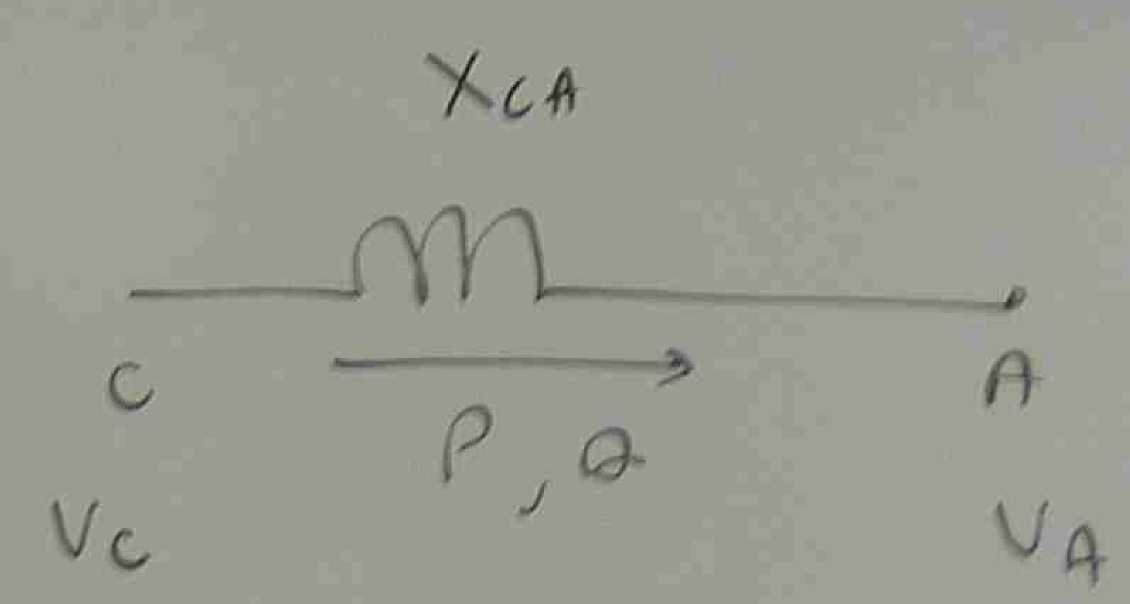
VOLTAGE & POWER FLOW RELATIONSHIP



V_A = VOLTAGE AT POINT (A) (RECEIVING END VOLTAGE)

V_C = VOLTAGE AT POINT (C) (SENDING END VOLTAGE)

X_{CA} = INDUCTIVE REACTANCE BETWEEN A & C

P = ACTIVE POWER FLOW FROM C TO A (WATT)

Q = REACTIVE POWER FLOW FROM C TO A (VAR)

$$V_C = \sqrt{\left(V_A + \frac{Q\,X_{CA}}{V_A}\right)^2 + \left(\frac{P\,X_{CA}}{V_A}\right)^2}$$

G END VOLTAGE)

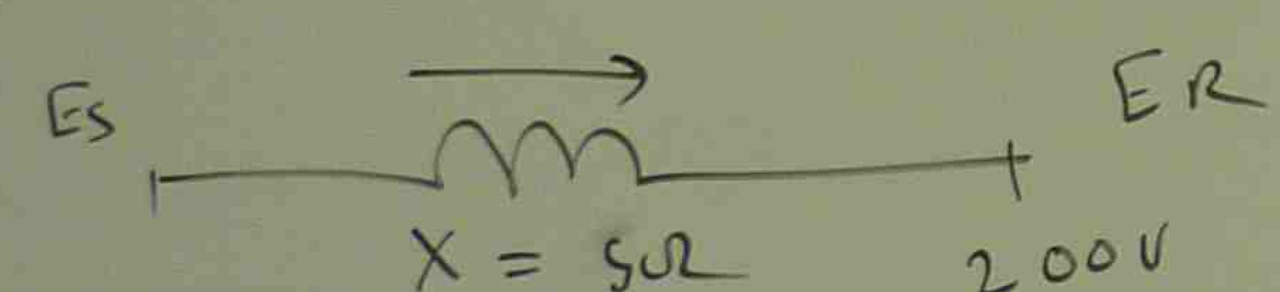
END VOLTAGE)

& C

A (WATT)

TO A (VAR)

Pb



P = 1000 WATT

Q = 500 VAR

FIND ES

$$E_S = \sqrt{\left(E_R + \frac{Q\,X}{E_R}\right)^2 + \left(\frac{P\,X}{E_R}\right)^2}$$

$$E_S = \sqrt{\left(200 + \frac{500 \times 5}{200}\right)^2 + \left(\frac{1000 \times 5}{200}\right)^2}$$

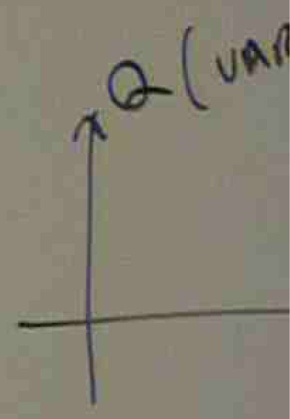
$$= \sqrt{(200 + 12.5)^2 + (25)^2}$$

$$= \sqrt{212.5^2 + 25^2}$$

$$= 213.9\,V$$

P = AC

Q =



POWER

ACTIVE PO

IN

REACT

$$\left(\frac{\ \ x_{CA}}{VA}\right)^2$$

$$\left(\frac{PX}{ER}\right)^2$$

$$E_S = \sqrt{\left(200 + \frac{500 \times 5}{200}\right)^2 + \left(\frac{1000 \times 5}{200}\right)^2}$$

$$= \sqrt{(200 + 12.5)^2 + (25)^2}$$

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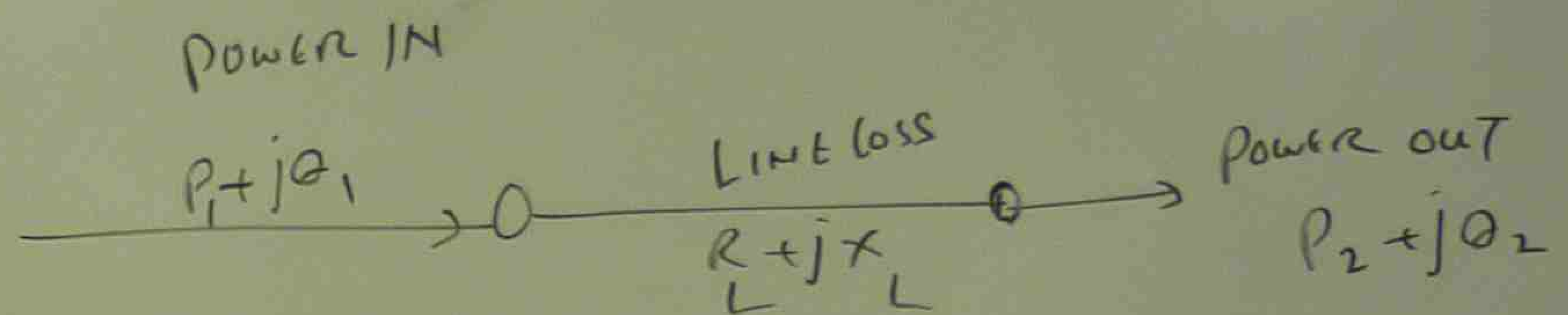
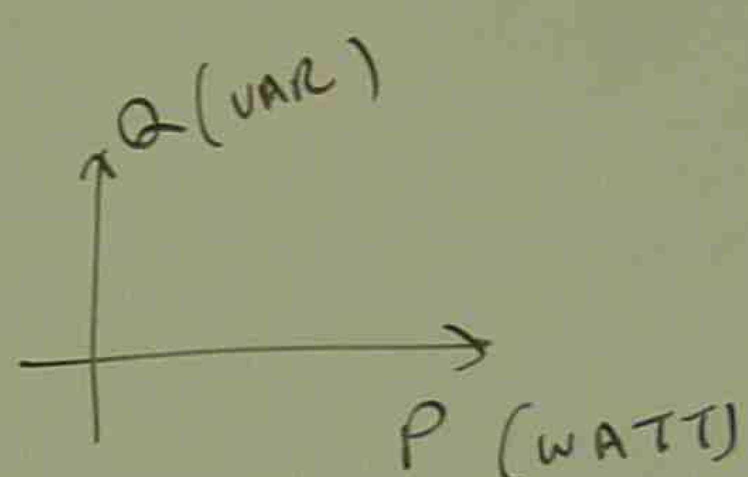


P = ACTIVE POWER

Q = REACTIVE POWER



R_L = LINE RESISTANCE

X_L = LINE INDUCTIVE REACTANCE

I = LINE CURRENT

POWER IN = POWER OUT + LINE LOSS

ACTIVE POWER INPUT = ACTIVE POWER OUTPUT + ACTIVE POWER LOSS

$$P_1 = P_2 + I^2 R$$

REACTIVE POWER INPUT = REACTIVE POWER OUTPUT + REACTIVE POWER LOSS

$$Q_1 = Q_2 + I^2 X$$

LINE C

ph

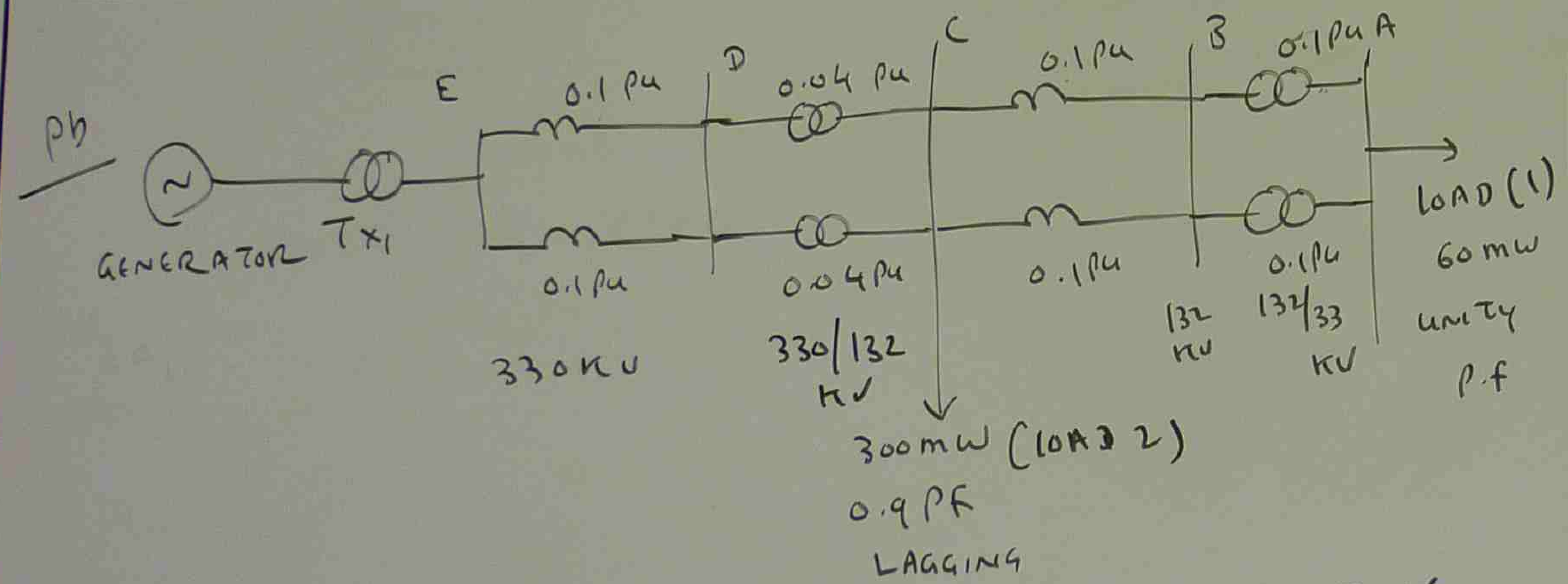
GENERATO

FIND

$I(P$

LINE CURRENT = $\dfrac{\text{ACTIVE POWER LOSS} + j\ \text{REACTIVE POWER LOSS}}{\text{RECEIVING END VOLTAGE}}$

$= \dfrac{\sqrt{(\text{ACTIVE POWER (LOSS)})^2 + (\text{REACTIVE POWER LOSS})^2}}{\text{RECEIVING END VOLTAGE}}$



FIND (a) GENERATOR VOLTAGE (b) ACTIVE & REACTIVE POWER SUPPLIED BY GENERATOR

$$Z(pu) = \frac{Z(\Omega) \times \text{BASE VA}}{(\text{BASE VOLTAGE})^2}$$

BASE = 100 MW ⟶ 1 pu

LOAD POWER = 0.6 pu UNITY PF

↓

$\cos\theta = 1$

$\theta = 0$

$\sin\theta = 0$

LOAD ACTIVE POWER = 0.6 pu

LOAD REACTIVE POWER = LOAD ACTIVE POWER $\tan\theta$

$= 0.6 \tan 0$

$= 0$

LOAD (2) AT (C) POINT

PF = 0.9 LAGGING

$\cos\theta = 0.9 \rightarrow \theta = \cos^{-1} 0.9 = 26$

LOAD (2) ACTIVE POWER = 3 pu

REACTIVE POWER = $3 \tan 26$

$= 1.46$ p.u

BASE = 100 MW ⟶ 1 pu

LOAD POWER = 0.6 pu UNITY PF

↓

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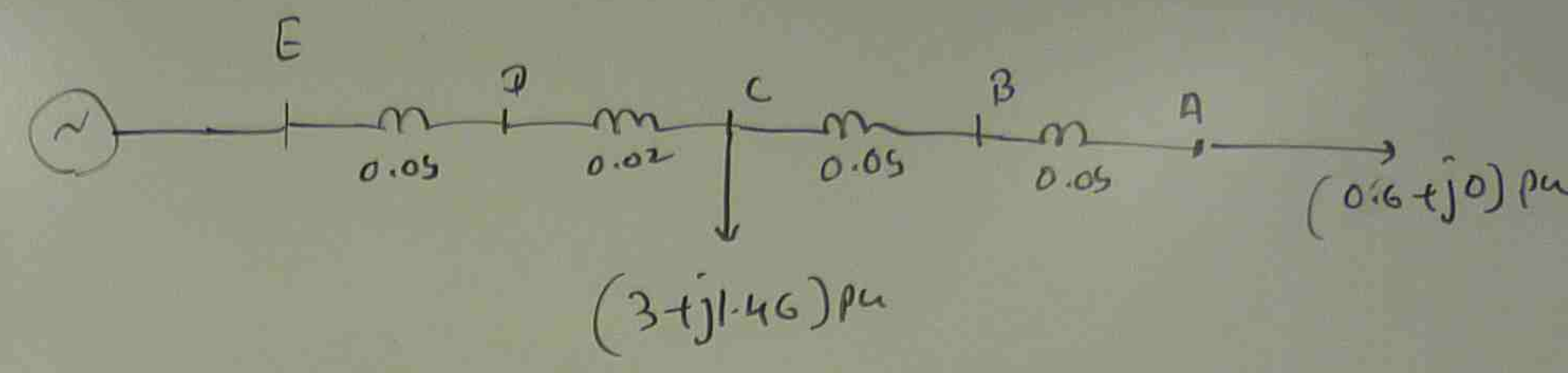
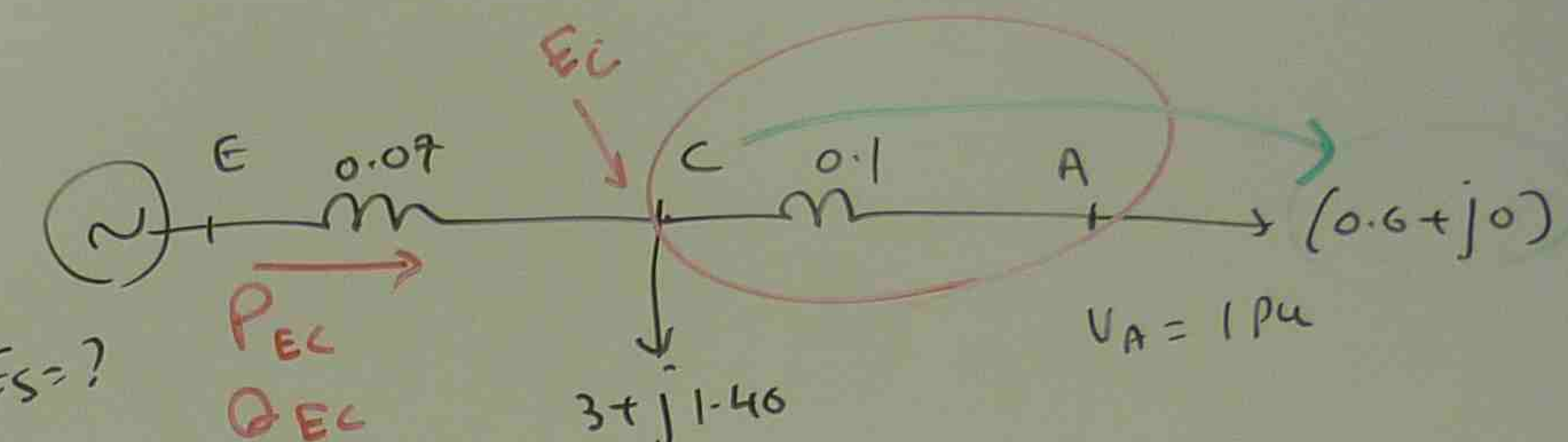




$$E_C = \sqrt{\left(V_A + \frac{Q_{C\to A} X_{CA}}{V_A}\right)^2 + \left(\frac{P_{C\to A} X_{CA}}{V_A}\right)^2}$$

$V_A = 1$ pu $\quad X_{CA} = 0.1$ pu $\quad P_{CA} = 0.6, \; Q_{CA} = 0$

$$E_C = \sqrt{\left(1 + \frac{0 \times 0.1}{1}\right)^2 + \left(\frac{0.6 \times 0.1}{1}\right)^2}$$

$$= \sqrt{1^2 + (0.06)^2}$$

$$= \sqrt{1 + 3.6 \times 10^{-3}} = \sqrt{1.0036} = 1.001$$

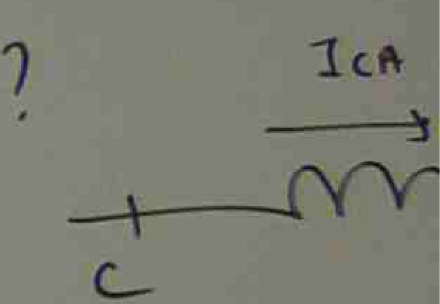
$E_S = \sqrt{\left(E_C + \frac{Q_{EC} X_{EC}}{E_C}\right. \ldots}$ [illegible]

$E_C = 1.001$ pu $\quad X_{EC}$ [illegible]

$P_{EC} = P_{CA} + I$ [illegible]

$Q_{EC} = Q_{CA} + I$ [illegible]

$I_{CA} = ?$

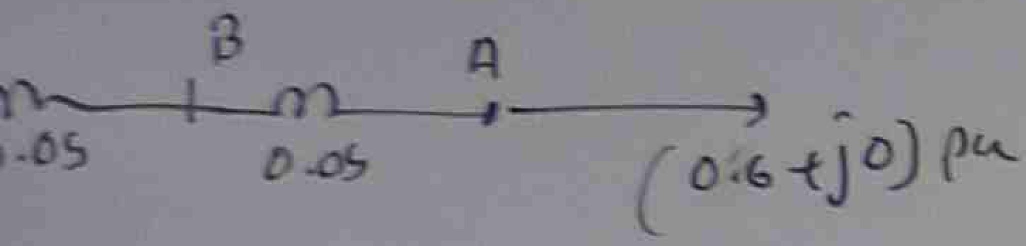


$I_{CA} = \sqrt{\frac{0.6^2 + 0 \ldots}{1}}$

$P_{EC} = P_{CA} + I_{CA}^2 R$ [illegible]

$Q_{EC} = Q_{CA} + I_{CA}^2$ [illegible]

$E_S = \sqrt{\left(1.001 + \frac{1.4 \ldots}{}\right.}$ [illegible]



pu

A

(0.6+j0)

$V_A = 1\,pu$

$$+ \left(\frac{P_{C\to A} X_{CA}}{V_A}\right)^2$$

$P_{CA} = 0.6$, $Q_{CA} = 0$

$$\left(\frac{6 \times 0.1}{1}\right)^2$$

$s = 1.001$

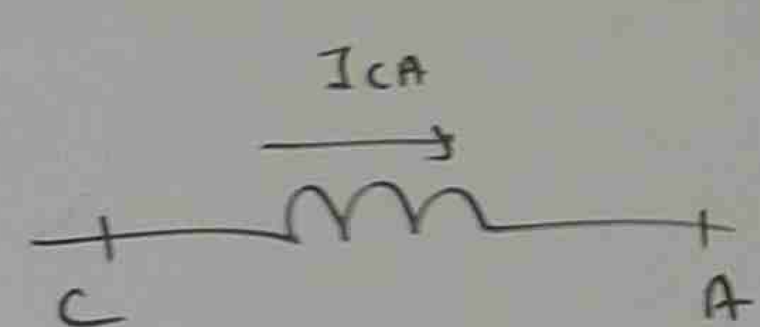
$$E_S = \sqrt{\left(E_C + \frac{Q_{EC} X_{EC}}{E_C}\right)^2 + \left(\frac{P_{EC} \times X_{EC}}{E_C}\right)^2}$$

$E_C = 1.001\,pu$ $\quad X_{EC} = 0.07$, $P_{EC} = ?$, $Q_{EC} = ?$

$$P_{EC} = P_{CA} + I_{CA}^2 R_{CA} + P_C$$

$$Q_{EC} = Q_{CA} + I_{CA}^2 X_{CA} + Q_C$$

$I_{CA} = ?$



$$I_{CA} = \frac{\sqrt{(\text{ACTIVE POWER LOSS } C-A)^2 + (\text{REACTIVE POWER LOSS } C-A)^2}}{V_A}$$

$$I_{CA} = \frac{\sqrt{0.6^2 + 0^2}}{1} = \frac{\sqrt{0.6^2}}{1} = 0.6\,pu$$

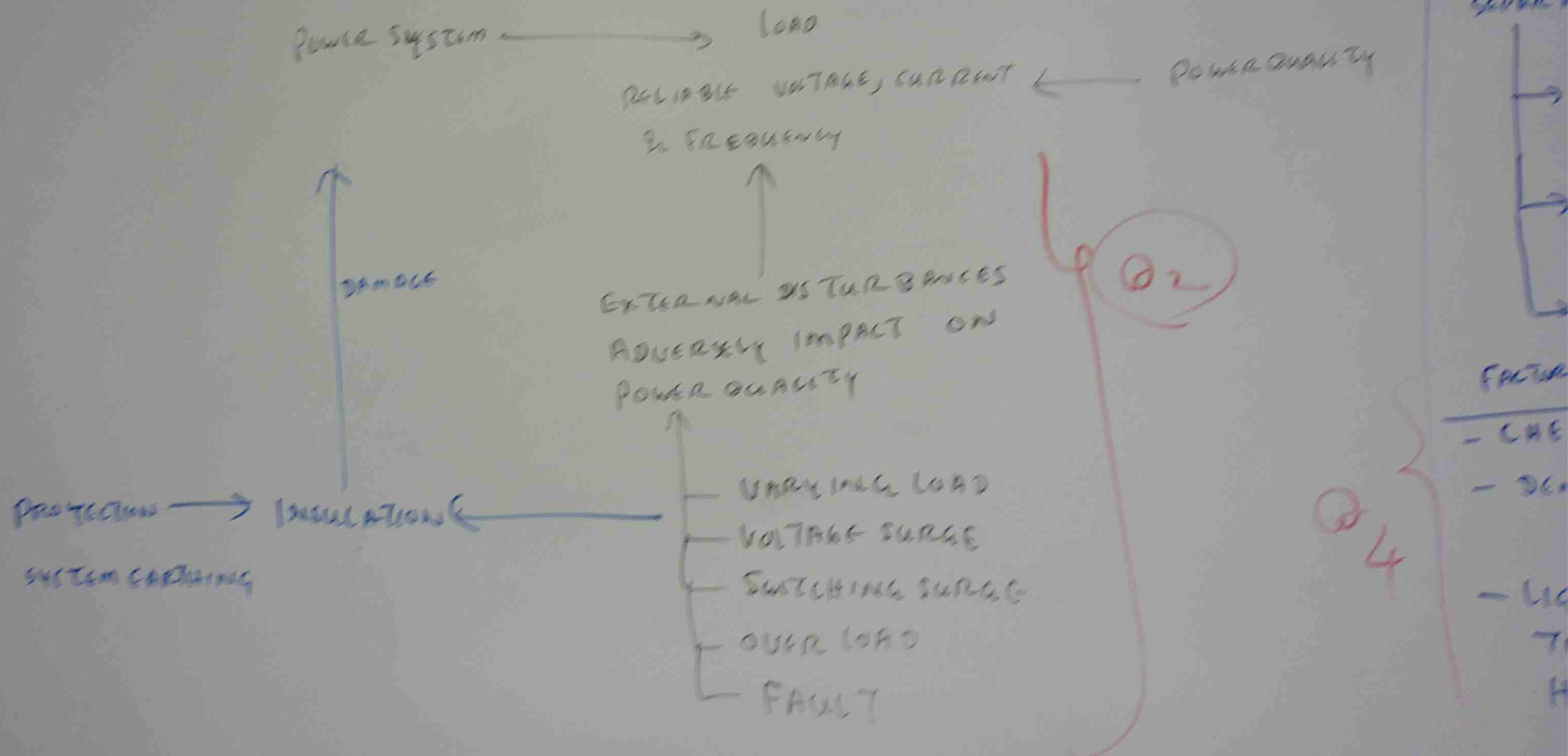
$$P_{EC} = P_{CA} + I_{CA}^2 R_{CA} + P_C = 0.6 + (0.6)^2 \times 0 + 3 = 3.6$$

$$Q_{EC} = Q_{CA} + I_{CA}^2 X_{CA} + Q_C = 0 + (0.6)^2 \times 0.1 + 1.46 = 0.036 + 1.46 = 1.496\,pu$$

$$E_S = \sqrt{\left(1.001 + \frac{1.496 \times 0.07}{1.001}\right)^2 + \left(\frac{3.6 \times 0.07}{1.001}\right)^2} = \sqrt{(1.001 + 0.1046)^2 + (0.251)^2}$$

$$= \sqrt{1.11^2 + 0.251^2} = \sqrt{1.3005} = 1.14\,pu$$

G037 + G038 + G039 SUPPLEMENTARY NOTES



SUPPLEMENTARY NOTES

...OAD

...VOLTAGE, CURRENT ← POWER QUALITY

...ENCY

...DISTURBANCES

IMPACT ON

...ALITY

...RYING LOAD

...LTAGE SURGE

...TCHING SURGE

...SER LOAD

FAULT

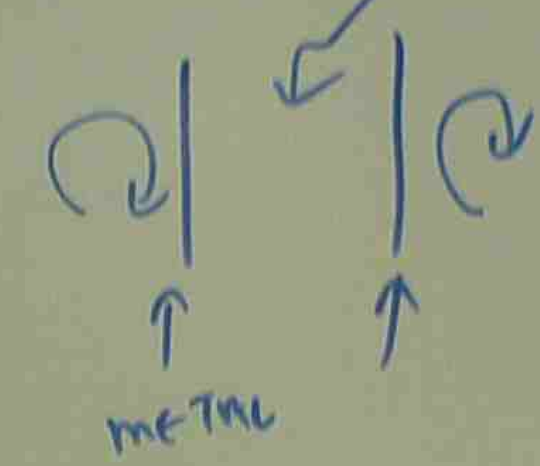
Q2

INSULATION

INSULATION IS REQUIRED TO KEEP ELECTRICAL CONDUCTORS SEPARATED FROM EACH OTHER.

Q3

- → CAPACITANCE
- → SURFACE LEAKAGE CURRENT
- → ELECTRIC HYSTERESIS



FACTORS THAT DETEORATE THE INSULATION

- CHEMICAL IMPACT
- DENSITY DECREASES → DOWNGRADE THE QUALITY OF GASEOUS INSULATION
- LIGHTNING
  TRAVELLING VOLTAGE SURGE
  HARMONIC

SF_6

Q4

TO PROTECT THE ...

FOLLOWING ACTIONS ...

(1) INVESTIGA...

AND PRO...

Q5

(2) PROTECT ...

(3) STUDY T...

OF INSUL...

INSULATI...

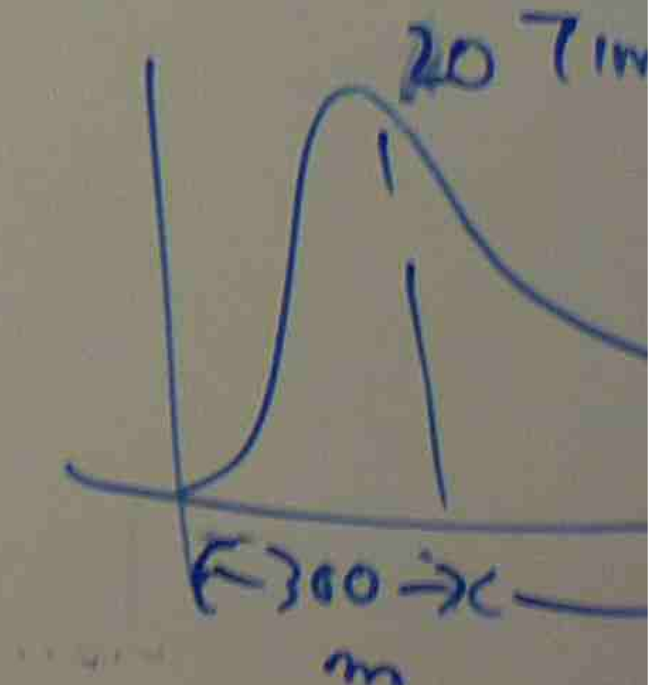
REFORCEM...

(4) PROVIDE ...

AND ...

LIGHTNING STR...

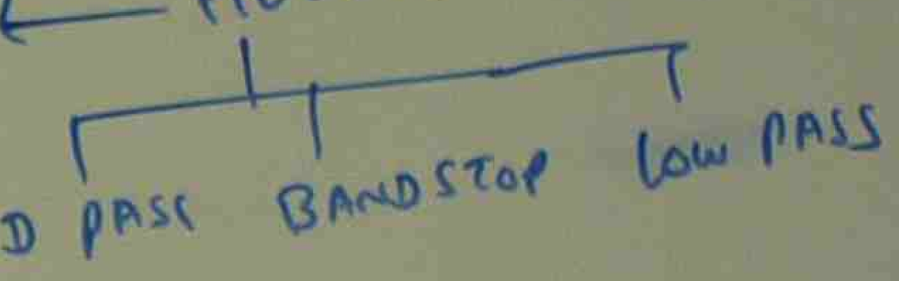
INSULATION



To protect the insulation from external damaging impacts, the following actions are required

(1) Investigate the source of electrical interferences and provide appropriate shielding (or) protection

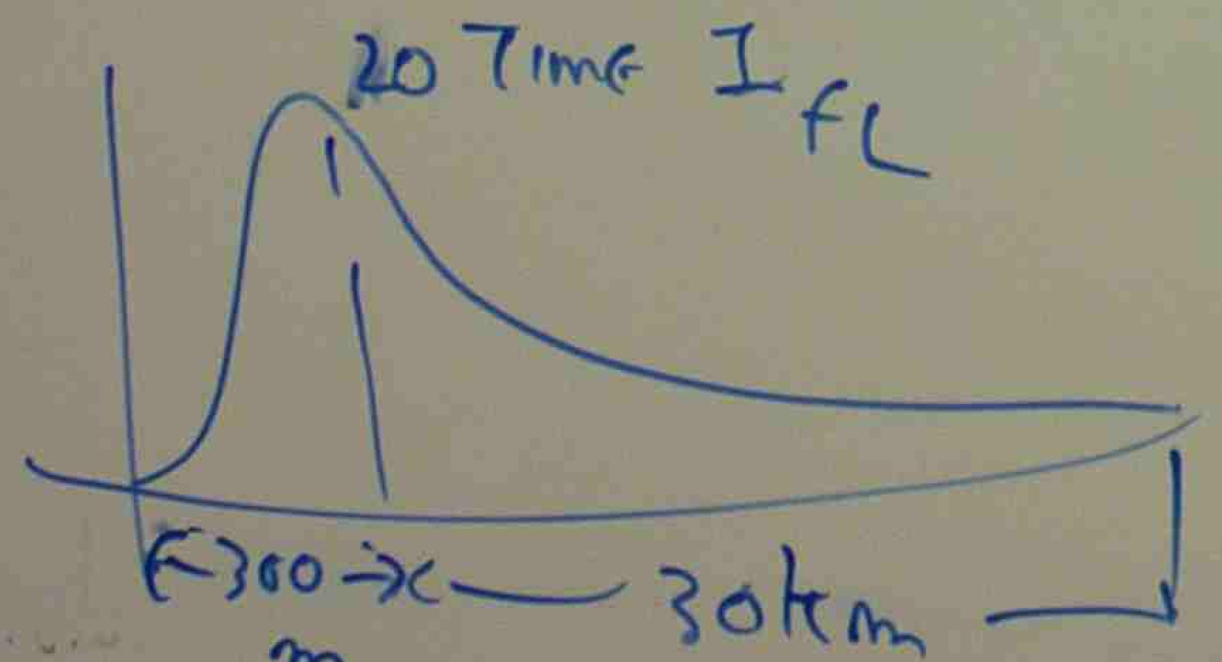
(2) Protect from travelling wave form | Harmonic protection ← Switching power supplies ← Filter

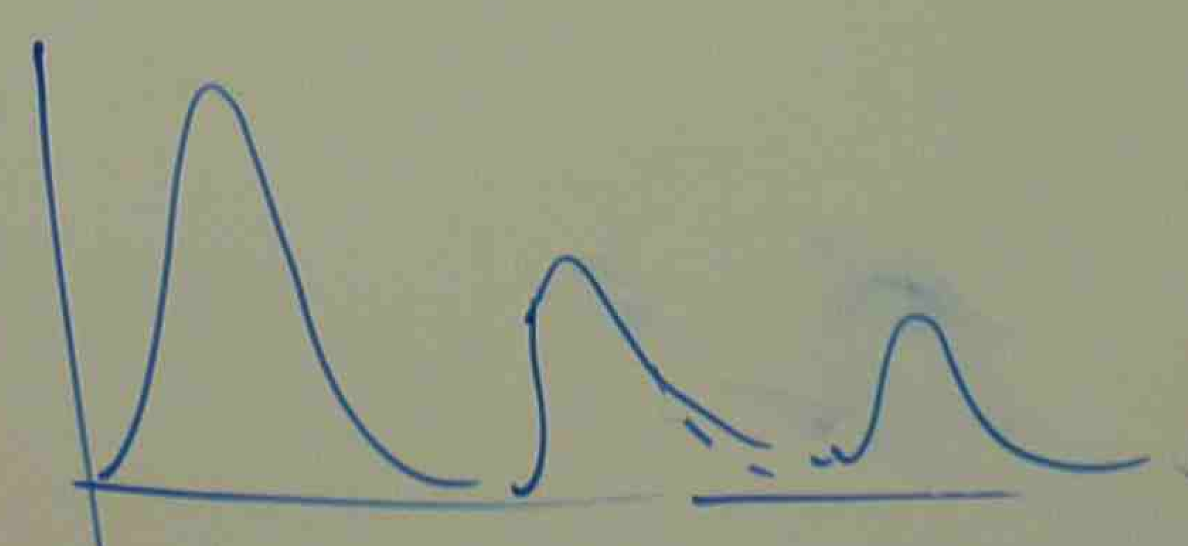


(3) Study the break down volt-time characteristics of insulation & find out the early signs of insulation deteoriation. Provide appropriate reforcement

(4) Provide appropriate protection for chemical and leakage.

Lightning strikes can severely damage the insulation





The insulation must posses the capacity to withstand the abnormal peak voltage for first a few second.

AS 1768-1991

Insulation must comply with AS1768 wave form standard

Switching m

The switchin
appropriate
surges

Q1 What
Power
Frequ

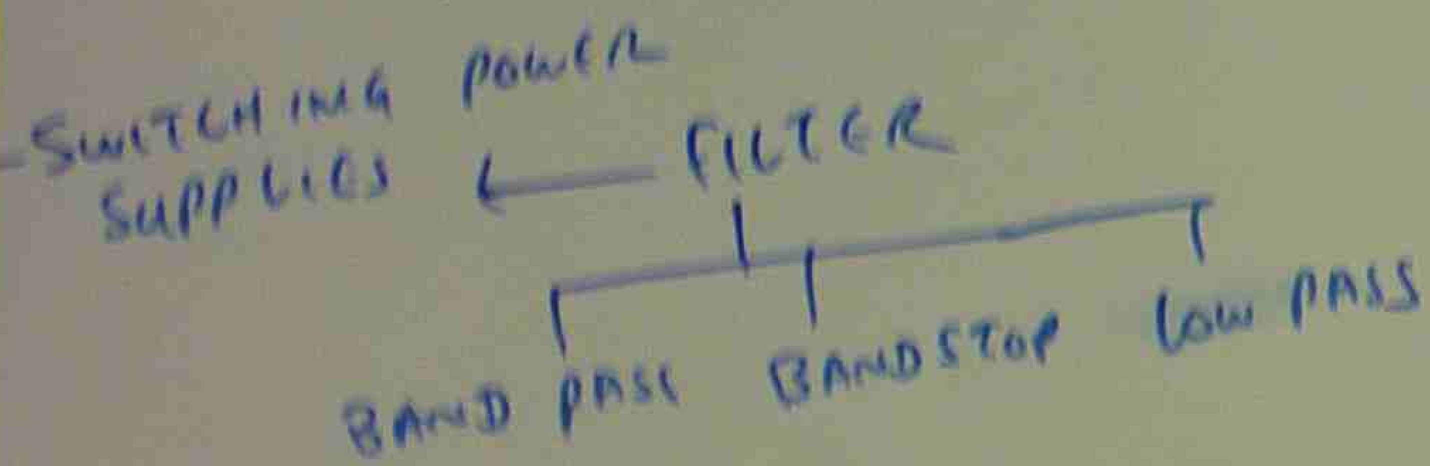
Q2 What

Q3

Q4

Q5

SF6



THE INSULATION MUST POSSES THE CAPACITY TO WITHSTAND THE ABNORMAL PEAK VOLTAGE FOR FIRST A FEW SECOND.

AS 1768-1991

INSULATION MUST COMPLY WITH AS1768 WAVEFORM STANDARD

SWITCHING MODE POWER SUPPLIES

THE SWITCHING POWER SUPPLIES CAN PRODUCE THE SWITCHING SURGES. APPROPRIATE FILTER MUST BE UTILIZED TO REMOVE THE SWITCHING SURGES

Q1 WHAT IS POWER QUALITY?

POWER QUALITY IS RELIABLE VOLTAGE, CURRENT AND FREQUENCY OF POWER SYSTEM

Q2 WHAT FACTORS CAN DAMAGE THE POWER QUALITY?

Q3 WHAT IS INSULATION?

Q4 WHAT ARE THE FACTORS THAT CAN DAMAGE INSULATION?

Q5 WHAT ACTIONS ARE REQUIRED TO PROTECT THE INSULATION FROM EXTERNAL DAMAGING IMPACTS

SURGES.

CHING

AND

ALITY ?

MAGE

ROTECT

DAMAGING

SITE EARTHING & SURGE PROTECTION

THE MAIN OBJECTIVES OF SITE EARTHING

Q6

1. TO AVOID PHYSICAL DAMAGE TO BUILDING AND EQUIPMENTS DUE TO DIRECT AND INDIRECT LIGHTNING STRIKES AND SYSTEM FAULT SURGES
2. TO PROVIDE SAFE WORKING ENVIRONMENT FOR PERSONNELS DURING LIGHTNING STRIKE
3. TO PROVIDE SHIELDING AND ALTERNATIVE PATH FOR INDUCED CURRENT TO REDUCE THE EFFECT OF COUPLED NOISE ON ELECTRONIC EQUIPMENTS
4. TO PROVIDE AN EQUIPOTENTIAL PLATFORM ON WHICH ELECTRONIC EQUIPMENTS CAN OPERATE WITHOUT LARGE DIFFERENTIAL VOLTAGE

Q7

- TOUCH VOLTAGE — VOLTAGE BETWEEN EQUIPMENT & EARTH
- STEP VOLTAGE — POTENTIAL DIFFERENCE IN 1m FOOTSTEP
- MESH VOLTAGE — MAXIMUM TOUCH VOLTAGE IN EARTHING GRID

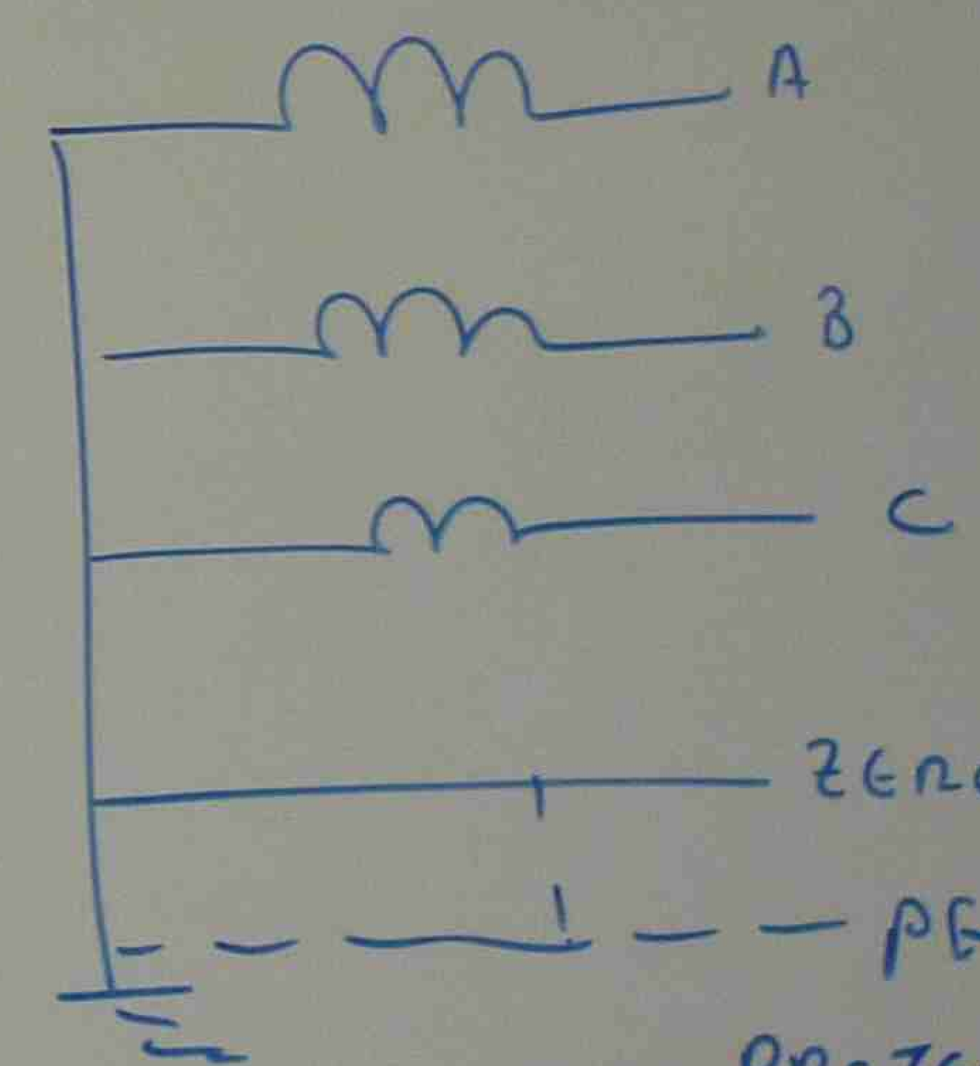
PROTECTIVE EARTH

ALL EXPOSED TERMINALS AT SAME VOLTAGE LEVEL

Q8

FUNCTIONAL EARTH

PROTECTION AGAINST ELECTRIC SHOCK



PROTECTIVE EARTH

Q6 WHAT

of SITE

Q7 EXPLA

STEP

Q8 WHAT

AND

RGE PROTECTION

UES OF SITE EARTHING

DAMAGE TO BUILDING AND EQUIPMENTS
ND INDIRECT LIGHTNING STRIKES AND
ES
WORKING ENVIRONMENT FOR PERSONNELS
G STRIKE
ELDING AND ALTERNATIVE PATH FOR
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ON ELECTRONIC EQUIPMENTS
AN EQUIPOTENTIAL PLATFORM ON
NIC EQUIPMENTS CAN OPERATE
RGE DIFFERENTIAL VOLTAGE

LTAGE — VOLTAGE BETWEEN EQUIPMENT & EARTH

AGE — POTENTIAL DIFFERENCE IN 1 m FOOTSTEP

LTAGE — MAXIMUM TOUCH VOLTAGE IN EARTHING GRID

PROTECTIVE EARTH

ALL EXPOSED TERMINALS AT SAME VOLTAGE LEVEL

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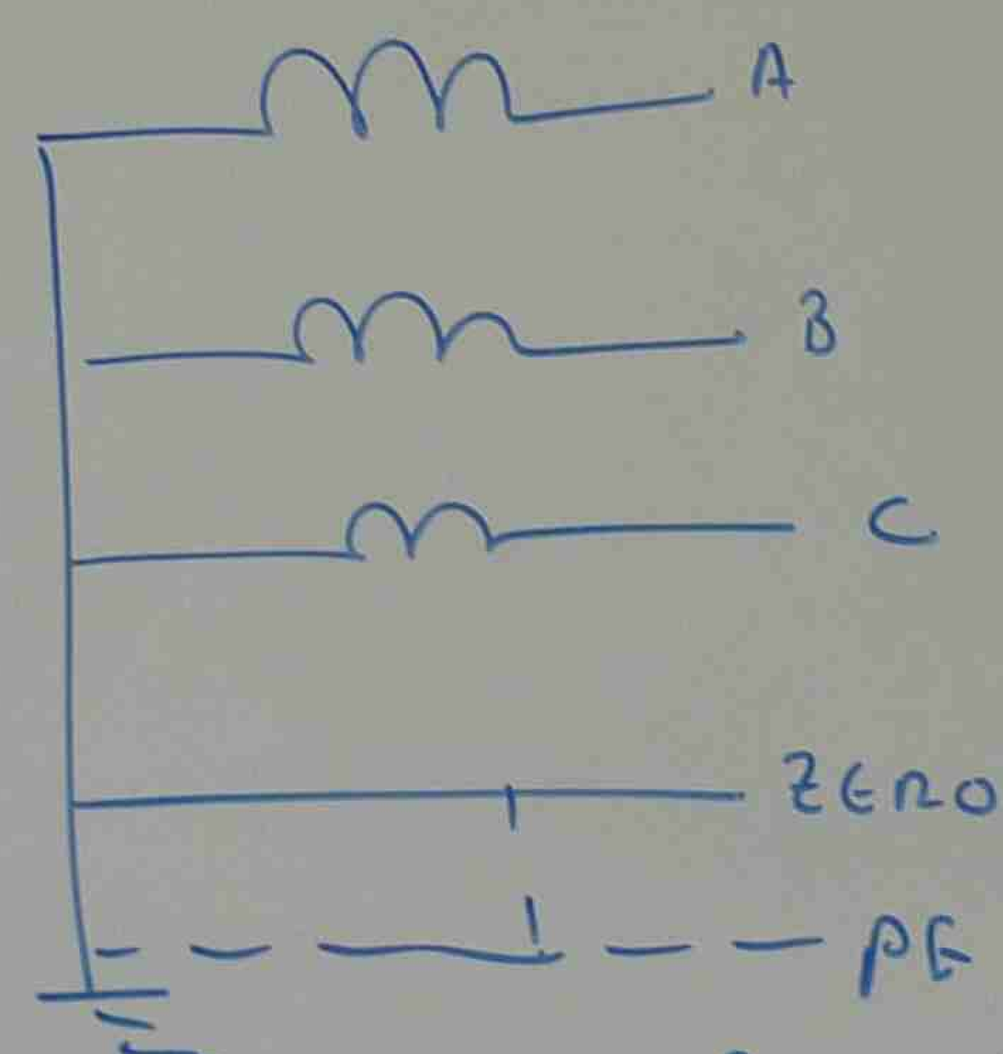
PROTECTION AGAINST ELECTRIC SHOCK



PROTECTIVE EARTH

Q6 WHAT ARE THE MAIN OBJECTIVES OF SITE EARTHING

Q7 EXPLAIN TOUCH VOLTAGE, STEP VOLTAGE, MESH VOLTAGE

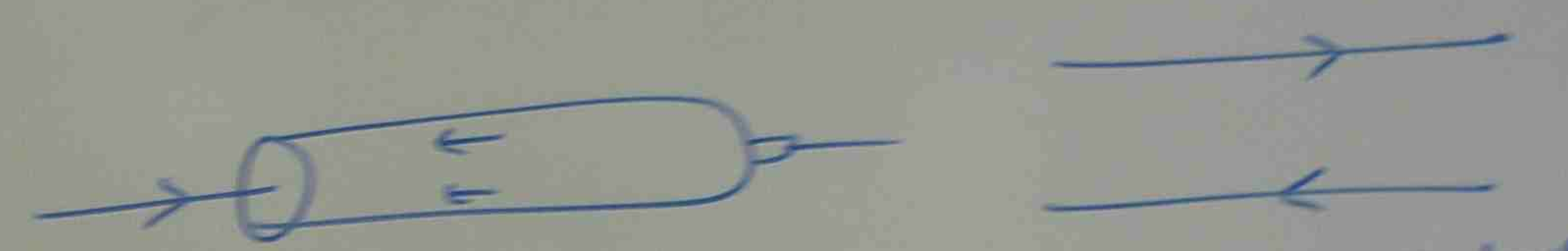
Q8 WHAT IS FUNCTIONAL EARTH AND PROTECTIVE EARTH?

G037

13

COUPLING INTERFERENCE INTO ELECTRICAL SYSTEM

UNBALANCED LINE / CABLE GENERATES INTERFERENCE



INTERFERENCE SIGNAL

- TRANSFER BY COUPLING EFFECT OF CAPACITOR
- PROTECTED BY SHIELDING

$$X_c = \frac{1}{2\pi f C}$$

COUPLING

COUPLING
ONE CIR
MATCH

ELECTRI

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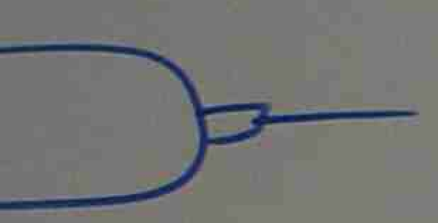
METAL

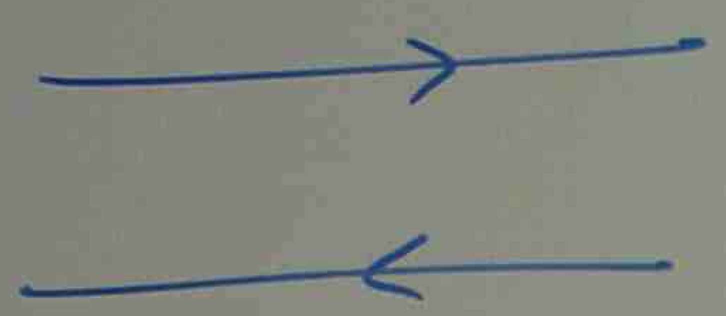
SURGE

- APPL
DEC
- TRA
IN
- ISO
- POW
- GR

...NCE IN TO ELECTRICAL SYSTEM

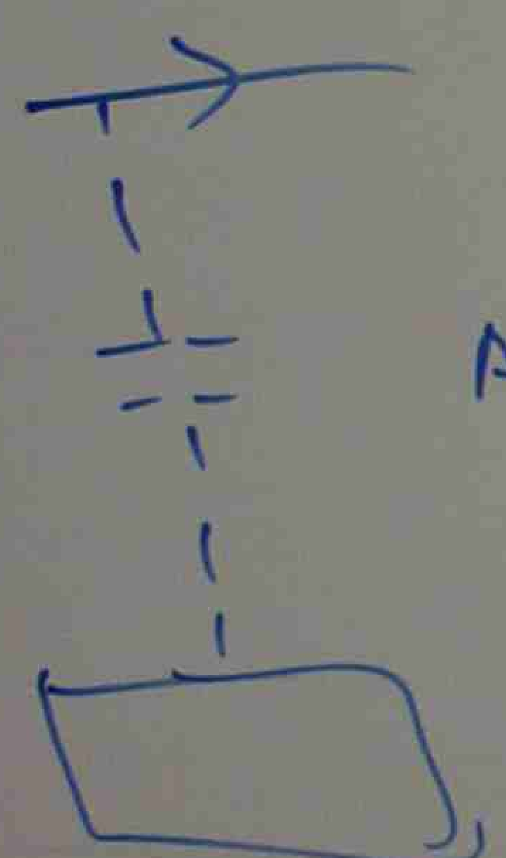
...CE GENERATES INTERFERENCE





...RENCE SIGNAL

PROTECTED BY SHIELDING



$$X_c = \frac{1}{2\pi f C}$$

COUPLING (9)

COUPLING IS TRANSFER OF ELECTRICAL ENERGY FROM ONE CIRCUIT SEGMENT TO ANOTHER. (IMPEDANCE MATCHING).

ELECTRICAL SHIELDING & SURGE PROTECTION (10)

LIGHTNING PROTECTION

COMPOSES OF NETWORK OF LIGHTNING RODS, METAL CONDUCTORS, GROUND ELECTRODES

SURGE PROTECTOR

- APPLIANCE DESIGNED TO PROTECT ELECTRICAL DEVICES FROM VOLTAGE SPIKE.
- TRANSIENT VOLTAGE SURGE SUPPRESSORS ARE USED IN POWERSYSTEM TO PROTECT VOLTAGE SURGE.
- ISOLATION TRANSFORMER
- POWER CONDITIONERS
- UNINTERRUPTIBLE POWERSUPPLY

POOR POW...

POOR POWER...

- DEGRADE...
- DECREASED... AND DIS...
- POOR ...
- INCREAS...

HARMON...

- HIGHER TH...
- CAN CAUS...

From

Q10

TRICAL

ARE USED

SURGE.

POOR POWER FACTOR ← IMPROVED BY

- CAPACITOR BANK
- SYNCHRONOUS MOTOR
- STATIC VAR CONTROL SYSTEM (SVC)

Q11

POOR POWER FACTOR HAS MANY DISADVANTAGES

- DEGRADED EFFICIENCY OF DISTRIBUTION POWER SYSTEM
- DECREASED CAPACITY OF TRANSMISSION, SUB TRANSMISSION AND DISTRIBUTION SYSTEM
- POOR VOLTAGE REGULATION
- INCREASED SYSTEM LOSSES.

HARMONIC

- HIGHER THAN FUNDAMENTAL FREQUENCY
- CAN CAUSE
  - TEMPERATURE RISE ABOVE RATED TEMPERATURE
  - VIBRATION WITH IN MACHINE
  - DECREASED LIFE TIME DUE TO INTERMITTENT OPERATION.
  - HEATING OF EQUIPMENTS & THERMAL AGING

HARMONIC DISTORTION DEPENDS ON

- LEVEL OF HARMONIC GENERATION
- SYSTEM FREQUENCY RESPONSE CHARACTERISTICS

Q12

TOTAL HARMONIC DISTORTION NEEDS TO BE CALCULATED.

- HARMONIC CAN BE CREATED IN TRANSFORMER
- FILTER WILL NEED TO BE USED.

Q9

Q10

Q11

Q12

Q9 WHAT IS COUPLING?

Q10 EXPLAIN ELECTRICAL SHIELDING & SURGE PROTECTION

Q11 WHAT ARE THE DISADVANTAGES OF POOR POWER FACTOR & HOW CAN IT BE IMPROVED?

Q12 WHAT ARE THE DISADVANTAGES OF HARMONIC, HOW IS THE SYSTEM DEPENDENT ON SELF PROTECTION FOR HARMONIC. WHICH METHODS ARE REQUIRED TO BE USED FOR HARMONIC PROTECTION?

Q13 HOW CAN ELECTRICAL INTERFERENCE OCCUR? SKETCH THE DIAGRAM.

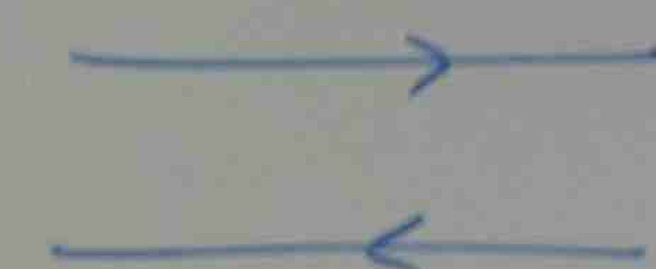
G039

13

COUPLING INTERFERENCE INTO ELECTRICAL SYSTEM

UNBALANCED LINE / CABLE GENERATES INTERFERENCE

UNBALANCED LINE



BALANCED LINE

INTERFERENCE SIGNAL

PROTECTED BY SHIELDING

TRANSFER BY COUPLING EFFECT OF CAPACITOR

$$X_c = \frac{1}{2\pi f c}$$

COUPLING

COUPLING IS T

ONE CIRCUIT

MATCHING).

ELECTRICAL S

LIGHTNING P

COMPOSES OF

METAL CON

SURGE PROT

- APPLIANCE
  DEVICES F
- TRANSIENT
  IN POWER
- ISOLATIO
- POWER CO
- UNINTE