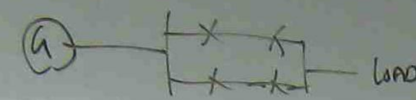
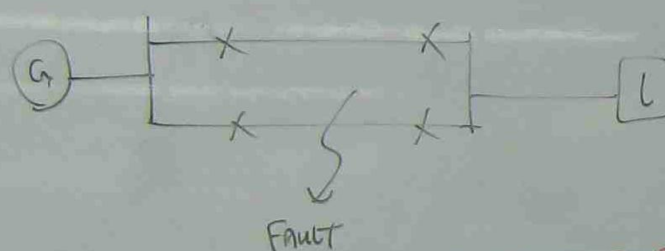
$-P_0\delta_2 + \cancel{P_0\delta_c}$



δ_0 = NORMAL LOADING ANGLE (RADIAN)

$P_1 \cos\delta_0$

$-\delta_2)$



)

P_1 = POWER TRANSFERRED DURING FAULT

$\delta_2)$ THEN C.B & RELAY TRIP OFF THE LINE

ONLY ONE LINE IS LEFT AFTER THE FAULT.

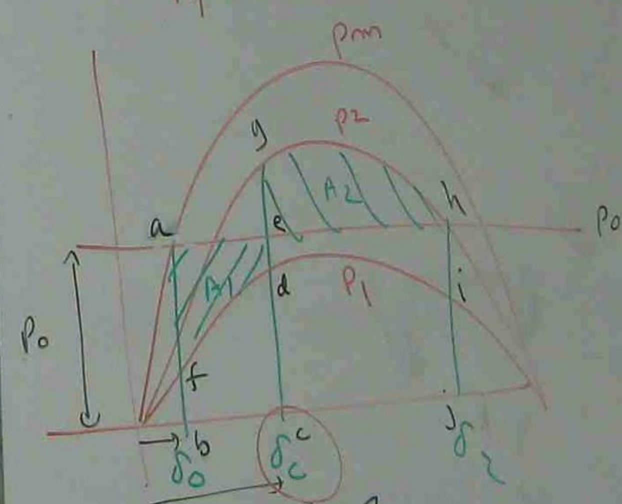
P_2 = POWER TRANSFERRED AFTER THE FAULT

A_1 = ACCELERATED AREA (CHANGE IN ROTOR TORQUE | SPEED | ENERGY DUE TO FAULT)

A_2 = DECELERATED AREA (RECOVERY)

TO MAINTAIN THE SYSTEM STABILITY, A_1 MUST BE EQUAL TO A_2

$$A_1 = A_2$$



$$A_1 = \square\, abce - \square\, bfdc$$

$$= ab \times bc - \int_{\delta_0}^{\delta_c} P_1 \sin\delta \, d\delta$$

$$= P_0(\delta_c - \delta_0) - \int_{\delta_0}^{\delta_c} P_1 \sin\delta \, d\delta \quad \text{— I}$$

$$A_2 = \square\, cghj - \square\, ehjc$$

$$A_2 = \int_{\delta_c}^{\delta_2} P_2 \sin\delta \, d\delta - hj \times eh$$

$$= \int_{\delta_c}^{\delta_2} P_2 \sin\delta \, d\delta - P_0(\delta_2 - \delta_c) \quad \text{— II}$$

I $\quad A_1 = P_0\delta_c - P_0\delta_0 - P_1 \left[-\cos\delta\right]_{\delta_0}^{\delta_c}$

$$A_1 = P_0\delta_c - P_0\delta_0 + P_1\left[\cos\delta_c - \cos\delta_0\right]$$

$$A_1 = P_0\delta_c - P_0\delta_0 + P_1\cos\delta_c - P_1\cos\delta_0 \quad \text{— 3}$$

$$A_2 = -P_2\left[\cos\delta\right]_{\delta_c}^{\delta_2}$$

$$A_2 = -P_2\left[\cos\delta_2\right.$$

$$= -P_2\cos\delta_2$$

$$-P_0$$

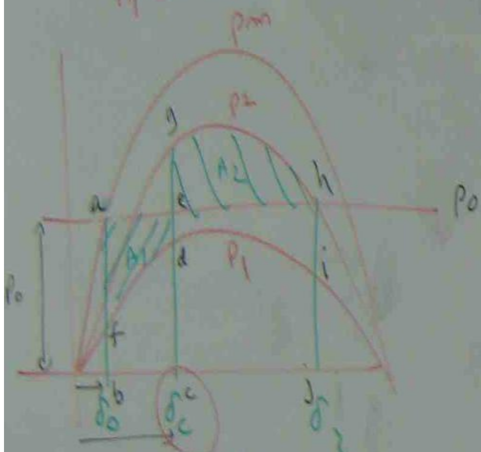
$$A_1 = A$$

A_1 = ACCELERATED AREA (CHANGE IN ROTOR TORQUE / SPEED / ENERGY DUE TO FAULT

A_2 = DECELERATED AREA (RECOVERY)

TO MAINTAIN THE SYSTEM STABILITY, A_1 MUST BE EQUAL TO A_2

$A_1 = A_2$



$A_1 = \square abce - \triangle bfdc$

$= ab \times bc - \int_{\delta_0}^{\delta_c} P_1 \sin\delta \, d\delta$

$= P_0(\delta_c - \delta_0) - \int_{\delta_0}^{\delta_c} P_1 \sin\delta \, d\delta$ — I

$A_2 = \triangle cghj - \square ehjc$

$A_2 = \int_{\delta_c}^{\delta_2} P_2 \sin\delta \, d\delta - hj \times eh$

$= \int_{\delta_c}^{\delta_2} P_2 \sin\delta \, d\delta - P_0(\delta_2 - \delta_c)$ — II

(I) $A_1 = P_0\delta_c - P_0\delta_0 - P_1 \left[-\cos\delta\right]_{\delta_0}^{\delta_c}$

$A_1 = P_0\delta_c - P_0\delta_0 + P_1\left[\cos\delta_c - \cos\delta_0\right]$

$A_1 = P_0\delta_c - P_0\delta_0 + P_1\cos\delta_c - P_1\cos\delta_0$ — (3)

$A_2 = -P_2\left[\cos\delta\right]_{\delta_c}^{\delta_2} - P_0\delta_2 + P_0\delta_c$

$A_2 = -P_2\left[\cos\delta_2 - \cos\delta_c\right] - P_0\delta_2 + P_0\delta_c$

$= -P_2\cos\delta_2 + P_2\cos\delta_c - P_0\delta_2 + P_0\delta_c$ — (4)

$A_1 = A_2$

$$\cancel{P_0\delta_c} - P_0\delta_0 + \underline{\underline{P_1\cos\delta_c}} - P_1\cos\delta_0 = -P_2\cos\delta_2 + \underline{\underline{P_2\cos\delta_c}} - P_0\delta_2 + \cancel{P_0\delta_c}$$

$\delta_0 =$ NORMAL

$$P_1\cos\delta_c - P_2\cos\delta_c = -P_2\cos\delta_2 - P_0\delta_2 + P_0\delta_0 + P_1\cos\delta_0$$

$$\cos\delta_c\,(P_1 - P_2) = P_1\cos\delta_0 - P_2\cos\delta_2 + P_0(\delta_0 - \delta_2)$$

$$\cos\delta_c = \frac{P_1\cos\delta_0 - P_2\cos\delta_2 + P_0(\delta_0 - \delta_2)}{(P_1 - P_2)}$$

$$\delta_c = \cos^{-1}\frac{P_1\cos\delta_0 - P_2\cos\delta_2 + P_0(\delta_0 - \delta_2)}{(P_1 - P_2)}$$

THEN C.B

P_1

Po

pb A GENERATOR OPERATING AT 50 HZ DELIVERS 1 PU POWER TO INFINITE BUSBAR THROUGH NETWORK IN WHICH RESISTANCE MAY BE NEGLECTED. A FAULT OCCURS WHICH REDUCES THE MAXIMUM POWER TRANSFERRABLE TO 0.4 PU WHEREAS BEFORE THE FAULT THIS POWER WAS 1.8 PU AND AFTER THE CLEARANCE OF THE FAULT, IT IS 1.3 PU. BY USE OF EQUAL AREA CRITERION, DETERMINE THE CRITICAL CLEARING ANGLE.

P1

Pm

P2

$\delta_c = ?$

$$\delta_c = \cos^{-1} \frac{P_1 \cos\delta_0 - P_2 \cos\delta_2 + P_0(\delta_0 - \delta_2)}{P_1 - P_2}$$

$P_1 = 0.4$ $P_2 = 1.3$, $P_0 = 1$, $P_{max} = 1.8$

$$\boxed{\delta_0 = \sin^{-1} \frac{P_0}{P_m}} \qquad \boxed{\delta_2 = 180 - \sin^{-1}\left(\frac{P_0}{P_2}\right)}$$

$$\delta_0 = \sin^{-1} \frac{1}{1.8} = 33.8^\circ \qquad \delta_2 = 180 - \sin^{-1} \frac{1}{1.3} = 129.72^\circ$$

FL

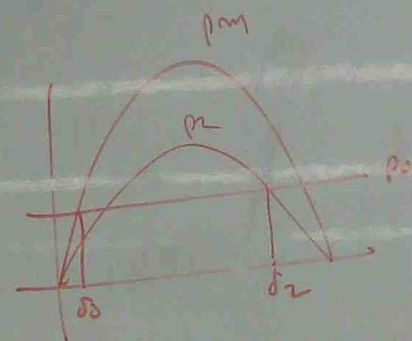
N

$180^\circ \longrightarrow \pi$ RADIAN

$33.8^\circ \longrightarrow ? = \dfrac{\pi \times 33.8}{180}$

$= \dfrac{3.1416 \times 33.8}{180}$

$= 0.58$



$180 \longrightarrow \pi$

$129.72 \longrightarrow ? = \dfrac{\pi \times 129.72}{180} = 2.26$

$$\delta_c = \cos^{-1} \frac{0.4 \cos 33.8 - 1.3 \cos 129.72 + 1(2.26 - 0.58)}{0.4 - 1.3}$$

$= \cos^{-1} 0.515$

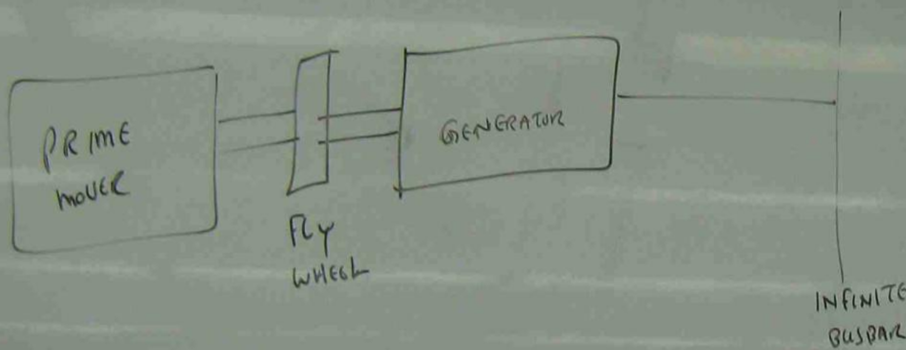
$= 58.9^\circ$

FIND RELAY SETTING TIME, IF THE MACHINE HAS 4 POLES.

$N = \dfrac{120f}{P} = \dfrac{120 \times 50}{4} = 1500$ rpm.

$1500 \times 360^\circ = 60$ sec

$58.9^\circ \longrightarrow ? = \dfrac{60 \times 58.9}{1500 \times 360^\circ} = 0.006$ sec $= 6$ms



$$M_c \frac{d^2\delta}{dt^2} + K_d \frac{d\delta}{dt} = (P_0 - \Delta P_0) -$$

PRIME MOVER POWER

DAMPING FUNCTION TO LIMIT OSCILLATION

CHANGE OF OUTPUT POWER

$$M_c \frac{d^2\delta}{dt^2} = P_0 - P_m \sin\delta$$

MOMENT OF INERTIA

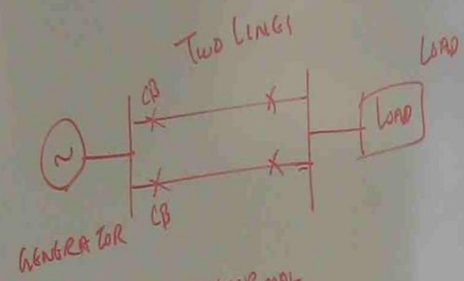
ANGULAR ACCELERATION

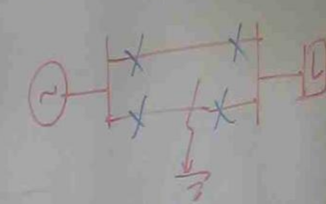
ELECTRICAL ENERGY OUT PUT BY GENERATOR

MECHANICAL ENERGY BY PRIME MOVER

T_1 – NEXT WEEK

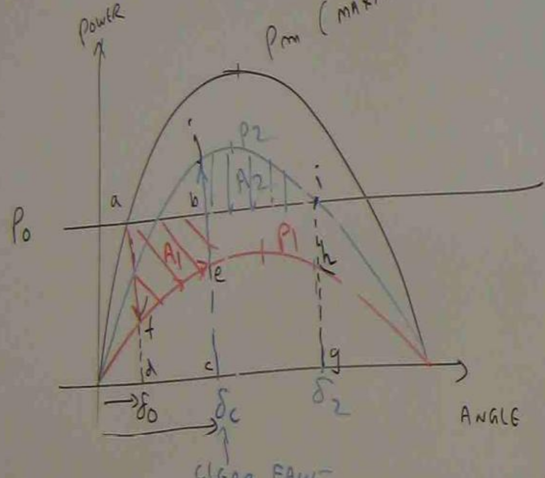
RE-VISION AFTER THE BREAK





P_1 = POWER DELIVERED TO LOAD DURING FAULT CONDITION

TRANSIENT STABILITY FAULT CLEARANCE



RELAY & CB OPERATES TO CLEAR THE FAULT AT δ_c

AFTER FAULT

A_1 = ACCELERATED AREA (DUE TO FAULT)

P_m = MAXIMUM POWER

P_o = NORMAL OUTPUT POWER

δ_0 = NORMAL LOAD ANGLE

P_1 = POWER TO LOAD DURING FAULT

P_2 = POWER TO LOAD AFTER FAULT.

δ_2 = FINAL ANGLE

A_2 = CONTROLLED AREA (RELAY OPERATION)

TO MAINTAIN STABILITY $A_1 = A_2$

1800 rpm

1800 × 360 ⟶ 60 sec

δ_c ⟶ ?

A1) $A_1 = abcd - dcef$

$= ad \times dc - \int_{\delta_0}^{\delta_c} P_1 \sin\delta \, d\delta$

$= P_0(\delta_c - \delta_0) - \int_{\delta_0}^{\delta_c} P_1 \sin\delta \, d\delta$

$= P_0(\delta_c - \delta_0) + P_1 \left(\cos\delta\right)_{\delta_0}^{\delta_c}$

$= P_0\delta_c - P_0\delta_0 + P_1\left[\cos\delta_c - \cos\delta_0\right]$

$A_1 = P_0\delta_c - P_0\delta_0 + P_1\cos\delta_c - P_1\cos\delta_0$ — (1)

A2 $A_2 = jcgi - bcgi$

$= \int_{\delta_c}^{\delta_2} P_2 \sin\delta \, d\delta - P_0(\delta_2 - \delta_c)$

$= -P_2\left[\cos\delta\right]_{\delta_c}^{\delta_2} - P_0\delta_2 + P_0\delta_c$

$A_2 = -P_2\left[\cos\delta_2 - \cos\delta_c\right] - P_0\delta_2 + P_0\delta_c$ — (2)

$A_1 = A_2$

$\cancel{P_0\delta_c} - P_0\delta_0 + P_1\cos\delta_c - P_1\cos\delta_0 = -P_2\left[\cos\delta_2 - \cos\delta_c\right] - P_0\delta_2 + \cancel{P_0\delta_c}$

$-P_0\delta_0 + P_1\cos\delta_c - P_1\cos\delta_0 = -P_2\cos\delta_2 + P_2\cos\delta_c - P_0\delta_2$

$P_1\cos\delta_c - P_2\cos\delta_c = -P_2\cos\delta_2 - P_0\delta_2 + P_0\delta_0 + P_1\cos\delta_0$

$\cos\delta_c\left[P_1 - P_2\right] = P_1\cos\delta_0 - P_2\cos\delta_2 + P_0(\delta_0 - \delta_2)$

$$\cos\delta_c = \frac{P_1\cos\delta_0 - P_2\cos\delta_2 + P_0(\delta_0 - \delta_2)}{P_1 - P_2}$$

δ_c = FAULT CLEARING ANGLE TO MAINTAIN STABILITY $= \cos^{-1}\left[\dfrac{P_1\cos\delta_0 - P_2\cos\delta_2 + P_0(\delta_0 - \delta_2)}{P_1 - P_2}\right]$

$$\delta_c = \cos^{-1}\left[\frac{P_1\cos\delta_0 - P_2\cos\delta_2 + P_0(\delta_0-\delta_2)}{P_1-P_2}\right]$$

$\delta_0 = \sin^{-1}\frac{P_0}{P_{max}}$ $\qquad$ $\delta_2 = 180 - \sin^{-1}\frac{P_0}{P_2}$

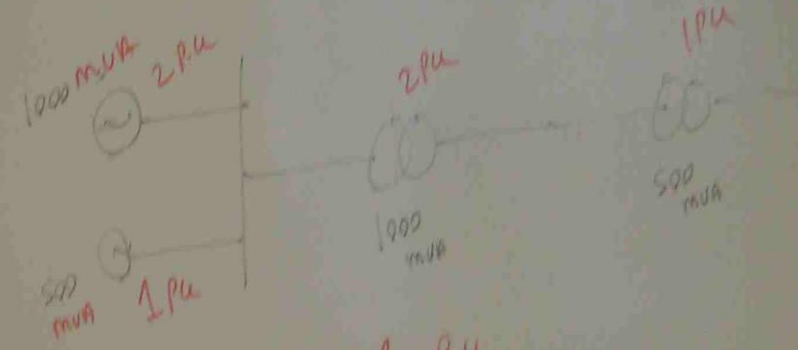
P_0 = POWER BEFORE FAULT, P_1 = POWER DURING FAULT, P_2 = POWER AFTER FAULT

Pb A GENERATOR OPERATING AT 50 HZ DELIVERS 1 P.U POWER TO INFINITE BUSBAR THROUGH NETWORK WHICH RESISTANCE MAY BE NEGLECTED. A FAULT OCCURS WHICH REDUCES THE MAXIMUM POWER TRANSFERABLE TO 0.4 P.U WHEREAS BEFORE THE FAULT THIS POWER WAS 1.8 P.U AND AFTER THE CLEARANCE OF THE FAULT, IT IS 1.3 P.U. BY USE OF EQUAL AREA CRITERION CALCULATE CRITICAL FAULT CLEARING ANGLE

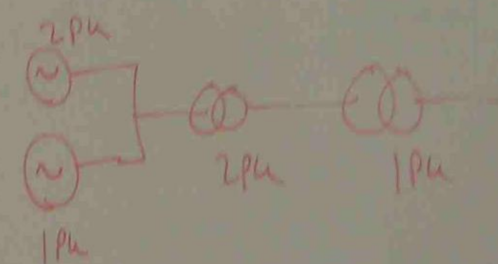
P_0, P_1, P_m, P_2

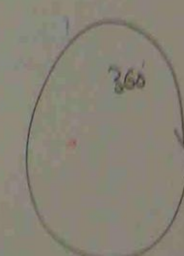
$$\delta_c = \cos^{-1}\frac{P_0(\delta_0-\delta_2)+P_1\cos\delta_0 - P_2\cos\delta_2}{P_1-P_2}$$

IF THE GENERATOR IS RUNNING AT 1500 RPM, CALCULATE RELAY SETTING TIM



LET 500 MVA = 1 P.U





$$\delta_0 = \sin^{-1}\frac{P_0}{P_m} = \sin^{-1}\frac{1}{1.8} = 33.8^\circ$$

$$\delta_2 = 180 - \sin^{-1}\frac{P_0}{P_2} = 180 - \sin^{-1}\frac{1}{1.3} = 129.72^\circ$$

?

$$\delta_c = \cos^{-1} \frac{1(\;-\;) + 0.4\cos 33.8 - 1.3\cos 129.72}{0.4 - 1.3}$$

$180° = \pi$ radian $= 3.1416$

33.8 ———— $? = \frac{3.1416 \times 33.8}{180} = 0.58$

129.72 ———— $? = \frac{3.1416 \times 129.72}{180} = 2.26$

$$\delta_c = \cos^{-1} \frac{1(0.58 - 2.26) + 0.4\cos 33.8 - 1.3\cos 129.72}{-0.9}$$

$\delta_c = 58.9°$

1500 rpm (1 rpm = 360°

$1500 \times 360° \longrightarrow 1\,\text{min} \longrightarrow 60\,\text{sec}$

$58.9°$ ———— $? = \frac{60 \times 58.9}{1500 \times 360} = 0.006\,\text{sec} = 6\,\text{ms}$

RELAY SETTING TIME

$A_1 = A_2$

$$P_0\delta_c - P_0\delta_0 + P_1\cos\delta_c - P_1\cos\delta_0 = -P_2\left[\cos\delta_2 - \cos\delta_c\right] - P_0\delta_2 + P_0\delta_c$$

$$-P_0\delta_0 + P_1\cos\delta_c - P_1\cos\delta_0 = -P_2\cos\delta_2 + P_2\cos\delta_c - P_0\delta_2$$

$$P_1\cos\delta_c - P_2\cos\delta_c = -P_2\cos\delta_2 - P_0\delta_2 + P_0\delta_0 + P_1\cos\delta_0$$

$$\cos\delta_c\left[P_1 - P_2\right] = P_1\cos\delta_0 - P_2\cos\delta_2 + P_0(\delta_0 - \delta_2)$$

$$\cos\delta_c = \frac{P_1\cos\delta_0 - P_2\cos\delta_2 + P_0(\delta_0 - \delta_2)}{P_1 - P_2}$$

$\delta_2 = 180 - \delta_0$

POWER

P_0 = BEFORE FAULT

P_1 = DURING FAULT

P_2 = AFTER FAULT

$$\boxed{\delta_c = \text{FAULT CLEARING ANGLE TO MAINTAIN STABILITY} = \cos^{-1}\frac{\left[P_1\cos\delta_0 - P_2\cos\delta_2 + P_0(\delta_0 - \delta_2)\right]}{P_1 - P_2}}$$