MCM 55'
- (B) 3 1/2"C-4#500MCM 25'
- (C) 3"C-3#500MCM 100'
- (D) 2"C-4#3/0 150'
- (E) 1 1/2"C-4#1AWG 75'

PER UNIT EQUIVALENT DIAGRAM

use secondary ⟹

- ✓ BASE kVA = 450 kVA
- ✓ BASE kV = .208 kV
- ✓ BASE A = 1249 A

★ Fault at main switchboard. ★



① FIND Per Unit Values

GIVEN Base kVA

GIVEN Base kV

FIND Base A $= I_{BASE} = \dfrac{\text{BASE kVA}}{\sqrt{3} \times \text{BASE kV}}$

② FIND R & X BASE

as per Table x per 1000 ft ratio

ex. For 150' R = .0805 X = .0519 per 1000 ft

$$R = \frac{.0805}{1000'} \times 150' = 0.012075$$

③ Use FORMULAE to FIND PU values

→ cable - X_{PU} & R_{PU}

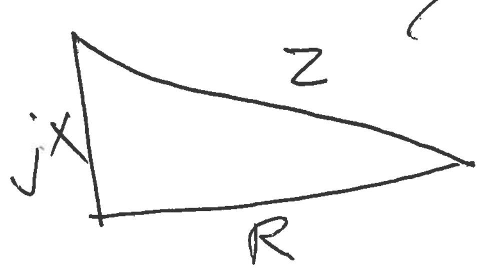
→ X'fmr & Motors special methods

④ COMBO calcs to find Z_{TOTAL}

? parallel ? add elements $Z = jX + R$

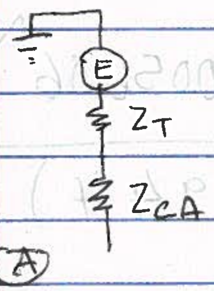
⑤ PLUG INTO FAULT CURRENT FORMULA

→ I



Go For ASYMMETRICAL

ANALYZE @ Transformer & Cable A



TRANSFORMER

Z_T use $R_{PU} = \sqrt{Z_{PU}^2 - X_{PU}^2}$

Given $Z\% = 6.19\% = .0619$

$X\% = 6.15\% = .0615$

by manufacturer

$\therefore R_{PU} = \sqrt{(.0619)^2 - (.0615)^2}$

$R_{PU} = \sqrt{.0000\,4936}$

$\boxed{R_{PU} = .00702\,5667}$

CABLE

Z_{CA} @ 500 MCM per 1000' Table 1.5-21 Cutler Hammer $R = .0294\ \Omega/1000'$ $X = .0349\ \Omega/1000'$

For 55' $R = \frac{.0294}{1000'} \times 55' = .001617$

FIND RATIO →

3 runs $\frac{R}{3} = \frac{.001617}{3} = .000539$ //

$X = \frac{.0349}{1000'} \times 55' = .0019195$

3 runs $\frac{X}{3} = \frac{.0019195}{3} = .000639833$ //

$R_{PU} = \frac{R \times \text{BASE kVA}}{(\text{Base kV})^2 \times 1000}$

$R_{PU} = \frac{.000539 \times 450}{(.208)^2 \times 1000} = 0.00560\,6277$

$X_{PU} = \frac{X \times \text{BASE kVA}}{(\text{Base kV})^2 \times 1000} = \frac{.000639 \times 450}{(.208)^2 \times 1000}$

$\boxed{X_{PU} = .00665\,5067}$

$\therefore Z_T + Z_{CA} = j(X_T + X_{CA}) + (R_T + R_{CA})$

$Z_1 = j(.0615 + .00665067) + (.00702 + .005606)$

$$Z_1 = j(.06815067) + (.012631944)$$

X_1 R_1

ANALYZE @ Motor & Cable C

$Z_M \Rightarrow Z_{PU} = \left(\frac{25}{100}\right)\frac{\text{BASE kVA}}{\text{TOTAL MOTOR kVA}} = 0.25 \times \frac{450}{55} = 2.04545...$

$R_{PU} = \sqrt{\frac{(Z_{PU})^2}{1 + (X/R)^2}} = \sqrt{\frac{(2.045)^2}{1+4^2}} = 0.496095596$

where $\frac{X}{R} = 4$

$\therefore X_{PU} = \sqrt{Z_{PU}^2 - R_{PU}^2} = \sqrt{2.045^2 - 0.4960^2}$

$$X_{PU} = 1.984382387...$$

CABLE

@500 MCM per 1000 ft. $R = .0294$ $X = .0349$

Given 100' $R = \frac{.0294}{1000} \times 100 = .00294$

$X = \frac{.0349}{1000} \times 100 = .00349$

$R_{PU} = \frac{R \times \text{Base kVA}}{(\text{Base kV})^2 \times 1000} = \frac{.00294 \times 450}{(.208)^2 \times 1000} = .03057969...$

$X_{PU} = \frac{.00349 \times 450}{(.208)^2 \times 1000} = 0.0363003388$

$\therefore Z_M + Z_{CC} = j(X_M + X_{CC}) + (R_M + R_{CC})$

$Z_2 = j(1.9843 + .0363) + (0.496 + .03057)$

$$Z_2 = j(2.020682775) + (0.532395984)$$

(X_2 = 2.020682775, R_2 = 0.532395984)

PARALLEL THEVININ

FOR $Z_T + Z_{CA} = Z_1$

$\frac{1}{Z_1} = G_1 + jB_1$

$G_1 = \frac{R_1}{R_1^2 + X_1^2}$ $\qquad -B_1 = \frac{X_1}{R_1^2 + X_1^2}$

$= \frac{.01263}{(.01263)^2 + (.0681)^2}$ $\qquad = \frac{.0681}{(.01263)^2 + (.0681)^2}$

$G_1 = 2.629...$ $\qquad B_1 = 14.1853$

FOR $Z_M + Z_{CC} = Z_2$

$\frac{1}{Z_2} = G_2 + jB_2$

$G_2 = \frac{R_2}{R_2^2 + X_2^2}$ $\qquad -B_2 = \frac{X_2}{R_2^2 + X_2^2}$

$= \frac{.53239...}{(.5323)^2 + (2.0268)^2}$ $\qquad = \frac{2.0206.}{(.5323)^2 + (2.0268)^2}$

$G_2 = .120747$ $\qquad B_2 = .463424$

$$\therefore \quad G = G_1 + G_2 = 2.629 + 0.120747$$

$$G = 2.75$$

$$B = -B_1 + -B_2 = -14.1853 + -0.46324$$

$$B = -14.65$$

$$R_{PU} = \frac{G}{G^2 + B^2} = \frac{2.75}{(2.75)^2 + (-14.65)^2} = 0.012377$$

$$X_{PU} = \frac{14.65}{(2.75)^2 + (-14.65)^2} = 0.065936$$

FIND FAULT CURRENT!!

$$I_{PU} = \frac{E_{PU}}{Z_{PU}} = \frac{1}{\sqrt{R_{PU}^2 + X_{PU}^2}}$$

$$= \frac{1}{\sqrt{(.012377)^2 + (.065936)^2}}$$

$$I_{PU} = 14.905$$

$$I_{FC} = 1249 \times 14.905 = 18.6\ kA \quad \text{SYMMETRICAL}$$

$$I_{FC-ASYM} = 18.6\ kA \times \text{ASYM-FACTOR} = 21.2\ kA \quad \text{ASYMMETRICAL}$$

$$\text{ASYM-FACTOR} = \frac{\sqrt{1 + 2e^{-2\pi/(X/R)_{FC}}} + 2\sqrt{1 + 0.5e^{-2\pi(X/R)_{FC}}}}{3}$$

$$= \frac{\sqrt{1 + 2e^{-2\pi(.065936/.012377)}} + 2\sqrt{1 + 0.5e^{-2\pi(.065936.../.012377)}}}{3}$$

$$= \frac{1.27 + 2.148}{3} = 1.1396749\ldots$$