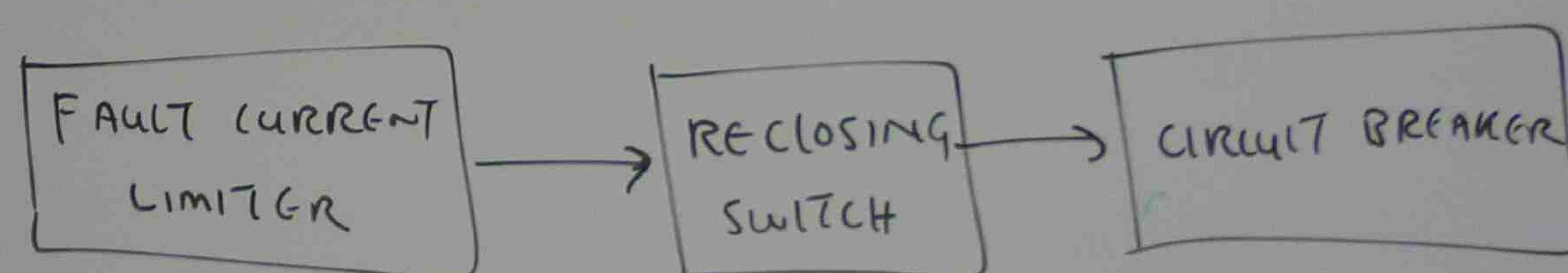
PREPARATION BEFORE EMERGENCY

- OPERATING REGIONS SHOULD OPERATE INDEPENDENTLY
- PERMITTING INTENTIONAL ISLANDING
- OPTIMAL LOAD SHEDDING OCCURS TO MAINTAIN ESSENTIAL LOADS.
- LIMIT SHORT CIRCUIT CURRENT.

DURING FAILURE

- EMERGENCY CURRENT LIMITER LIMITS THE FAULT.
- CUT OFF CIRCUIT BREAKER BY RELAY.
- RECLOSING.



AFTE

- OPT
- EFF

DEM

- DIST
- GREAT SYST
- COMP
- RED
- GROW
- PL

BEFORE EMERGENCY

GIONS SHOULD OPERATE INDEPENDENTLY

TENTIONAL ISLANDING

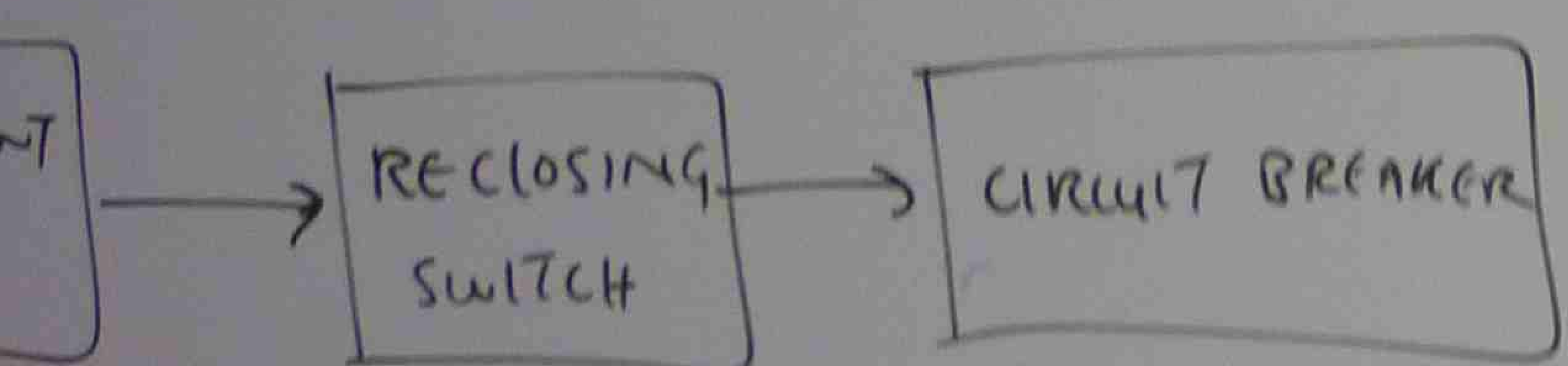
SHEDDING OCCURS TO MAINTAIN ESSENTIAL LOADS.

IRCUIT CURRENT.

RE

URRENT LIMITER LIMITS THE FAULT.

CUIT BREAKER BY RELAY.



AFTER FAILURE HAS OCCURED

- OPTIMAL LOAD SHEDDING.
- EFFICIENCY IMPROVEMENT

DEMAND MANAGEMENT

- DISTRIBUTED GENERATION
- GREATER ACCESS TO UTILITIES AND TRANSMISSION SYSTEMS
- COMPETITION OF RETAIL CUSTOMERS.
- REDUCTION IN COST OF RENEWABLE RESOURCES.
- GROWING USE OF DEMAND SIDE MANAGEMENT.
- PLAN FOR FUTURE LOAD GROWTH

WWW.

D

DISTR

- DIREC
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D016

NETWORK

DISTRIBUTED CONTROL

- DIRECT CONTROL TECHNIQUE
- LOAD CONTROL TECHNIQUE

DISTRIBUTED CONTROL EXAMPLES

- METERS FOR LIGHTING
- VENTILATION CONTROL WITH ADDITIONAL METERS
- CONTROL OF TARGETED EQUIPMENTS.

DISTRIBUTED CONTROL IS PROVIDED FOR VOLTAGE REGULATION, VOLTAGE TOLERANCE, BACKUP EMERGENCY ..) STAND BY POWER SYSTEM, LOAD SHEDDING AND LOAD MANAGEMENT.

HARMONIC CALCULATIONS

$$E_{T\,Rms} = \sqrt{E_1^2 + E_2^2 + E_3^2}$$

pb (1)

A

IS

(a

(b

CALCULATIONS

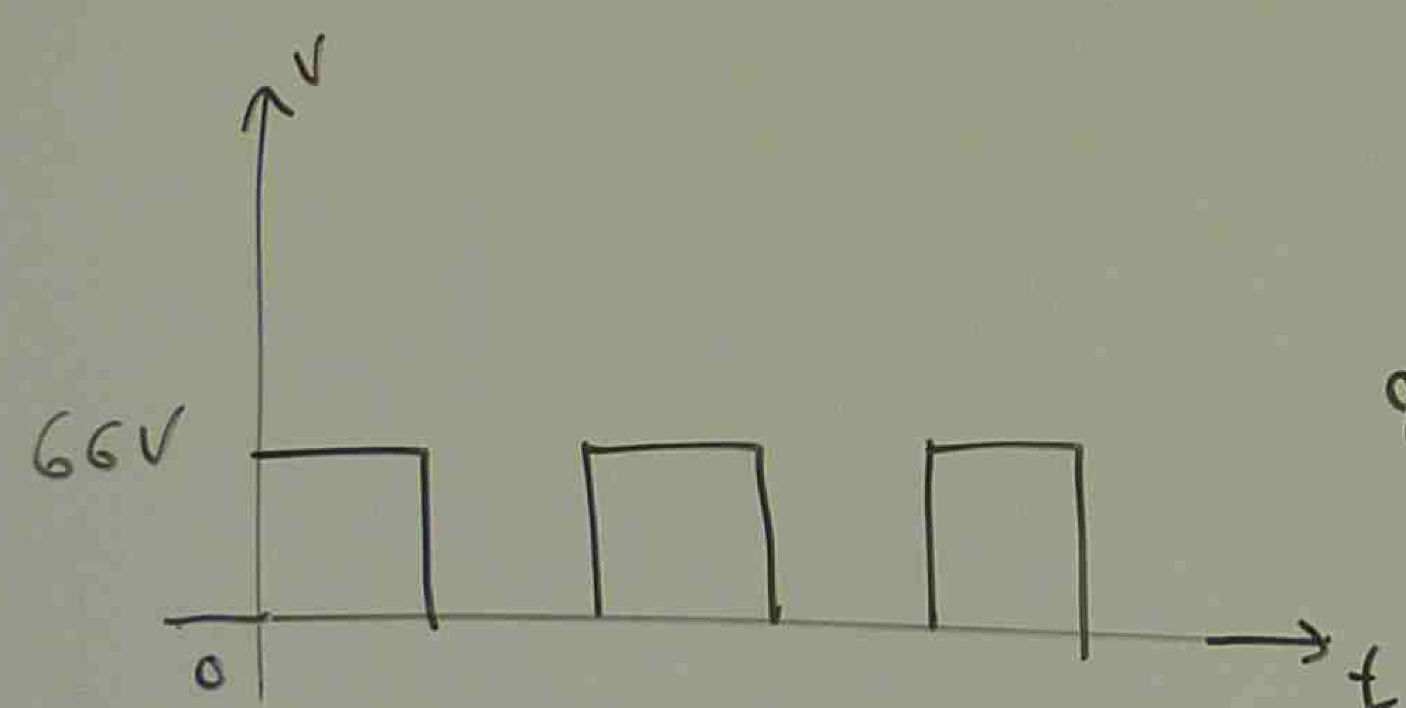
ε_3

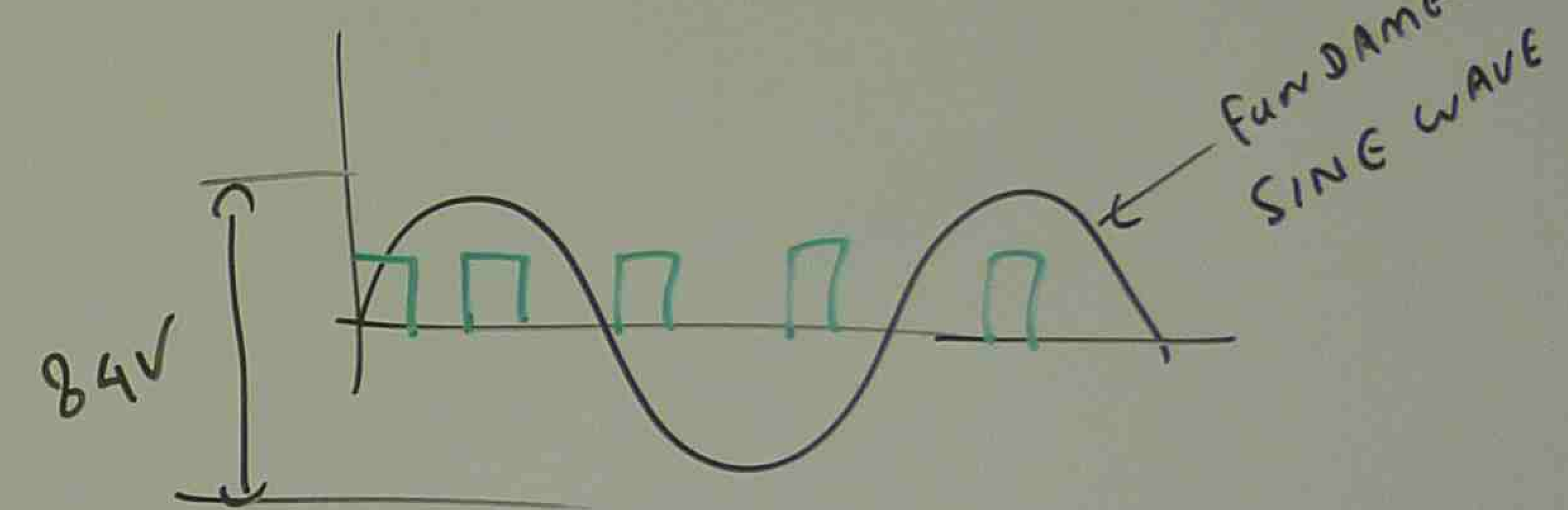
$^2 + \varepsilon_3^2$

pb (1)

A SQUARE WAVE HAS AN AMPLITUDE OF 66V. THE AMPLITUDE OF FUNDAMENTAL IS 84 V. CALCULATE

(a) THE EFFECTIVE VALUE OF SQUARE WAVE
(b) THE EFFECTIVE VALUE OF FUNDAMENTAL
(c) THE EFFECTIVE VALUE OF ALL HARMONICS.





(a) EFFECTIVE VALUE OF SQUARE WAVE = 66V

(b) EFFECTIVE VALUE OF FUNDAMENTAL (SINE WAVE) V_{RMS} $= \dfrac{V_{MAX}}{\sqrt{2}}$

$= \dfrac{84}{1.4142} = 59.4V$

(c)

pb (2)

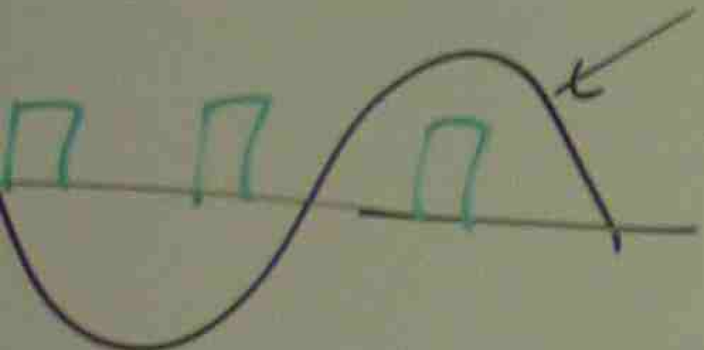
SO

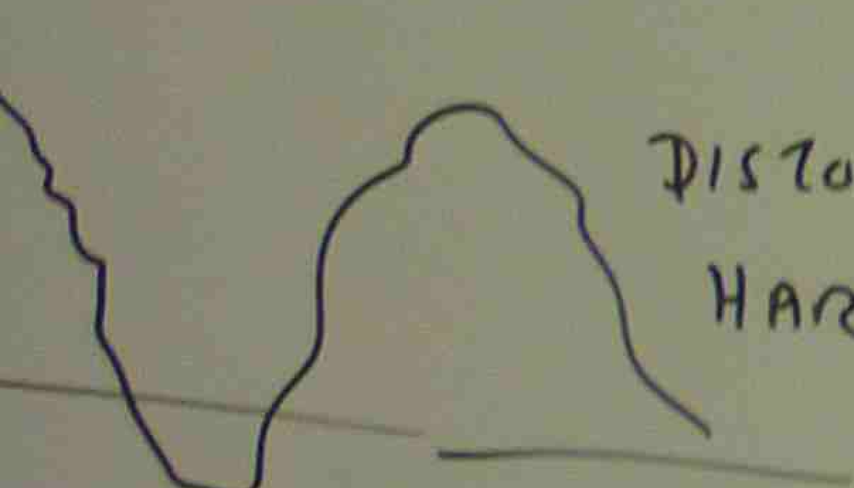
AND

CON

IN

...MPLITUDE OF FUNDAMENTAL





(c)

$$\text{EFFECTIVE VALUE OF SQUARE WAVE} = \sqrt{\begin{pmatrix}\text{EFFECTIVE VALUE OF} \\ \text{FUNDAMENTAL}\end{pmatrix}^2 + \text{HARMONICS}^2}$$

$$66 = \sqrt{59.4^2 + E_H^2}$$

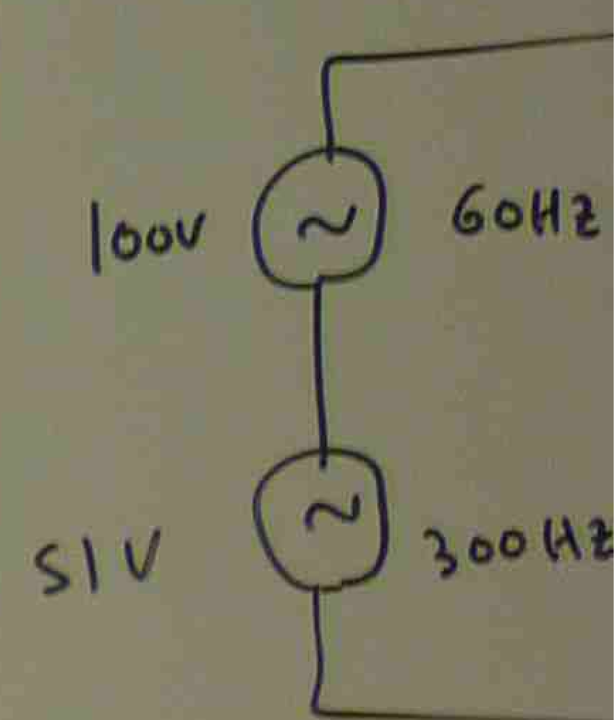
$$66^2 = 59.4^2 + E_H^2$$

$$E_H^2 = 66^2 - 59.4^2$$

$$E_H = \sqrt{66^2 - 59.4^2} = 28.76\ V$$

PB ② THE GIVEN FIGURE SHOWS A DISTORTED VOLTAGE SOURCE COMPOSED OF A FUNDAMENTAL OF 100V, 60 HZ AND 5^{th} HARMONIC OF 51 V, 300HZ. THE SOURCE IS CONNECTED TO A RESISTOR OF 24Ω IN SERIES WITH AN INDUCTANCE OF 18.6 mH AT 60HZ.

CALCULATE (a) ...
ABSORBED BY ...



$I_{60} =$ ...

$(E_{60} =$ THE VOLT...

$P_{60} = I$...

300HZ

$X_{300} = 2\pi f$...

$Z_{300} = \sqrt{\ }$...

$I_{300} =$ ...

$P_{300} =$ ...

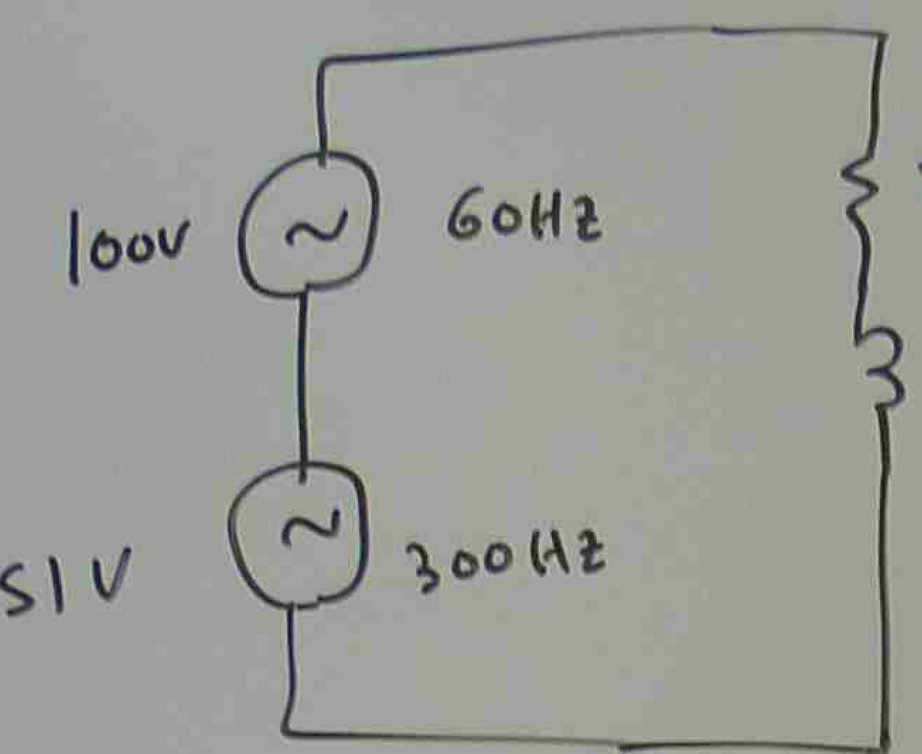
$I_T = \sqrt{I_{60}^2 + \ldots}$

VALUE OF $)^2$ + HARMONICS^2
MENTAL

76 V

DISTORTED VOLTAGE
NTAL OF 100V, 60 HZ
. THE SOURCE IS
Ω IN SERIES WITH AN
Z.

CALCULATE (a) Z AT 60HZ & 300 HZ (b) ACTIVE AND REACTIVE POWER ABSORBED BY RESISTOR AND INDUCTOR (C) TOTAL POWER DISSIPATED.



$X_L = 2\pi f L$

$X_{60HZ} = 2 \times 3.1416 \times 60 \times 18.6 \times 10^{-3} = 7\Omega$

$Z_{60} = \sqrt{R^2 + X_{60}^2} = \sqrt{24^2 + 7^2} = 25\Omega$

$I_{60} = \frac{E_{60}}{Z_{60}} = \frac{100}{25} = 4A$

(E_{60} = THE VOLTAGE AT 60HZ, Z_{60} = THE IMPEDANCE AT 60HZ)

$P_{60} = I_{60}^2 R = 4^2 \times 24 = 384W$, $Q_{60} = I_{60}^2 X_{60} = 4^2 \times 7 = 112\ VAR$

300HZ

$X_{300} = 2\pi f L = 2 \times 3.1416 \times 300 \times 18.6 \times 10^{-3} = 35\Omega$

$Z_{300} = \sqrt{R^2 + X_{300}^2} = \sqrt{24^2 + 35^2} = 42.4\Omega$

$I_{300} = \frac{E_{300}}{Z_{300}} = \frac{51}{42.4} = 1.2A$

$P_{300} = I_{300}^2 R = 1.2^2 \times 24 = 34.6W$, $Q_{300} = I_{300}^2 X_{300} = 1.2^2 \times 35 =$

$I_T = \sqrt{I_{60}^2 + I_{300}^2} = \sqrt{4^2 + 1.2^2} = 4.18A$, $P_T = \sqrt{P_{60}^2 + P_{300}^2} = \sqrt{384^2 + 34.6^2}$

$= 418.6W$

③

NO. 4 AWG CABLE HAVING A LENGTH OF 75 m HAS A RESISTANCE OF 25.7 mΩ WHEN IT CARRIES A 60 HZ CURRENT OF 100 A IT'S TEMPERATURE IS THEN 70°C IN AN AMBIENT TEMPERATURE OF 25°C.
AFTER INSTALLATION OF AN ELECTRONIC DRIVE, THE CABLE WAS FOUND TO CARRY AN ADDITIONAL 7th HARMONIC CURRENT OF 50 A, 420 HZ. CALCULATE THE NEW LOSSES IN THE CABLE AND APPROXIMATE TEMPERATURE RISE. IF ADDITIONAL LOSS IS 25% TEMPERATURE RISE IS ALSO 25%.

ORIGINAL CURRENT 100 A AT 60 HZ

ORIGINAL COPPER LOSS = $I^2 R = 100^2 \times 25.7 \times 10^{-3} = 257$ W

7th HARMONIC → 50 A AT 420 HZ

LOSSES DUE TO HARMONIC CONTENT = $I_H^2 R = 50^2 \times 25.7 \times 10^{-3} = 64$ W

TOTAL POWER LOSSES = ORIGINAL COPPER LOSS + HARMONIC LOSS

$= 257 + 64 = 321$ WATT

$\% \text{ ADDITION LOSS} = \dfrac{\text{HARMONIC LOSS}}{\text{ORIGINAL LOSS}} \times 100 = \dfrac{64}{321} \times 100 = 25\%$

$\text{TEMPERATURE RISE} = \dfrac{\%\text{ ADDITIONAL LOSS} + 100}{100} \times \text{ORIGNAL TEMPERATURE}$

$\text{TEMPERATURE RISE} = \dfrac{25+100}{100} \times 70$

$= \dfrac{125}{100} \times 70 = 81^\circ C$ ~~X~~

④

ENT OF 100A

ENT OF 50A,

S IS 25%.

$\times$ 70

o = 81 C

(4) A DISTORTED VOLTAGE IS CONNECTED ACROSS THE TERMINALS OF A COIL HAVING 1200 TURNS. THE VOLTAGE HAS A FUNDAMENTAL COMPONENT OF 150V, 60 HZ AND A THIRD HARMONIC OF 120 V, 180 HZ. THE HARMONIC LAGS 135° BEHIND THE FUNDAMENTAL. CALCULATE (a) TOTAL VOLTAGE (b) FUNDAMENTAL FLUX (c) THIRD HARMONIC FLUX.

MATHEMATICAL EQUATION FOR FUNDAMENTAL & HARMONIC VOLTAGES

$$E_{F\,rms} = E_{F\,max} \sin\theta = 150\sqrt{2}\sin\theta = 212\sin\theta$$

$$E_{H\,rms} = E_{H\,max}\sin(3\theta - 135) = 120\sqrt{2}\sin(3\theta - 135) = 170\sin(3\theta - 135)$$

$$\text{(a)}\quad E_{T\,rms} = \sqrt{E_{F-rms}^2 + E_{H-rms}^2} = \sqrt{150^2 + 120^2} = 192\ \text{V}$$

$$E = 4.44\, f\, N\, \phi$$

E = VOLTAGE (1ϕ MOTOR, 3ϕ TRANSFORMER PHASE VOLTAGE)

f = FREQUENCY (HZ) N = NO. OF TURNS

ϕ = FLUX (Wb)

$$\phi_{60} = \frac{E_{60}}{4.44 \times f_{60} \times N} = \frac{150}{4.44 \times 60 \times 1200} = 469\ \mu\text{Wb}$$

$$\phi_{180} = \frac{E_{180}}{4.44\, f_{180}\, N} = \frac{120}{4.44 \times 180 \times 1200} = 125\ \mu\text{Wb}$$

(5) A FAC

HAS AN

25 KV

CALCULA

(c) I

ACRO

S

RESON

o TURNS.

RMONIC of

IC FLUX.

(30 – 135)

RMER

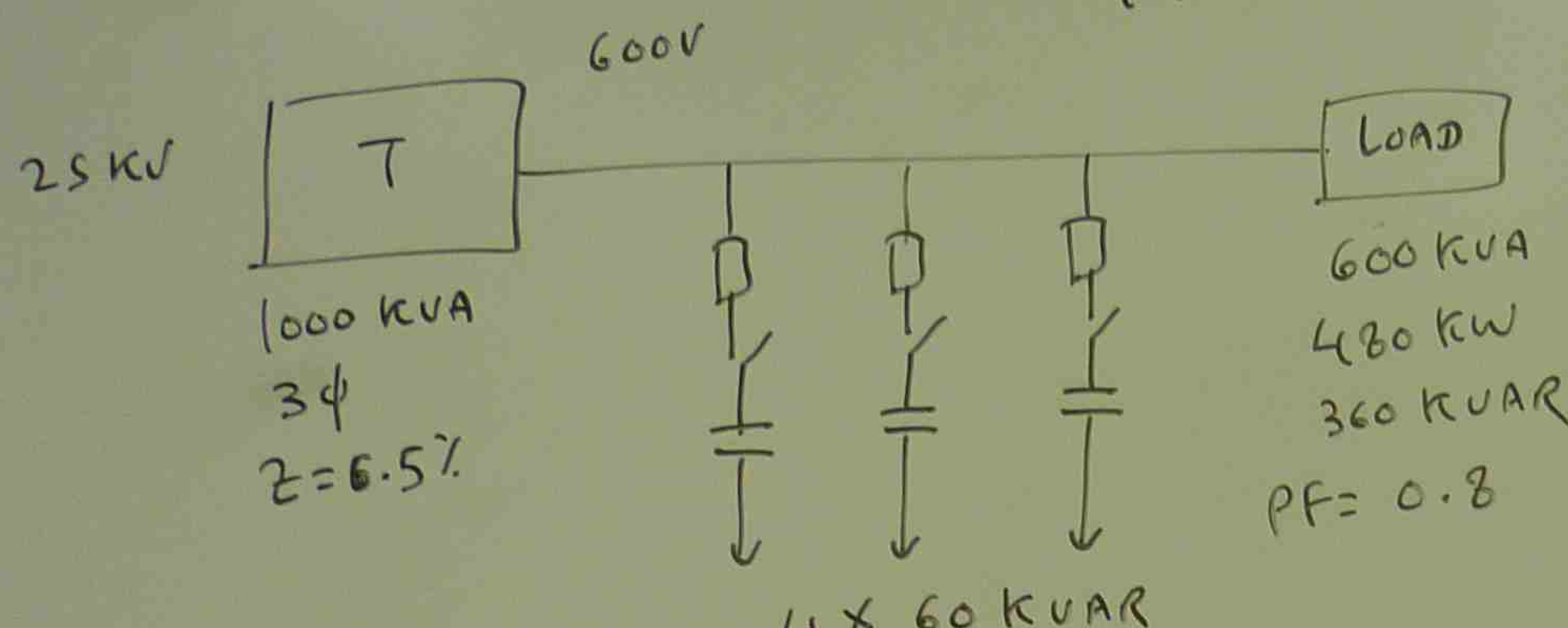
VOLTAGE)

TURNS

(5) A FACTORY BUILT IN 1980S IS POWERED BY A 1000 KVA 25 KV/600 V TRANSFORMER THAT HAS AN IMPEDANCE OF 6.5 %.

T = TRANSFORMER

f = 60 HZ



CAPACTIVE REACTANCE FUNDAMENTAL = 6 Ω

RESONANCE AT 5^{th} HARMONIC.

60% VOLTAGE AT CAPACITOR BANK.

CALCULATE (a) FUNDAMENTAL INDUCTIVE REACTANCE (b) 5^{th} HARMONIC INDUCTIVE REACTANCE (c) IMPEDANCE (d) FUNDAMENTAL CURRENT THROUGH CAPACITOR (e) LINE TO LINE VOLTAGE ACROSS CAPACITOR TERMINAL.

$$X_C = 6\,\Omega, \quad X_C \text{ nth HARMONIC} = \frac{X_C \text{ FUNDAMENTAL}}{n}$$

$$\text{5th HARMONIC } X_{C\,5th} = \frac{6}{5} = 1.2\,\Omega$$

RESONANCE AT 5^{th} HARMONIC

$$X_C = X_L \longrightarrow X_L = 1.2\,\Omega$$

$$X_L = 2\pi f L$$

$$1.2 = 2 \times 3.1416 \times (60 \times 5)\, L$$

$$L = \frac{1.2}{2 \times 3.1416 \times 60 \times 5} = 637 \times 10^{-6}\ H$$

$$= 637\ \mu H$$

(a) X

(b)

(c)

(d)

(e)

1000 kVA 25 kV/600 V TRANSFORMER THAT

$f = 60\,HZ$

CAPACTIVE REACTANCE FUNDAMENTAL = $6\,\Omega$

RESONANCE AT 5^{th} HARMONIC.

60% VOLTAGE AT CAPACITOR BANK.

(b) 5^{th} HARMONIC INDUCTIVE REACTANCE

GH CAPACITOR (e) LINE TO LINE VOLTAGE

$$\frac{X_c \text{ FUNDAMENTAL}}{n}$$

$$= 2\pi f L$$

$$= 2\times 3.1416 \times (60\times 5)\, L$$

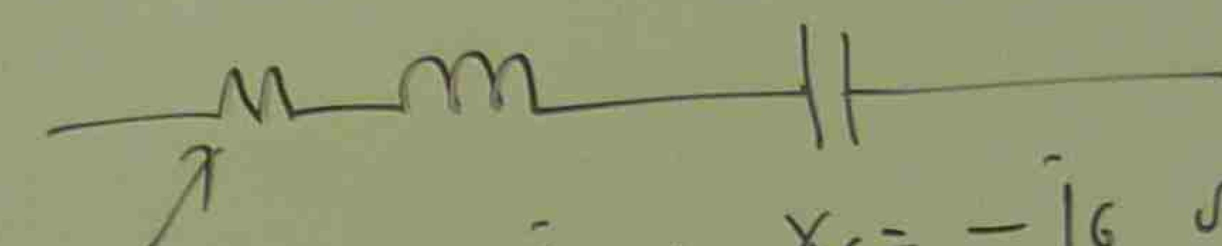
$$\frac{\quad}{1416\times 60\times 5} = 637\times 10^{-6}\, H$$

$$= 637\,\mu H$$

(a) X_L FUNDAMENTAL $= 2\pi f L = 2\times 3.1416\times 60\times 637\times 10^{-6} = 0.24\,\Omega$

(b) X_L 5th HARMONIC $= 1.2\,\Omega$

(c)



$R \simeq 0$ $\quad X_L = +j0.24\,\Omega$ $\quad X_c = -j6\,\Omega$

$$Z_T = R + X_L + X_c$$

$$= 0 + j0.24 + (-j6) = -j\,5.76\,\Omega$$

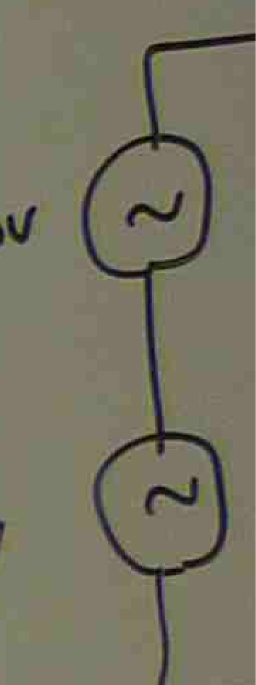
(d) $I = \dfrac{E}{Z_T} = \dfrac{600/\sqrt{3}}{5.76} = 62.5\,A$

(e) $E_L = I \times X_c \times \sqrt{3}$

$$= 62.5 \times 6 \times 1.7321 = 650\,V$$

CALCULATE

ABSORBES



(E_{60} = TH

P_6

300Hz

X_{300} =

Z

I_T =

6. THE PRIMARY WINDING OF A TRANSFORMER CARRIES A DISTORTED CURRENT HAVING THE FOLLOWING COMPONENTS.

FUNDAMENTAL CURRENT = 520 A

THIRD HARMONIC = 270 A

23^{rd} HARMONIC = 47 A

THE WINDING HAS A DC RESISTANCE OF 3 mΩ AND THE STRAY LOSSES ARE EQUAL TO 4 % OF TOTAL JOULE EFFECT LOSSES.

CORE LOSS

COPPER LOSS

CALCULATE (a) THE EFFECTIVE VALUE OF I_T OF THE CURRENT.

(b) K FACTOR

(c) THE JOULE EFFECT LOSSES IN THE PRIMARY WINDING.

(d) THE STRAY LOSSES AND THE TOTAL LOSSES IN THE PRIMARY WINDING.

(e) THE COMPONENT IN I_T THE PRODUCES THE LARGEST JOULE EFFECT LOSS.

(f) THE COMPONENT IN I_T THAT PRODUCES THE LARGEST STRAY LOSS.

(a)

(b)

K =
T

K
T

(c)

S A DISTORTED

THE STRAY — CORE LOSS
FECT LOSSES. — COPPER LOSS

F THE CURRENT.

E PRIMARY

TAL LOSSES

PRODUCES THE

.

PRODUCES THG

(a) $I_T = \sqrt{I_f^2 + I_{3rd}^2 + I_{23rd}^2}$

$= \sqrt{520^2 + 270^2 + 47^2}$

$= 587.8$ Amp

(b)

$$K_T = \frac{(1 \text{ for } I_f)^2 I_f^2 + (3 \text{ for } 3rd)^2 I_{3rd}^2 + (23 \text{ for } 23_{rd})^2 I_{23rd}^2}{I_T^2}$$

$$K_T = \frac{1^2 \times 520^2 + 3^2 \times 270^2 + 23^2 \times 47^2}{587.8^2}$$

$= 6.06$

(c) Joule Effect losses $= I_T^2 R_o = 587.8^2 \times 3 \times 10^{-3}$

$= 1037$ WATT

(d)

(e) T

(f)

I_{23rd}^2

(d) Stray loss = % stray loss × Joule's effect loss × K

$$= \frac{4}{100} \times 1037 \times 6.06$$

$= 251$ watt

(e) Total losses = Joule effect loss + stray loss

$= 1037 + 251 = 1288$ watt

(f) Largest stray loss = Largest harmonic current caused by stray loss

$$= \frac{(23 \text{ for } I_{23rd})^2 \, I_{23rd}^2}{I_T^2} = \frac{23^2 \times 47^2}{587.8^2}$$

$= 3.38$

Largest stray loss = Total stray loss × $\frac{K_{23}}{K_T}$

$$= 251 \times \frac{3.38}{6.06}$$

$= 140$ W

---

(7) A 3ϕ synchronous generator produces an open circuit line voltage of 6928 V when the DC exciting current is 50 A. The AC terminals are then short circuited and three line currents are found to be 800 A.

(a) Calculate the synchronous reactance per phase

(b) Calculate the terminal voltage if three 12 Ω resistors are connected in wye across the terminal.

pm

F

pm

$E_{ph} = 4.$

$\phi \propto I$

Ef

Short c

Ef 4

LARGEST STRAY LOSS = TOTAL STRAY LOSS × $\frac{K_{23}}{K_T}$

$= 251 \times \frac{3.38}{6.06}$

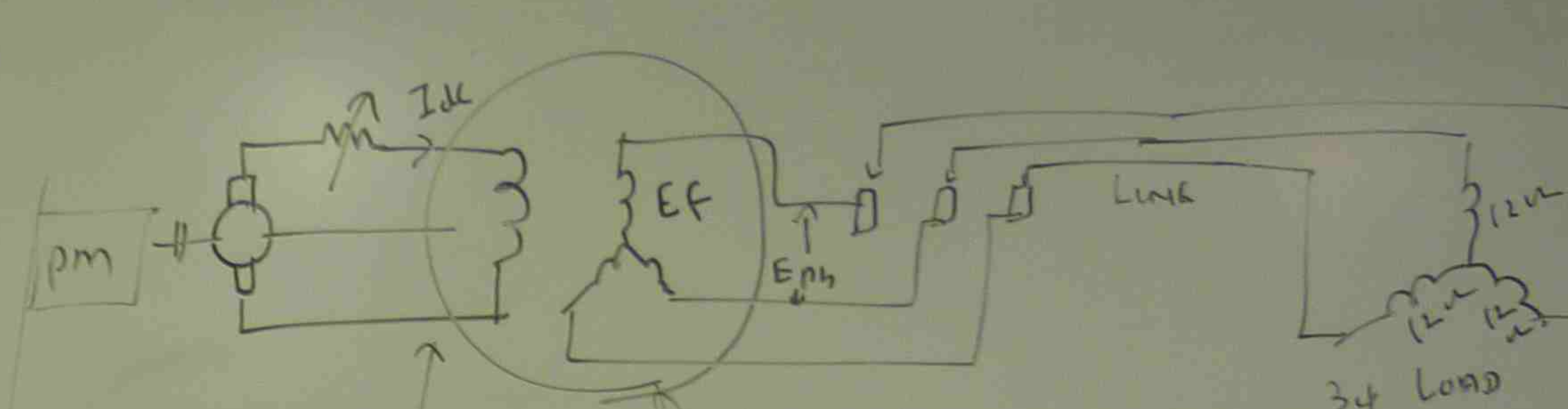
$= 140\,W$

---

(7) A 3 ϕ SYNCHRONOUS GENERATOR PRODUCES AN OPEN CIRCUIT LINE VOLTAGE OF 6928 V WHEN THE DC EXCITING CURRENT IS 50 A. THE AC TERMINALS ARE THEN SHORT CIRCUITED AND THREE LINE CURRENTS ARE FOUND TO BE 800 A.

(a) CALCULATE THE SYNCHRONOUS REACTANCE PER PHASE

(b) CALCULATE THE TERMINAL VOLTAGE IF THREE 12 Ω RESISTORS ARE CONNECTED IN WYE ACROSS THE TERMINAL.



FIELD EXCITATION WINDING

3φ VOLTAGE WINDING

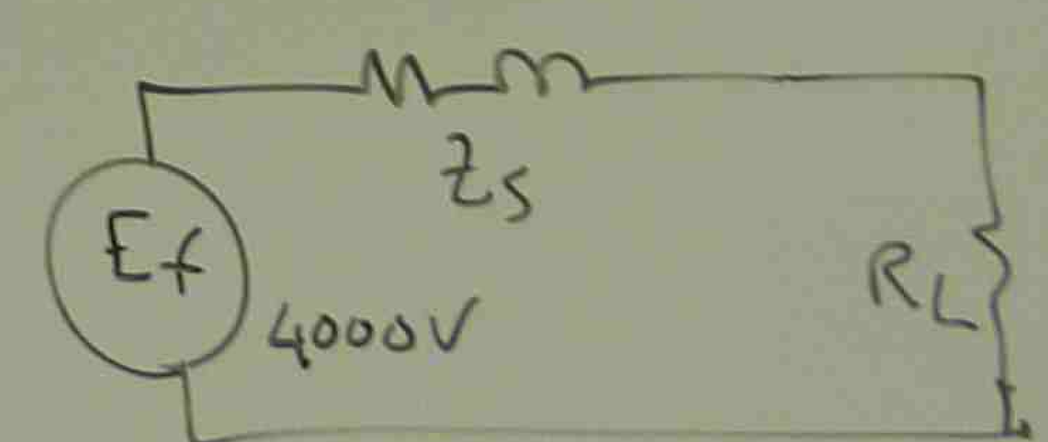
pm – PRIME MOVER (STEAM TURBINE / DIESEL ENGINE / WATER TURBINE)

$E_{ph} = 4.44\, f\, N\, \phi$ ← flux

$N_S = \frac{120 f}{P}$

SYNCHRONOUS SPEED; f ← FREQUENCY; P ← NO. OF POLES

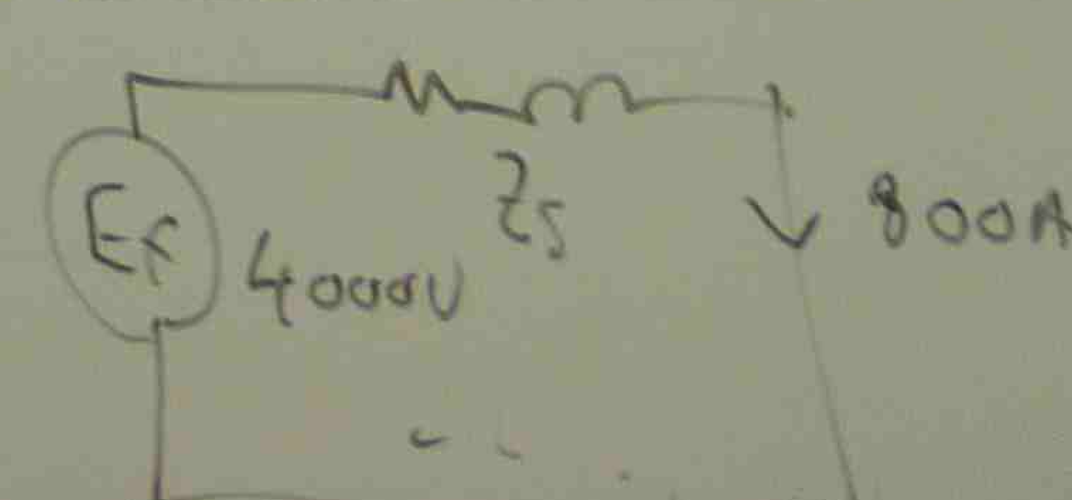
$\phi \propto I_{dc}$

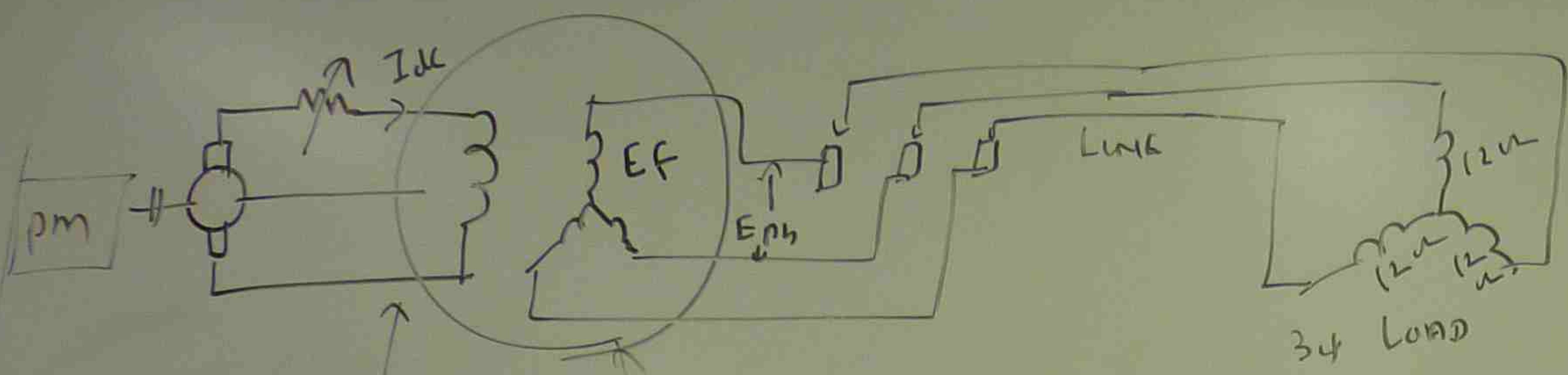


$E_{f\,ph} = \frac{E_f \text{ LINE (OPEN CIRCUIT)}}{\sqrt{3}}$

$= \frac{6928}{1.7321} = 4000V$

SHORT CIRCUIT AC TERMINALS





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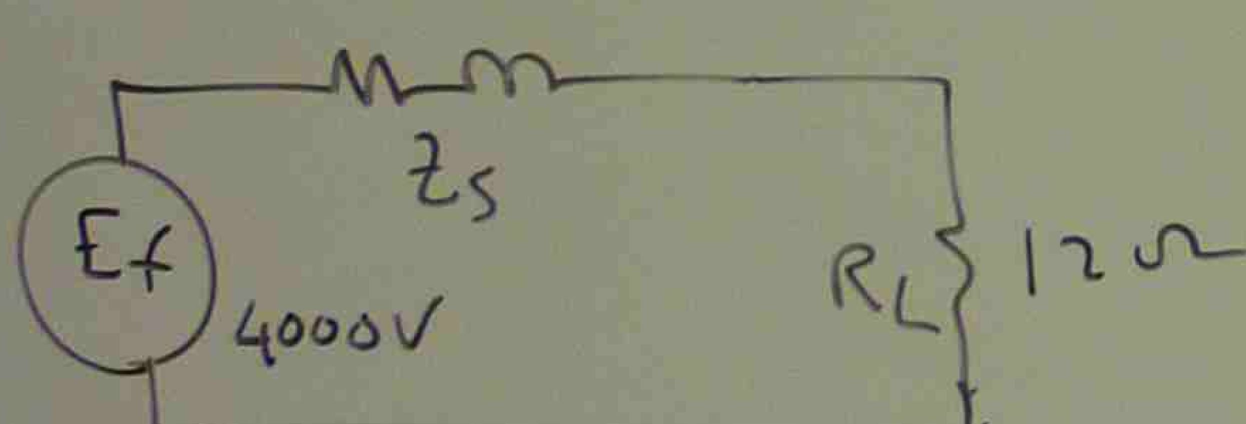
$E_{ph} = 4.44\, f\, N\, \phi$ ← FLUX

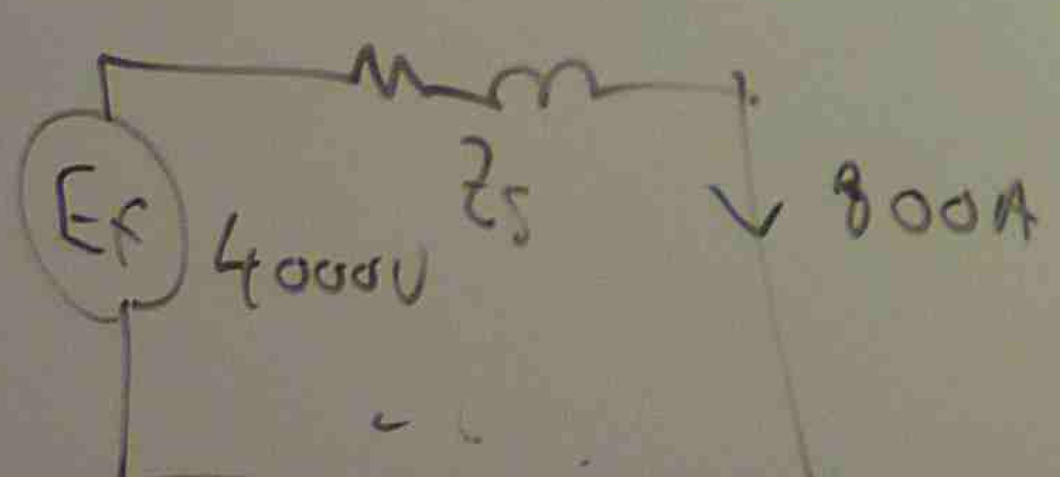
$N_S = \frac{120 f}{P}$ (f ← FREQUENCY, P ← NO. OF POLES; N_S ← SYNCHRONOUS SPEED)

$\phi \propto I_{dc}$



$$E_{f\,ph} = \frac{E_f \text{ LINE (OPEN CIRCUIT)}}{\sqrt{3}} = \frac{6928}{1.7321} = 4000V$$

SHORT CIRCUIT AC TERMINALS

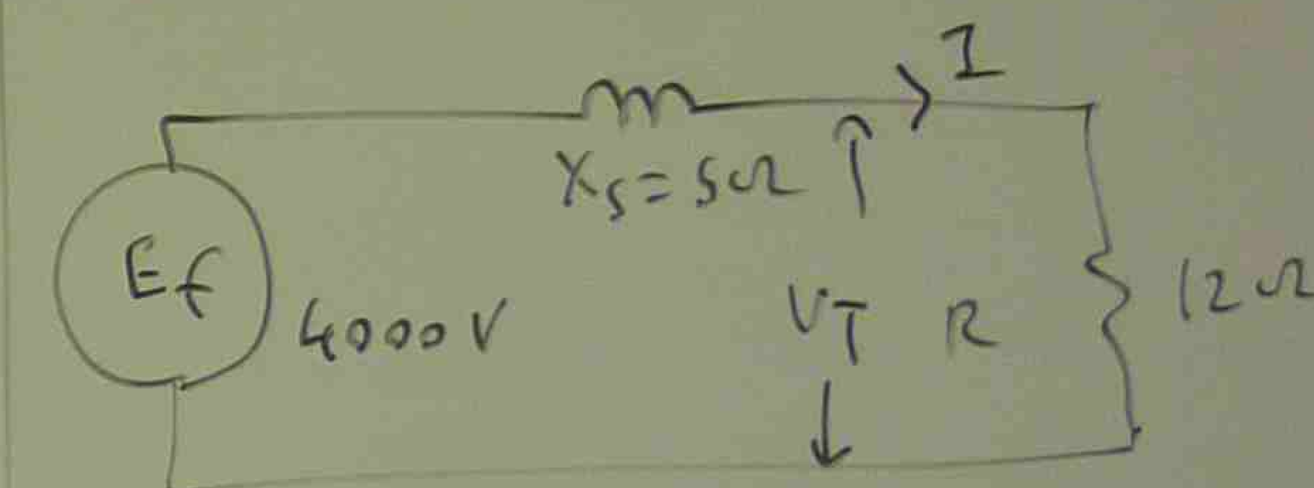


$R \simeq 0$

$X_S \simeq Z_S$

(a) $X_S = Z_S = \frac{E_f\,(ph)}{I_{\text{SHORT CIRCUIT}}}$

$= \frac{4000}{800} = 5\Omega$



$$I = \frac{E_f}{\sqrt{R^2 + X_S^2}} = \frac{4000}{\sqrt{12^2 + 5^2}}$$

$$= \frac{4000}{13} = 308\,A$$

$V_{T\,ph} = I R = 308 \times 12 = 3696\,V$

$V_T \text{ LINE} = \sqrt{3} \times 3696 = 6403\,V$

LARGEST STRAY LOSS = TOTAL STRAY LOSS × $\frac{K_{23}}{K_T}$

$= 251 \times \frac{3.38}{6.06}$

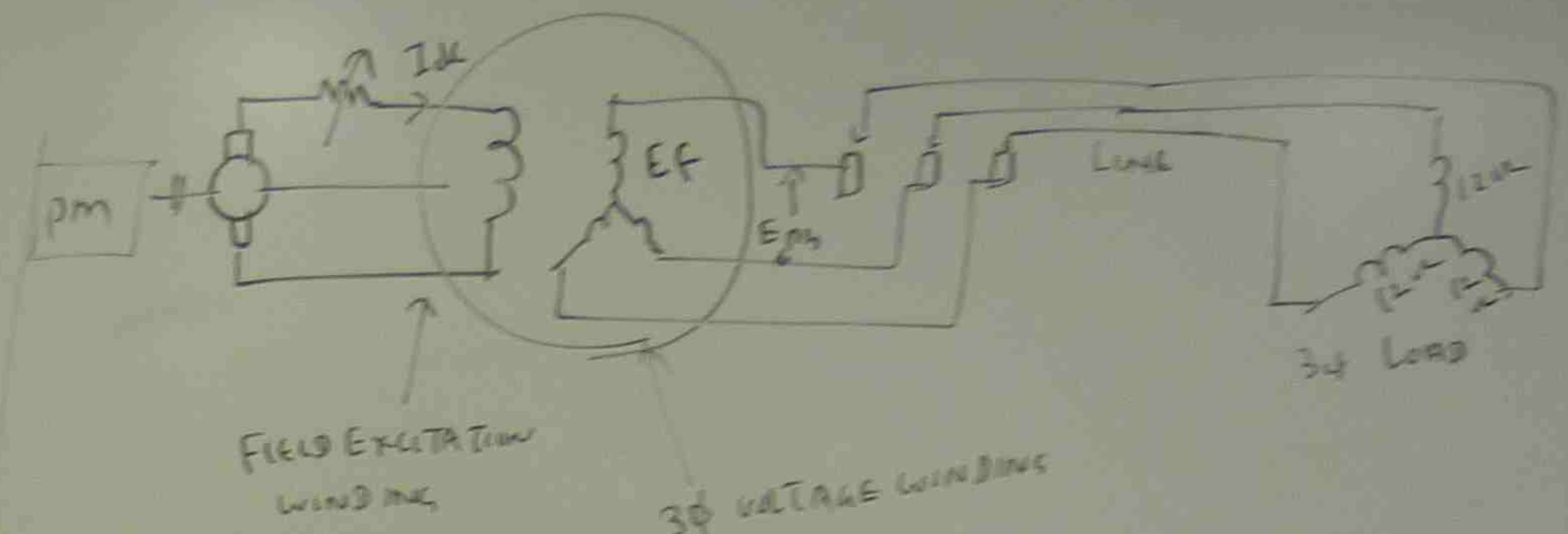
$= 140W$

GENERATOR (GENERATION)

(7) A 3 ϕ SYNCHRONOUS GENERATOR PRODUCES AN OPEN CIRCUIT LINE VOLTAGE OF 6928 V WHEN THE DC EXCITING CURRENT IS 50 A. THE AC TERMINALS ARE THEN SHORT CIRCUITED AND THREE LINE CURRENTS ARE FOUND TO BE 800 A.

(a) CALCULATE THE SYNCHRONOUS REACTANCE PER PHASE

(b) CALCULATE THE TERMINAL VOLTAGE IF THREE 12 Ω RESISTORS ARE CONNECTED IN WYE ACROSS THE TERMINAL.

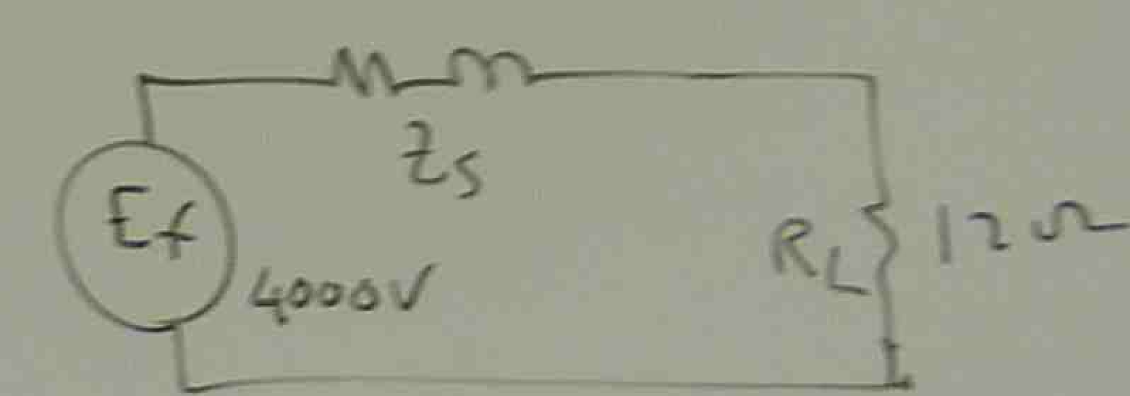


pm – PRIME MOVER (STEAM TURBINE / DIESEL ENGINE / WATER TURBINE)

$E_{ph} = 4.44 f N \phi$ ← flux

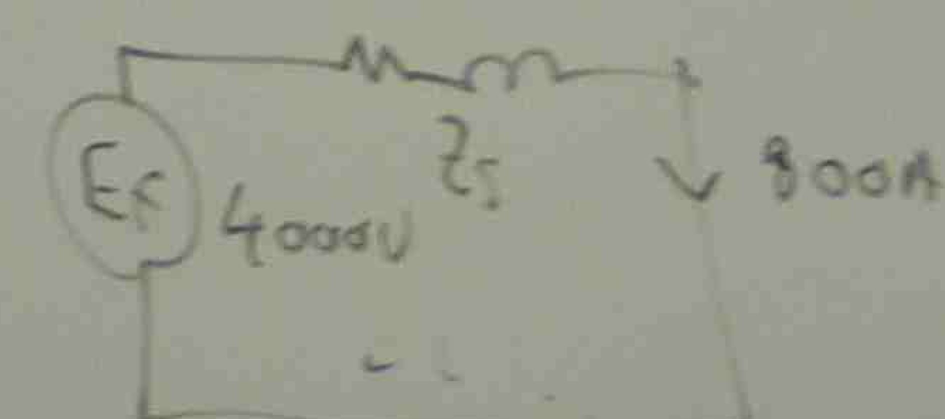
$\phi \propto I_{dc}$

$N_S = \frac{120 f}{P}$ — f ← FREQUENCY, P ← no. of poles, N_S ← SYNCHRONOUS SPEED



$$E_{f\,ph} = \frac{E_f \text{ LINE (OPEN CIRCUIT)}}{\sqrt{3}} = \frac{6928}{1.7321} = 4000V$$

SHORT CIRCUIT AC TERMINALS



$R \simeq 0$

$X_s \simeq$

(a) $X_s = Z_s$

$I =$

V_T

12Ω

(OPEN CIRCUIT)

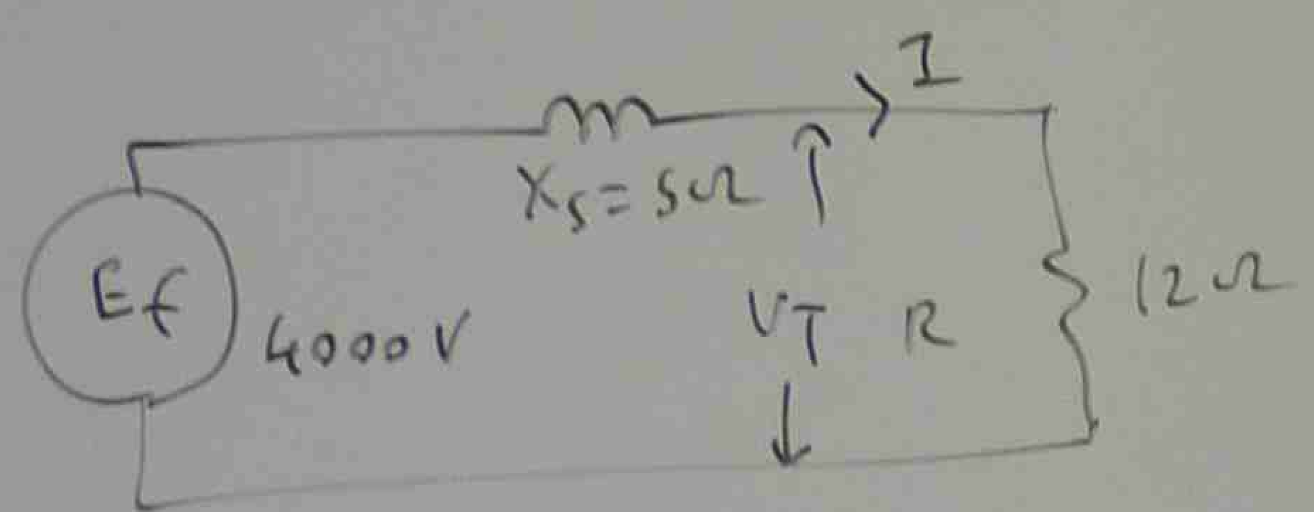
4000V

$R \simeq 0$

$X_s \simeq Z_s$

(a) $X_s = Z_s = \dfrac{E_f\,(ph)}{I_{\text{SHORT CIRCUIT}}}$

$= \dfrac{4000}{800} = 5\Omega$



$I = \dfrac{E_f}{\sqrt{R^2 + X_s^2}} = \dfrac{4000}{\sqrt{12^2 + 5^2}}$

$= \dfrac{4000}{13} = 308\text{ A}$

$V_{T\,ph} = IR = 308 \times 12 = 3696\text{ V}$

$V_{T\,\text{LINE}} = \sqrt{3} \times 3696 = 6403\text{ V}$

(8) A 30 MVA, 15 KV, 60 HZ AC GENERATOR HAS A SYNCHRONOUS REACTANCE OF 1.2 P.U AND AC RESISTANCE OF 0.02 P.U.

CALCULATE

(a) THE BASE VOLTAGE, BASE POWER AND BASE IMPEDANCE OF THE GENERATOR.

(b) THE ACTUAL VALUE OF SYNCHRONOUS REACTANCE

(c) THE ACTUAL WINDING RESISTANCE PER PHASE

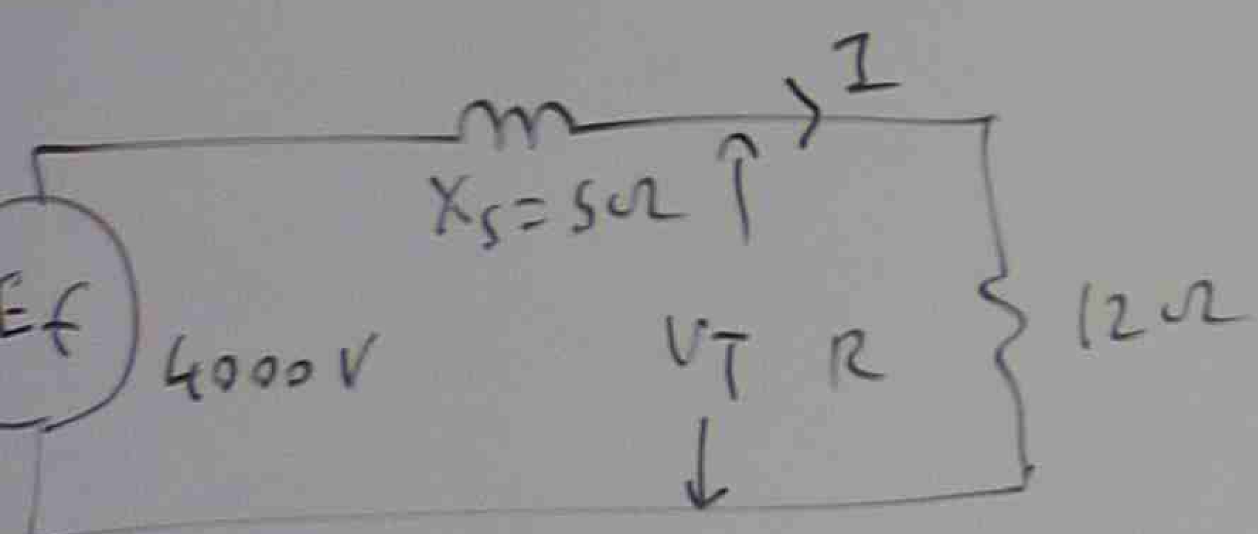
(d) THE TOTAL FULL LOAD COPPER LOSS

$R \simeq 0$

$X_s \simeq Z_S$

$$X_s = Z_s = \frac{E_f\,(ph)}{I_{\text{SHORT CIRCUIT}}}$$

$$= \frac{4000}{800} = 5\Omega$$



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(d) THE TOTAL FULL LOAD COPPER LOSS

$$\text{BASE IMPEDANCE} = \frac{(\text{BASE VOLTAGE PER PHASE})^2}{\text{BASE POWER PER PHASE}}$$

$$\text{ACTUAL IMPEDANCE} = \underset{(\text{P.U})}{\text{PER UNIT VALUE}} \times \text{BASE IMPEDANCE}$$

PER UNIT

(a) $V_{BASE/ph} = \dfrac{15000}{\sqrt{3}} = 8660\,V$

$P_{BASE/ph} = \dfrac{30\ MVA}{3} = 10\ MVA$

BASE Z = $\dfrac{E_{B(ph)}^2}{P_{BASE/ph}} = \dfrac{8660^2}{10 \times 10^6} = 7.5\,\Omega$

(BASE IMPEDANCE)

(b) SYNCHRONOUS REACTANCE ACTUAL VALUE $= X_{ACTUAL} = P.u(X) \times$ BASE Z

$= 1.2 \times 7.5 = 9\,\Omega$

(c) R_{ACTUAL} = AC RESISTANCE ACTUAL VALUE $= P.u(R) \times$ BASE Z

$= 0.02 \times 7.5 = 0.15\,\Omega$

(d) $\boxed{\text{Full LOAD COPPER LOSS } (1\phi) = (I_{pu})^2 \times R_{pu.} \times P_{BASE/ph}}$

$= 1^2 \times 0.02 \times 10\ MVA = 0.2\ MW$

$= 0.2 \times 10^3$

$= 200\ kW$

Full LOAD COPPER LOSS $3\phi = 3 \times 200 = 600\ kW$

(a)

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(d) $\boxed{\text{Full load copper loss } (1\phi) = (I_{pu})^2 \times R_{pu.} \times P_{BASE/ph}}$

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$= 0.2 \times 10^3$

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Full load copper loss $3\phi = 3 \times 200 = 600\ kW$

(a) A 36
REACTA
THE NO L
IF THE
21 KV
DRAW
(a) NO
LOAD
$E_0 =$
$E_f =$
(a) NO

7.5Ω

ASE Z

9Ω

Z

0.15Ω

pu. × P_{BASE}/ph

× 10 MVA = 0.2 MW

$= 0.2 \times 10^3$

= 200 kW

(a) A 36 MVA, 20.8 kV, 3φ ALTERNATOR HAS A SYNCHRONOUS REACTANCE OF 9Ω AND A NOMINAL CURRENT 1 KA.

THE NO LOAD SATURATION CURVE SHOWS Ef.

IF THE EXCITATION FOR TERMINAL VOLTAGE IS FIXED AT 21 KV. CALCULATE THE EXCITING CURRENT REQUIRED AND DRAW THE PHASOR DIAGRAM FOR THE FOLLOWING CONDITIONS.

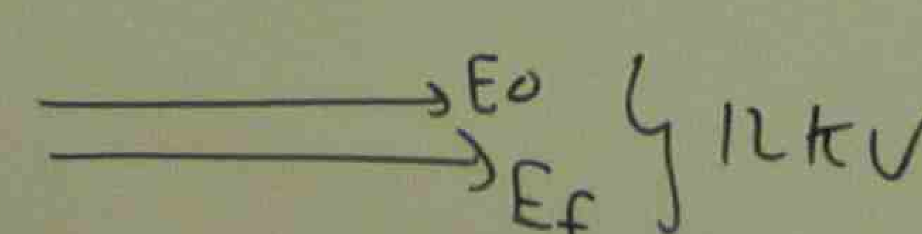
(a) NO LOAD (b) RESISTIVE LOAD OF 36 MW (c) CAPACITIVE LOAD OF 12 MVAR

E_o = NO LOAD TERMINAL VOLTAGE (LINE TO LINE)

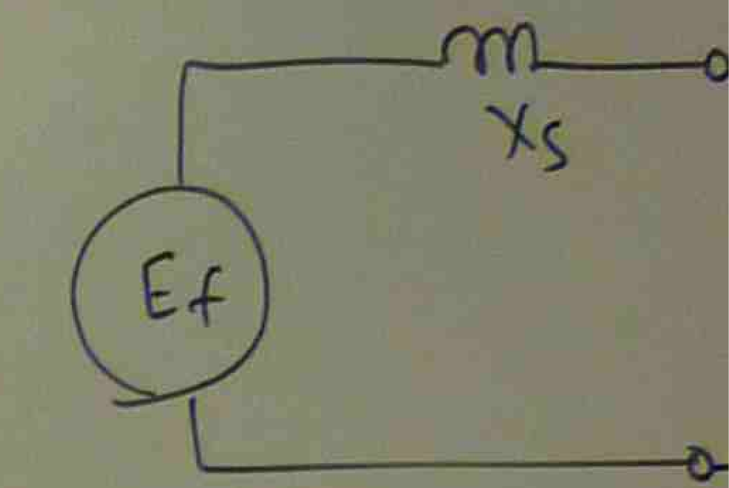
E_f = GENERATED VOLTAGE

(a) NO LOAD

$$E_{f(ph)} = E_{o(ph)} = \frac{20.8}{\sqrt{3}} = 12 \text{ kV}/ph$$



(b)

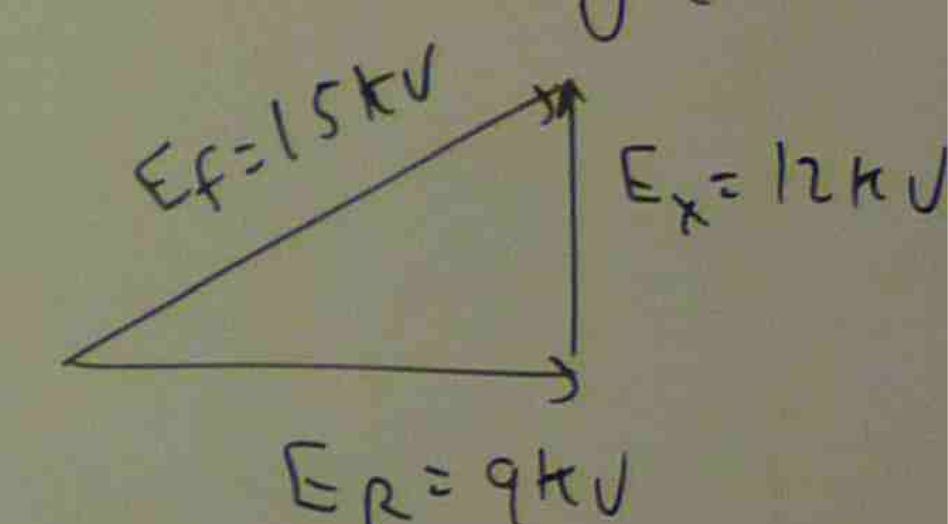


$I_{ph} = \frac{\text{POWER}}{\text{VOLT}}$

$E_F = \sqrt{(I_{ph} \times R}$

$= \sqrt{(1000 \times 9}$

$= \sqrt{(9kV)}$



ALTERNATOR HAS A SYNCHRONOUS

A NOMINAL CURRENT 1 KA.

VE SHOWS Ef.

RMINAL VOLTAGE IS FIXED AT

XCITING CURRENT REQUIRED AND

FOR THE FOLLOWING CONDITIONS.

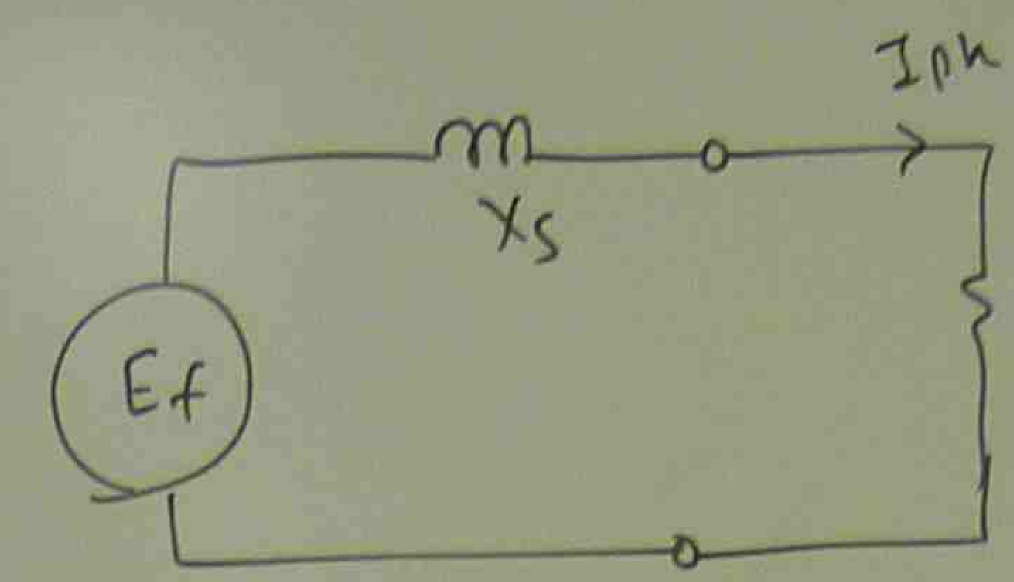
LOAD OF 36 MW (c) CAPACITIVE

AL VOLTAGE (LINE TO LINE)

$\frac{20.8}{\sqrt{3}} = 12\ kV\ /ph$

V

(b)



RESISTIVE LOAD $3\phi = 36\,MW$

POWER PER PHASE $= \frac{36}{3} = 12\,MW$

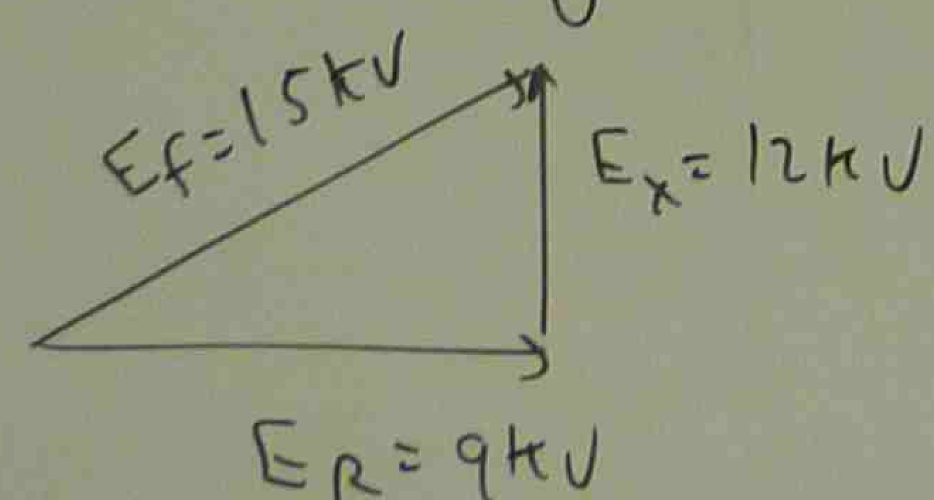
$$I_{ph} = \frac{\text{POWER PER PHASE}}{\text{VOLTAGE PER PHASE}} = \frac{12 \times 10^6}{12 \times 10^3} = 1000\ A$$

$$E_F = \sqrt{(I_{ph} \times R_{ph})^2 + (I_{ph} \times X_{ph})^2}$$

TERMINAL VOLTAGE

$$= \sqrt{(1000 \times 9)^2 + (12\,kV)^2}$$

$$= \sqrt{(9\,kV)^2 + (12\,kV)^2} = \sqrt{9^2 + 12^2}\ kV = 15\ kV$$



(c) CAPACITIVE

SINGLE PHASE

CAPACITIVE CU

Iph

$E_x =$

$E_x = 3\,k$

I_{ph}

RESISTIVE LOAD $3\phi = 36\,MW$

POWER PER PHASE $= \frac{36}{3} = 12\,MW$

$\frac{\text{...R PHASE}}{\text{...ER PHASE}} = \frac{12 \times 10^6}{12 \times 10^3} = 1000\,A$

$+ (I_{ph} \times X_{ph})^2$ TERMINAL VOLTAGE

$(12\,kV)^2$

$(12\,kV)^2 = \sqrt{9^2 + 12^2}\,kV = 15\,kV$

(c) CAPACITIVE LOAD $= 12\,MVAR\ 3\phi$

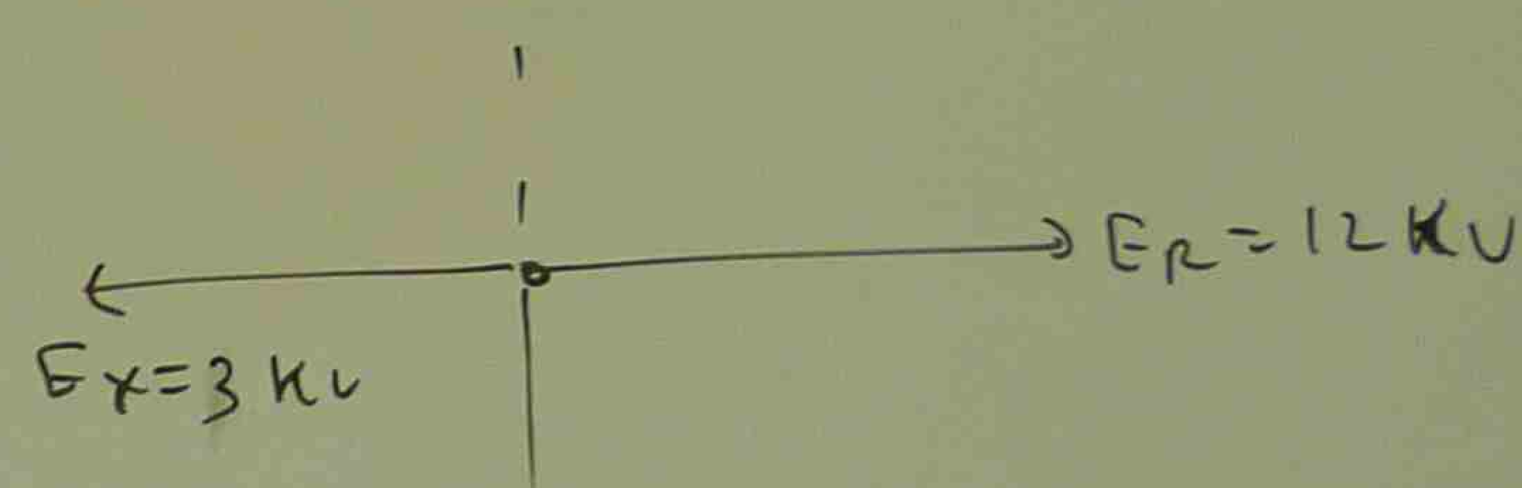
SINGLE PHASE CAPACITIVE LOAD $= \frac{12}{3} = 4\,MVAR$

Q_{ph}

CAPACITIVE CURRENT $I_{ph} = \frac{Q_{ph}}{E_{ph}} = \frac{4\,MVAR}{12\,kV} = \frac{4 \times 10^6}{12 \times 10^3}$

$I_{ph} = 333$ Amp

$E_x = I \times X = \frac{333 \times 9}{1000} = 3\,kV$



$E_T = E_R - E_x = 12 - 3 = 9\,kV$

(10) A 36 MVA, 21...

IF THE EXCITING...

CALCULATE THE FO...

(a) THE ACTIVE P...

(b) THE PEAK P...

(a) $X_s = 9\,\Omega$

$P_{1\phi} = \frac{E_s \ldots}{\ldots}$

$= \frac{10\ldots}{\ldots}$

$=$

$P_{(3\phi)} = 3 \times 6\ldots$

(10) A 36 MVA, 21 kV, 1800 rpm, 3ϕ GENERATOR CONNECTED TO A POWER GRID HAS A SYNCHRONOUS REACTANCE OF 9Ω / PHASE. IF THE EXCITING VOLTAGE IS 12 kV (LINE TO NEUTRAL) AND THE SYSTEM VOLTAGE IS 17.3 kV (LINE TO LINE).

CALCULATE THE FOLLOWINGS

(a) THE ACTIVE POWER WHICH THE MACHINE DELIVERS WHEN THE TORQUE ANGLE IS 30° (ELECTRICAL)

(b) THE PEAK POWER THAT THE GENERATOR CAN DELIVER BEFORE IT FALLS OUT OF STEP (LOSE SYNCHRONISM)

(a) $X_s = 9\Omega$, $E_{o\,ph} = \frac{21\,kV}{\sqrt{3}} = 12\,kV$

$$E_{syst\,ph} = \frac{17.3\,kV}{\sqrt{3}} = \frac{17.3}{1.7321} = 10\,kV$$

$$\boxed{P_{1\phi} = \frac{E_{syst(ph)} \times E_{o(ph)}}{X_s} \sin\delta}$$

$$= \frac{10 \times 12}{9} \sin 30$$

$$= 6.67\,mW$$

$$P_{(3\phi)} = 3 \times 6.67 = 20\,mW$$

(b)

$$P_{max(ph)} = \frac{E_{syst} \times E_{o\,ph}}{X_s} \sin 90°$$

$$= \frac{10 \times 12}{9}$$

$$= \frac{120}{9} = 13.33\,mW$$

$$P_{max\,3\phi} = 3 \times 13.33 = 40\,mW$$

AR

$= \frac{4 \times 10^6}{12 \times 10^3}$

$= 333$ Amp

3 kV

V

$= 9\,kV$

(8) A SY

OF O

CALC

(a)

(b)

(c)

(d