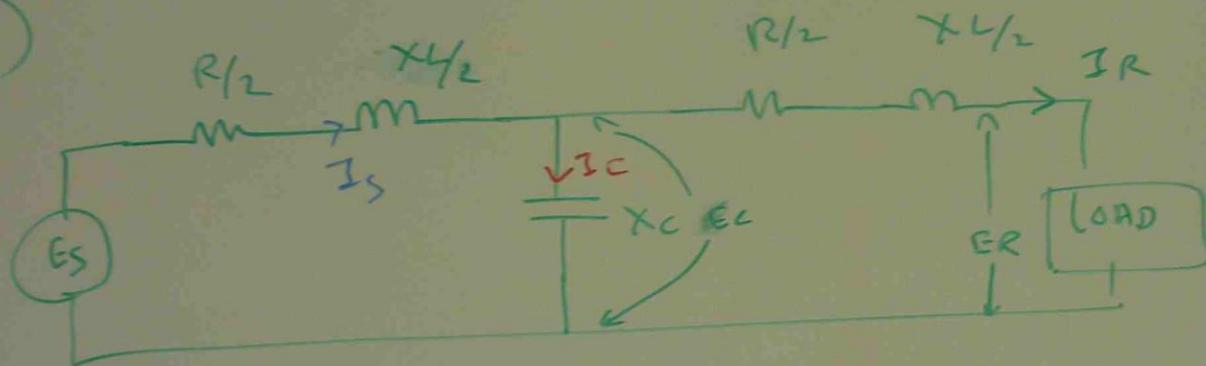
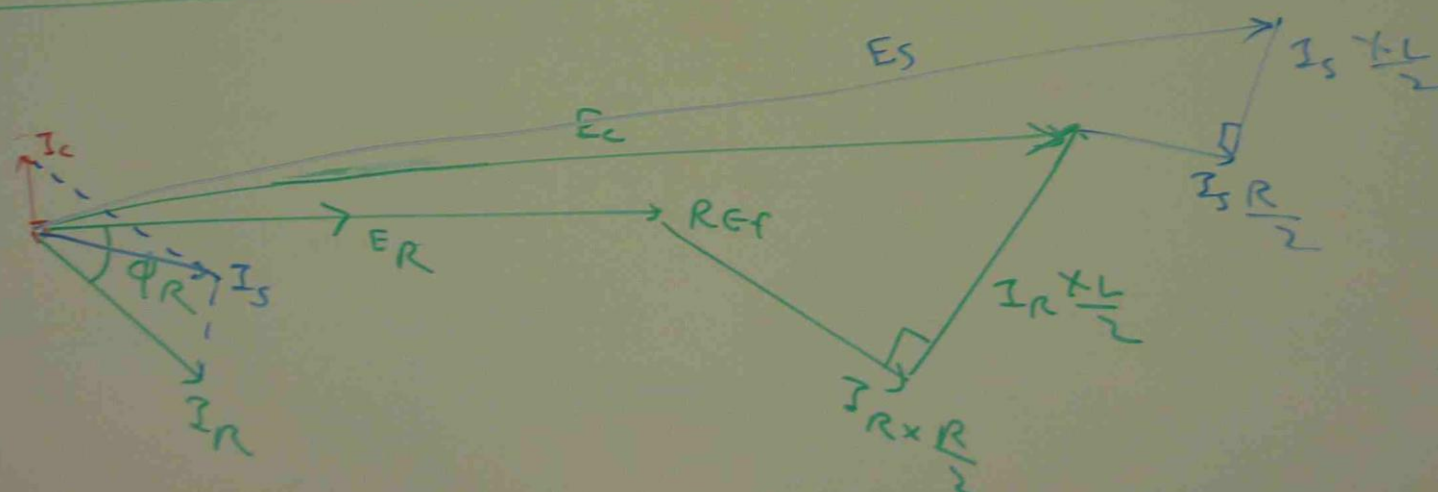
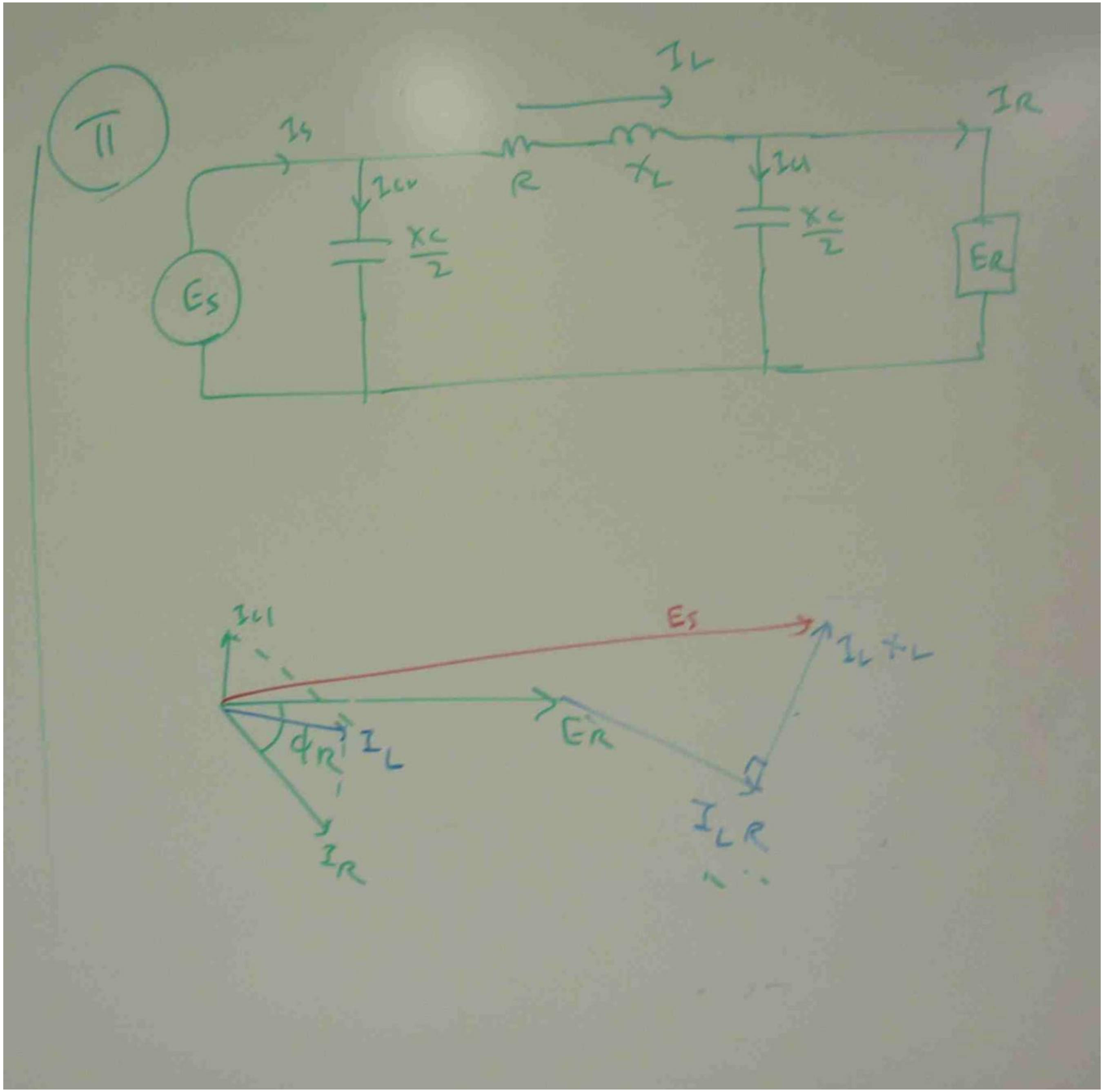
HIGH VOLTAGE TRANSMISSION LINE

· T & Π EQUIVALENT CIRCUIT

T





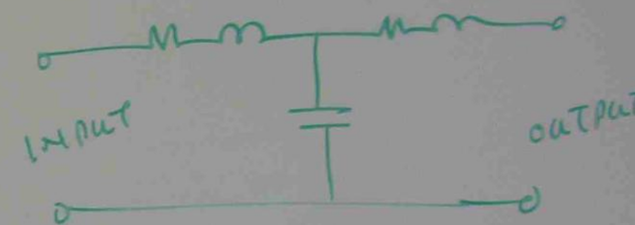


Π
I_L
I_R
I_s
I_{C1}
R
X_L
I_{C2}
$\frac{X_C}{2}$
$\frac{X_C}{2}$
E_s
E_R
I_{C1}
E_s
$I_L X_L$
E_R
ϕ_R
I_L
I_R
$I_L R$

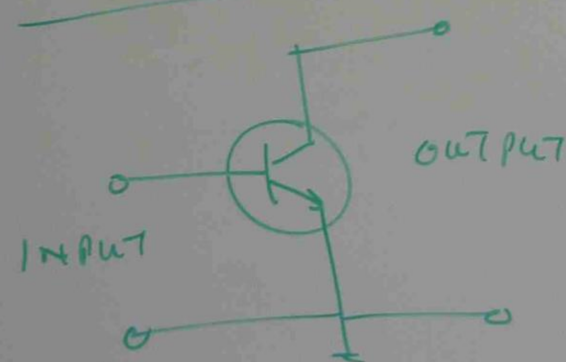
TWO PORTS NETWORK EQUIVALENT FOR TRANSMISSION LINE

TRANSFORMER

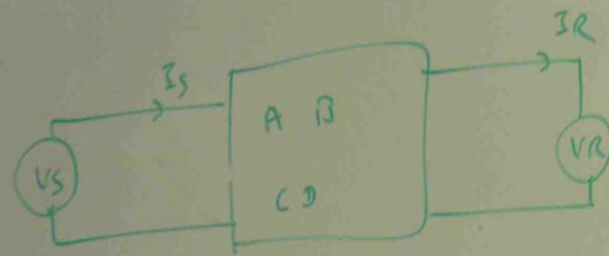
TRANSMISSION LINE



TRANSISTOR / AMPLIFIER



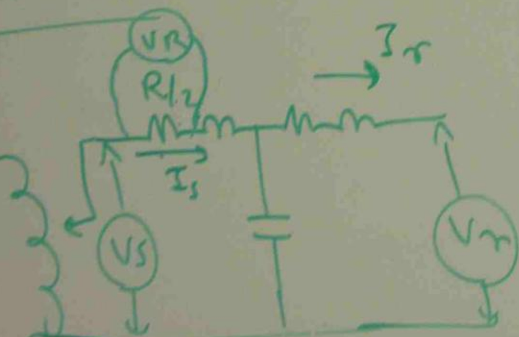
TWO PORTS NETWORK EQUIVALENT CIRCUIT



$$V_s = A\,V_r + B\,I_r$$

$$I_s = C\,V_r + D\,I_r$$

OPEN CIRCUIT

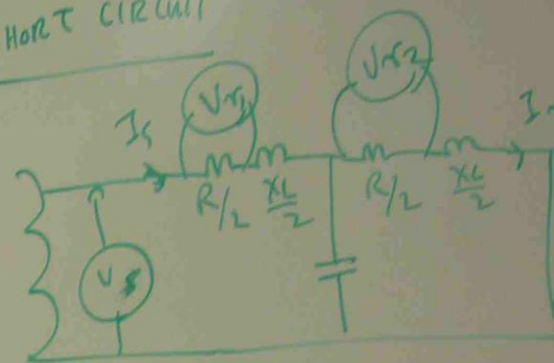


$$I_s = \frac{V_R}{R/2}$$

$I_r = 0$

$$A = \frac{V_s}{V_r} \qquad C = \frac{I_s}{V_r}$$

SHORT CIRCUIT



$$I_R = \frac{V_{r2}}{R/2}$$

$$B = \frac{V_s}{I_r} \qquad I_s = \frac{V_{r1}}{R/2}$$

$$D = \frac{I_s}{I_r}$$

Pb BY DOING OPEN CIRCUIT TEST AND SHORT CIRCUIT TEST FOR POWER LINE MODEL, THE FOLLOWING VALUES ARE OBTAINED. (11)

OCT $V_s = 13V$, $V_r = 13.43V$ $I_s = 0.09$ Amp.

SCT $V_s = 13V$ $I_r = 0.49A$ $I_s = 0.485$ Amp

FIND GENERALIZED EQUATION.

$$\boxed{\begin{aligned} V_s &= A V_r + B I_r \\ I_s &= C V_r + D I_r \end{aligned}}$$

OCT

$$A = \frac{V_s}{V_r} = \frac{13}{13.43} = 0.97$$

$$C = \frac{I_s}{V_r} = \frac{0.09}{13.43} = 0.97 \times 10^{-3}$$

SCT

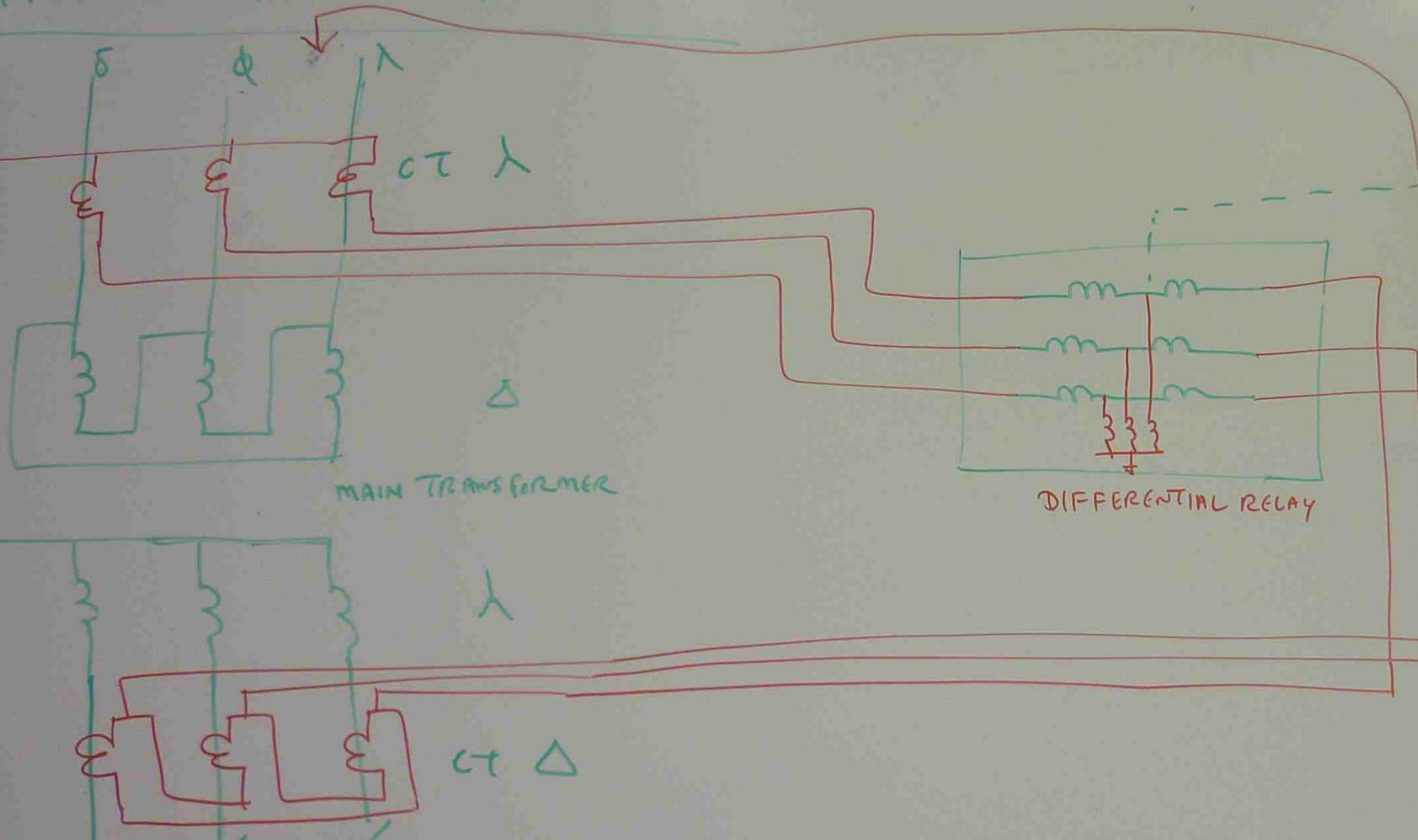
$$B = \frac{V_s}{I_r} = \frac{13}{0.49} = 26.55$$

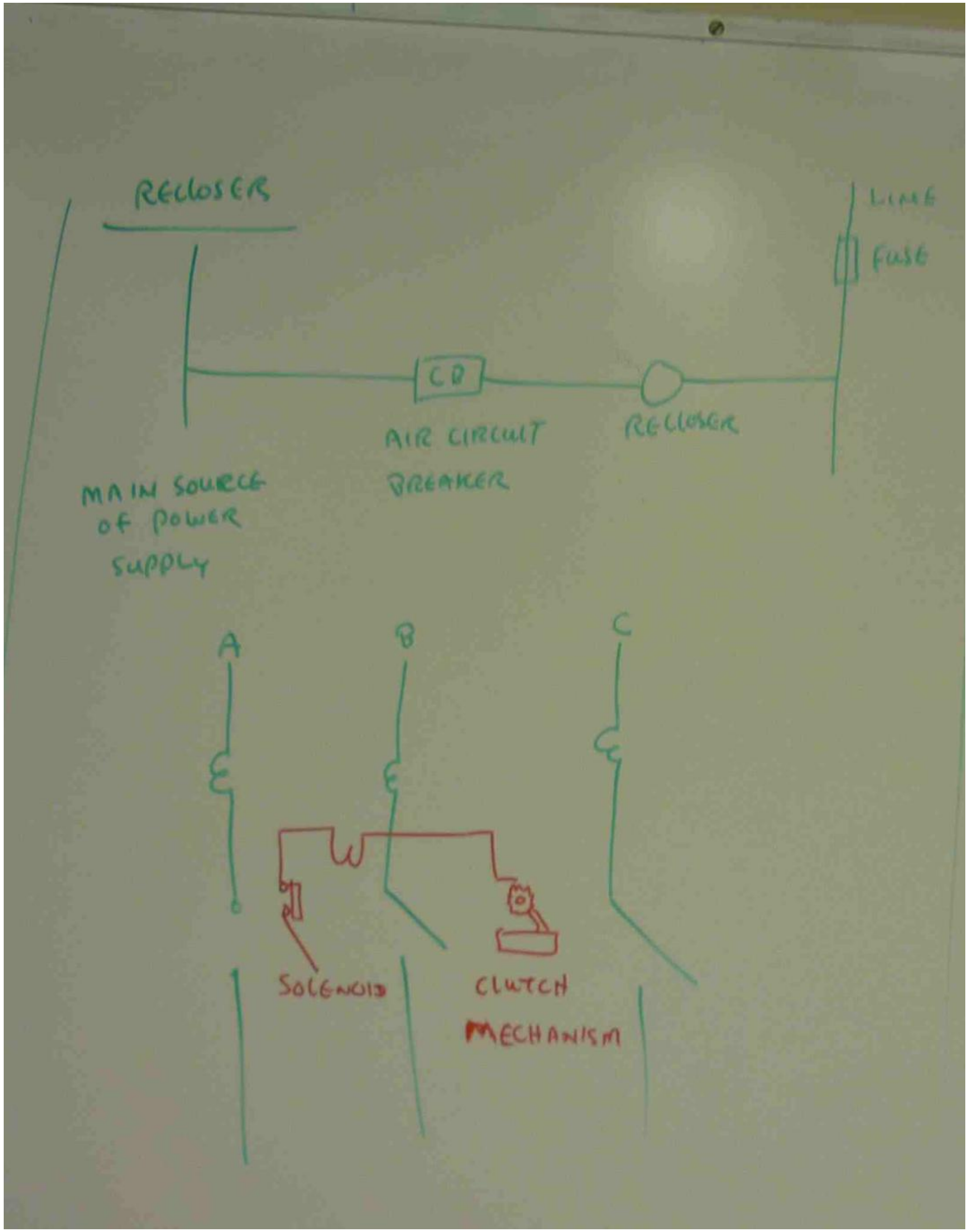
$$D = \frac{I_s}{I_r} = \frac{0.485}{0.49} = 0.98$$

$$V_s = 0.97 V_r + 26.55 I_r$$

$$I_s = 0.97 \times 10^{-3} V_r + 0.98 I_r$$

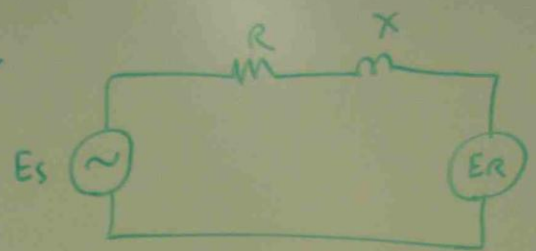
FFERENTIAL PROTECTION OF POWER TRANSFORMER




RECLOSER
LINE
FUSE
CB
AIR CIRCUIT BREAKER
RECLOSER
MAIN SOURCE OF POWER SUPPLY
A
B
C
SOLENOID
CLUTCH MECHANISM

3ϕ LINE CALCULATION

pb



SINGLE PHASE EQUIVALENCE (SHORT LINE)

IN ABOVE CIRCUIT, THE LOAD CONSUMES 1500 WATT AT POWER FACTOR 0.8 AND VOLTAGE OF 460V.

THE TRANSMISSION LINE IMPEDANCE IS $Z = 2 + j5\Omega$.

CALCULATE THE SENDING END VOLTAGE FOR

(a) 0.8 P.F LAGGING

(b) 0.8 PF LEADING

$$I = \frac{POWER}{\sqrt{3}\, E \cos\theta} = \frac{1500}{1.7321 \times 460 \times 0.8}$$

$$= 4.08 \text{ Amp}$$

(a) LAGGING PF

$\theta = \cos^{-1} 0.8 = 36.8^\circ$

$4.08 \angle -36.8$ Amp

$$\overline{E_S} = \overline{E_R} + \overline{I}\,(R + jX)$$

$$= 460 + 4.08\angle{-36.8}\;(2 + j5)$$

$$= 460 + 4.08\angle{-36.8} \times \left(\sqrt{2^2 + 5^2}\;\angle \tan^{-1}\tfrac{5}{2}\right)$$

$$= 460 + 4.08\angle{-36.8} \times 5.385\angle 68.1$$

$$= 460 + 21.97\angle 68.1 - 36.8$$

$$= 460 + 21.97\angle 31.3$$

$$= 460 + 21.97\;(\cos 31.3 + j\sin 31.3)$$

$$= 474 + j11.4$$

$$= \sqrt{474^2 + 11.4^2}\;\angle \tan^{-1}\frac{11.4}{474}$$

$$= 479\angle 1.4 \;\checkmark$$

(b) 0.8 PF LEADING

$\bar{E}_S = \bar{E}_R + \bar{I}(R+jX)$

$= 460 + 4.08\angle 36.8\,(2+j5)$

$= 460 + 4.08\angle 36.8 \times 5.385\angle 68.1$

$= 460 + 21.97\angle 36.8+68.1$

$= 460 + 21.97\angle 104.9$

$= 460 + 21.97(\cos 104.9 + j\sin 104.9)$

$= 460 + 21.97(-0.247 + j0.966)$

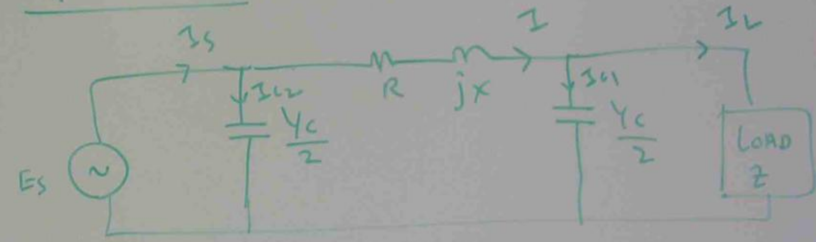
$= 454 + j21.22$

$= \sqrt{454^2 + 21.22^2}\ \angle \tan^{-1}\frac{21.22}{454}$

$= 455\angle 2.7$ V

WRITING VOLTAGE AND CURRENT EQUATIONS FOR TRANSMISSION LINE π AND T EQUIVALENT CIRCUITS

π CIRCUIT



$I_{c_1} = \frac{E_R}{\frac{X_c}{2}}$ (OR) $E_R \times \frac{Y_c}{2}$

$Y_c = \frac{1}{X_c}$

$\bar{I} = \bar{I}_L + \bar{I}_{c_1}$

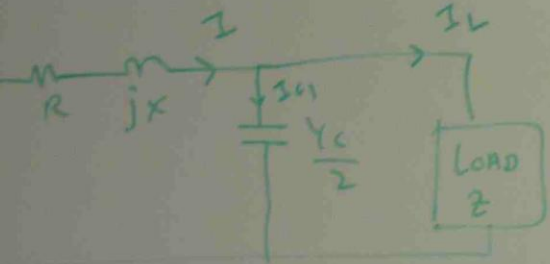
$\bar{E}_S = \bar{E}_R + \bar{I}(R+jX)$

$\bar{I}_{c_2} = \frac{E_S}{\frac{X_c}{2}}$ (OR) $E_S \times \frac{Y_c}{2}$

$\bar{I}_S =$

... AND CURRENT EQUATIONS FOR

π AND T EQUIVALENT



$\frac{E_R}{\frac{X_C}{2}}$ (OR) $E_R \times \frac{Y_C}{2}$

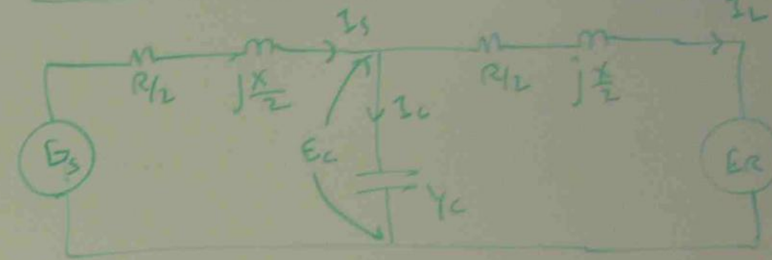
$\overline{I}_L + \overline{I}_{C_1}$

$\overline{I}\,(R + jX)$

$\frac{\ldots S}{\frac{X_C}{2}}$ (OR) $E_S \times \frac{Y_C}{2}$

$\overline{I}_S = \overline{I} + \overline{I}_{C_2}$

T CIRCUIT



$\overline{E}_C = \overline{E}_R + \overline{I}_L\left(\frac{R}{2} + j\frac{X}{2}\right)$

$\overline{I}_C = \frac{\overline{E}_C}{X_C}$ (OR) $\overline{E}_C \times \overline{Y}_C$

$\overline{I}_S = \overline{I}_C + \overline{I}_L$

$\overline{E}_S = \overline{E}_C + \overline{I}_S\left(\frac{R}{2} + j\frac{X}{2}\right)$

(b) 0.8 PF LEADING

$$\bar{E_S} = \bar{E_R} + \bar{I}\,(R + jX)$$

$$= 460 + 4.08\angle 36.8\,(2 + j5)$$

$$= 460 + 4.08\angle 36.8 \times 5.385\angle 68.1$$

$$= 460 + 21.97\angle 36.8 + 68.1$$

$$= 460 + 21.97\angle 104.9$$

$$= 460 + 21.97\,(\cos 104.9 + j\sin 104.9)$$

$$= 460 + 21.97\,(-0.247 + j0.966)$$

$$= 454 + j21.22$$

$$= \sqrt{454^2 + 21.22^2}\ \angle \tan^{-1}\frac{21.22}{454}$$

$$= 455\angle 2.7 \ \checkmark$$

WRIT

TR

CI

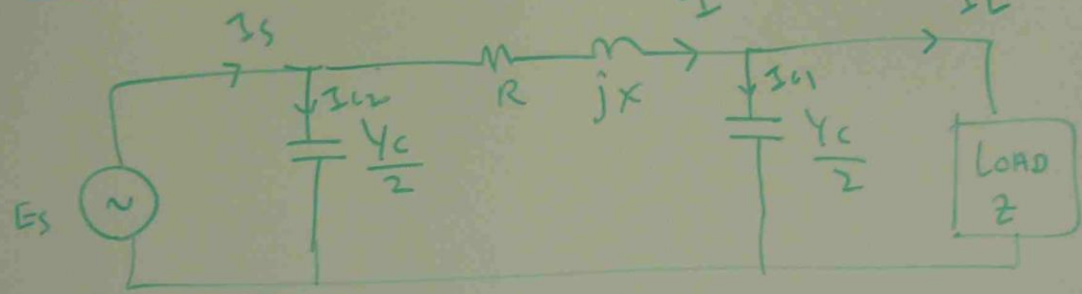
T1

E_S

$$Y_c = \frac{1}{X_c}$$

WRITING VOLTAGE AND CURRENT EQUATIONS FOR TRANSMISSION LINE Π AND T EQUIVALENT CIRCUITS

Π CIRCUIT



$$\bar{I}_S = \bar{I} + \bar{I}_{C_2}$$

$$I_{C_1} = \frac{E_R}{\frac{X_C}{2}} \quad \text{(OR)} \quad E_R \times \frac{Y_C}{2}$$

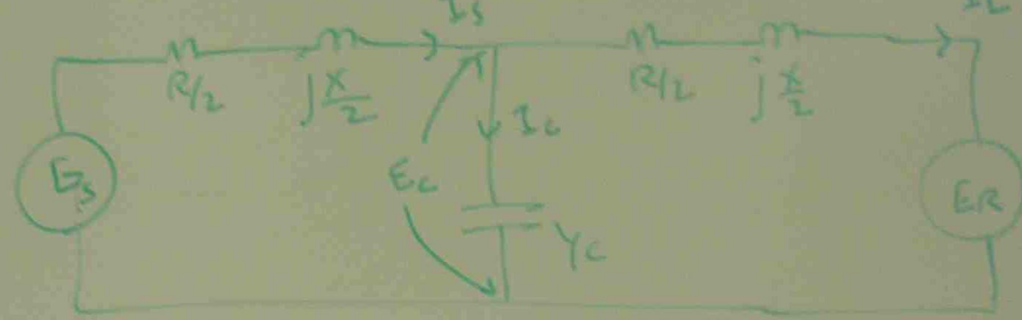
$$Y_C = \frac{1}{X_C}$$

$$\bar{I} = \bar{I}_L + \bar{I}_{C_1}$$

$$\bar{E}_S = \bar{E}_R + \bar{I}\,(R + jX)$$

$$\bar{I}_{C_2} = \frac{E_S}{\frac{X_C}{2}} \quad \text{(OR)} \quad E_S \times \frac{Y_C}{2}$$

T CIRCUIT



$$\bar{E}_c = \bar{E}_R + \bar{I}_L\left(\frac{R}{2} + j\frac{X}{2}\right)$$

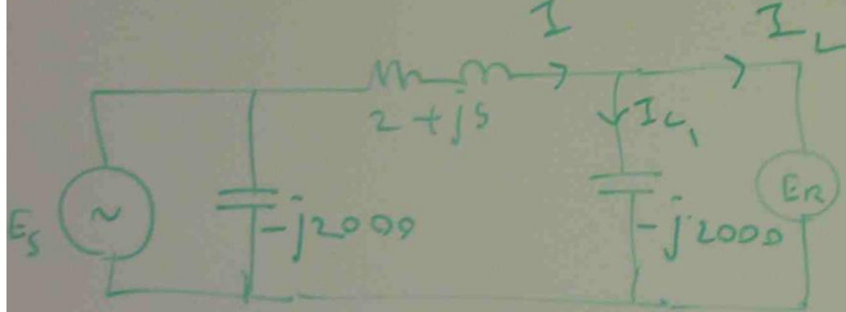
$$\bar{I}_c = \frac{\bar{E}_c}{X_c} \text{ (or) } \bar{E}_c \times \bar{Y}_c$$

$$\bar{I}_s = \bar{I}_c + \bar{I}_L$$

$$\bar{E}_s = \bar{E}_c + \bar{I}_s\left(\frac{R}{2} + j\frac{X}{2}\right)$$

Pb. A 3ϕ 33KV LINE IS SUPPLYING 300KW AT 0.8 PF LAGGING. LINE RESISTANCE, INDUCTIVE REACTIVE AND CAPACITIVE REACTANCE ARE 2Ω, 5Ω AND 4000Ω RESPECTIVELY

CALCULATE THE SENDING END VOLTAGE BY USING EQUIVALENT Π METHOD.



$$\frac{33000}{\sqrt{3}} = 19052V$$

$$I_L = \frac{300\times10^3}{\sqrt{3}\times E_{R_{LINE}} \times Pf} = \frac{300\times10^3}{1.7321\times 33\times10^3\times 0.8}$$

$$= 6.56$$

$$\theta = \cos^{-1} 0.8 = 36.8^{\circ}$$

$$I_L = 6.56 \angle{-36.8} \text{ Amp}$$

$$I_{C_1} = \frac{E_R}{\frac{X_C}{2}} = \frac{19052}{-j2000} = \frac{19052}{2000\angle -90} = 9.52\angle 90 \text{ A}$$

$$= j9.52 \text{ Amp.}$$

$$I = I_{C_1} + I_L$$

$$= j9.52 + 6.56\angle -36.8$$

$$= j9.52 + 6.56(\cos 36.8 - j\sin 36.8)$$

$$= j9.52 + 6.56(0.8 - j0.6)$$

$$= j9.52 + 5.248 - j3.936$$

$$= 5.248 + j5.584 \text{ A}$$

$$= \sqrt{5.248^2 + 5.584^2}\ \angle \tan^{-1}\frac{5.584}{5.248}$$

$$= 7.66\ \angle \tan^{-1} 1.064$$

$$I = 7.66\angle 46.7 \text{ Amp.}$$

$$\bar{E}_s = \bar{E}_R + I\,(R + jX)$$

$$= 19052 + 7.66\angle 46.7\ (2 + j5)$$

$$= 19052 + 7.66\angle 46.7 \times \left(\sqrt{2^2 + 5^2}\right)\angle \tan^{-1}\frac{5}{2}$$

$$= 19052 + 7.66\angle 46.7 \times 5.385\angle 68.1$$

$$= 19052 + 41.24\angle 114.8$$

$$= 19052 + 41.24\,(\cos 114.8 + j\sin 114.8)$$

$$= 19052 + 41.24\,(-0.419 + j0.907)$$

$$= 19052 - 17.27 + j37.4$$

$$= 19034 + j37.4$$

$$= \sqrt{19034^2 + 37.4^2}\ \angle \tan^{-1}\frac{37.4}{19034}$$

$$= 19034\angle 0.06$$

$E_{s\,\text{LINE}} = \sqrt{3} \times 19034$

$= 32968$

$= 32.96\ \text{kV}$

ECONOMIC CHOICE OF EQUIPMENTS AND SYSTEM PLANNING

THE FOLLOWING FACTORS ARE TO BE CONSIDERED FOR POWER SYSTEM PLANNING

(a) CONNECTED LOAD (OR) INSTALLED LOAD
(b) DEMAND FACTOR
(c) DIVERSITY FACTOR
(d) LOAD FACTOR.

DISTRIBUTION PLANNING

- SUB STATION SIZE
- FEEDER SIZE
- VOLTAGE REGULATION
- LOAD CHARACTERISTICS
- SIZE OF TRANSFORMER

SUB TRANSMISSION SYSTEM PLANNING

- TRADING POLICY
- CAPITAL FUND
- ORGANIZATIONAL ARRANGEMENT

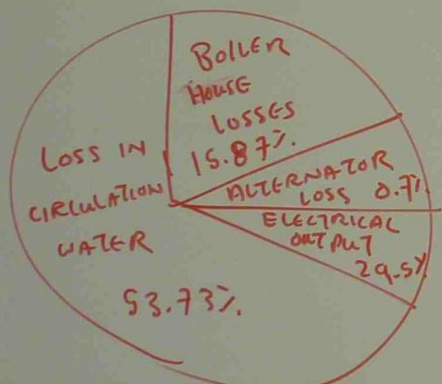
PLANNING

- LOAD FORECAST
  - PLANNING FOR FUTURE DEMAND
- RELIABILITY OF SUPPLY
- TYPES OF LOADS
  - SUBSTATION DESIGN
- CUSTOMER LOAD CONTROL
  - LOCAL CONTROL
  - REMOTE CONTROL

UNBALANCE

- → EFFECT OF THIRD HARMONICS
- → EFFECT OF FLOURESCENT LAMPS
- → MAGNITUDE OF HARMONIC COMPONENT.

HEAT BALANCE DIAGRAM OF MODERN STEAM POWER STATION



TIME VALUE OF MONEY

MONEY IS TO BE INVESTED TO INSTALL THE POWER SYSTEM EQUIPMENTS.

TIME VALUE OF MONEY DUE TO INTEREST NEEDS TO BE TAKEN INTO ACCOUNT.

LUMP SUMS

LUMP SUM OF MONEY (P) IS INVESTED AT COMPOUND INTEREST FOR (n) YEARS AT (i) PER UNIT (PERCENTAGE)

S = SUM AFTER (n) YEARS.

$$\boxed{S = P(1+i)^n}$$

ANNUAL INVESTMENT

WHEN REGULAR SUM OF MONEY "R" IS INVESTED AT COMPOUND INTEREST, THE SUM (S) AT THE END OF (n) YEARS AT (i) PER UNIT INVESTMENT.

$$S = \frac{R(1+i)^n - 1}{i}$$

$$P = \frac{R(1+i)^n - 1}{i(1+i)^n}$$

↑

CONVERSION OF ANNUAL INVESTMENT INTO LUMPSUM.

Q1) A SUM OF \$1000 IS INVESTED AT 6% FOR 10 YEARS AT COMPOUND INTEREST.

(a) CALCULATE THE SUM AT THE END OF 10 YEARS

(b) IF INSTEAD OF LUMP SUM AT THE END OF 10 YEARS, THE LOAN OF \$1000 IS TO BE PAID BY A FIXED AMOUNT EACH YEAR, CALCULATE THE ANNUAL AMOUNT.

$P = \$1000$, $i = 6\%$ $n = 10$

(a) $S = P(1+i)^n = 1000\left(1 + \frac{6}{100}\right)^{10} = 1000 \times (1.06)^{10}$

$= \$1791$

(b) $R = \frac{P\left[i(1+i)^n\right]}{(1+i)^n - 1}$

$= \frac{1000\left[0.06(1+0.06)^{10}\right]}{(1+0.06)^{10} - 1}$

$R = \$135$

NOTE

ANNUAL INTEREST ON BORROWED AMOUNT OF MONEY TO BUILD A NEW POWER SYSTEM, DEPRECIATION ON CAPITAL EQUIPMENTS, TIME VALUE OF MONEY ARE IMPORTANT FACTORS FOR INVESTMENT IN POWER SYSTEM.

THE EQUIPMENTS OPERATION LIFE DEPENDS ON QUALITY OF MAINTENANCE SERVICE, USAGE OF EQUIPMENTS, THE AMOUNT OF OVER LOAD AND DISTURBANCE, THERE MUST BE A PLAN FOR RE-INVESTMENT FOR REPLACEMENT OF CAPITAL EQUIPMENTS AFTER THE USEFUL LIFE HAS BEEN EXPIRED.

FUND ALLOCATION FOR RESEARCH AND DEVELOPMENT TO ACQUIRE THE NEW TECHNOLOGIES TO KEEP COMPETITIVENESS AND PRESERVE THE FUND FOR UNFORESEEN NATURAL DISASTERS ARE IMPORTANT ECONOMIC ASPECTS IN RUNNING THE POWER SYSTEM.