Rheostat → R, variac → V

No: Date: / /

- KCL - algebraic sum of currents at a junction is zero
- KVL - algebraic sum of all voltages (Pd) around a closed loop is zero.

E gen.
- active
  - ideal — (voltage source, I " generators)
  - non-ideal
- passive
  - linear R L C
  - non-linear diode, transistors

I flow → unidirectional pn diode
bidirectional R, CL

		adv	dis adv
hydro	Victorea, Laxapana, Kotmale	• low maintainance cost • fuel cost (free) water	• capital cost ↑ • vulnerable to adverse weather conditions
fuel (coal, oil) (thermal) → steam turbine		• can be situated near source reducing fuel transmission cost	• env. pollution • fuel cost ↑
gas	norochcholi, Kerawalapitiya		
nuclear		high efficiency	• risk of radiation leaks • waste disposal (management) • waste is harmful to env & human
wind	puttalum rural electrification, Hambantota		• not consistent (continuously available)
Solar	"		• high capital cost • low efficiency (20-30%)

power consumption
power loss (heat)
No hum, flickering

Source	prime mover	Alternator
~~tidal~~ water	water (hydro) turbines	mechanical → E
nuclear, coal, oil, gas	steam engines, turbines; IC engines; gas ~~steam~~ turbines	
wind	wind turbines	
solar	photovoltaic cells → solar E	
Fuel cell (chemical E) drives E generator → E		

OTEC (ocean thermal E conv + comp. gas) — Trincomalee, unawatuna — gas turbine coherent unit system → sys of units used to measure physical qts. that are defined s.t. eq^n relating numerical values expressed in units of sys. have exactly same form, including numerical factors, as the corresponding eq^n directly relating qts.

sys units defined using base same form, numerical factors

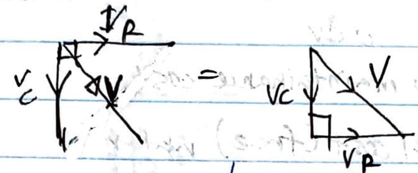
- resistivity vs resistance
- conductivity vs conductance

Peak factor = $\frac{\text{Peak}}{\text{rms}} = \sqrt{2}$

Form factor = $\frac{\text{rms}}{\text{avg}} = 1.111$

- Admittance → S (G, B, R, X all (+)ve
- angular frequency(ω) vs frequency (Hz)

phasor diagram



$S = r\theta$

$A = r^2\theta_{sr}$

- CEB 33 kV, LECO 11 kV } 230V
  LOW

B Ω   8 Ω   10 Ω

$5 + j(+8 - 10) = 5 - j2\ \Omega$

- $\boxed{\nabla^2 V = -\frac{\rho}{\varepsilon}}$ ← Poissons
  ρ – charge density
  ε – permittivity

$\rho = 0$ charge density — Laplace $\boxed{\nabla^2 V = 0}$ } ℓ. potential field is zero in a source free region

$\boxed{C = \frac{\varepsilon A}{d}}$
- ε – abs. permittivity of dielectric mat (F/m)
- A – surface Area of conductive dielectric metal plates
- d – distance between

$Q = CV$

$V = IR$

$V = L\frac{di}{dt}$ → $L = \frac{\phi}{I}$ ⇒ $\phi = kI$

$L = \frac{\phi_B}{i} = \boxed{\frac{N^2 A \mu}{l}}$
- ϕ_B – magnetic flux
- i – current
- N – Number of turns in wire coil
- A – Area of coil
- μ – abs. permeability (H)
- l – length of coil

$\boxed{I = nAvQ}$
- n – # electrons per 1 m^3 charge density (m^{-3})
- A – surface Area of cross section (cross sectional area)
- v – drift velocity
- Q – charge value (e^- charge)

$\boxed{R = \frac{\rho l}{A}}$
- ρ – resistivity – (Ωm)
- l – length of conductor
- A – surface Area of conductor. (cross sectional Area

electricity → type of E, occurs naturally / produced, expressed flow of e^- charge current

AC theory

Peak value = max +/−

- $f_{harmonics} = n \times f_{fundamentals}$ — odd / even

periodic, magnitude ∧ dir changes, alternating +/ ⊖

- leads / lags: $+\phi$, $-\phi$

- $V_{mean} = \dfrac{\int v(t)}{T}$ — +/− one cycle } area with +/−

- $V_{avg} = \dfrac{\int v(t)}{T/2}$ — half (+) cycle or rectified full cycle (area half ×2)

- $V_{rms} = \sqrt{\dfrac{\int v^2(t)}{T}}$

Sinusoid

$V_{mean} = 0$

$V_{avg} = \dfrac{2V_m}{\pi}$

} area under the curve / time

$V_{rms} = \dfrac{V_m}{\sqrt{2}}$

- peak = abs. max — +/− with units

peak − peak val (abs distance)

$\omega = 2\pi f$ $\quad T = \dfrac{1}{f}$

Form factor = $\dfrac{rms}{avg}$

Peak factor = $\dfrac{Peak}{rms}$

- advantages of AC over DC
  - production → economical
  - stepped up & down
  - easily rectified to DC

---

radians in cal

peak values

$v(t) = V_m \cos(\omega t - \theta^\circ)$

$\sin(90 + (\omega t - \theta^\circ))$ (+)ve

$V = 10 \angle 30^\circ$

rms

$V \rightarrow 240V / 50Hz$

* units A, V, Ω, $rads^{-1}$

- polar → $V_{rms} \angle \phi$ → state whether lags / leads w.r.t. I or V

$= V_{rms} e^{j\phi}$

- cartesian → $V_{rms}(\cos\phi + j\sin\phi)$

Impedence $Z = \dfrac{V}{I} = R + jX$ (Ω) — R: resistance, X: reactance

Admittance $Y = \dfrac{1}{Z} = \dfrac{I}{V} = G + jB$ (Ω^{-1}) } S (siemens) — G: conductance, B: susceptance

Resistor

$V = IR$

$Z_R = R + j0$

Inductor (mH keep it)

$V = L\dfrac{di}{dt}$ → slope ↓ cos + 90°

$V_L \Rightarrow Z_L = 0 + j\omega L$

Capacitor (μF keep it)

$Q = CV \Rightarrow \int i = CV$ ↓ sin ↓ −cos

$I = C\dfrac{dV}{dt}$

$V_C \Rightarrow Z_C = 0 - \dfrac{j}{C\omega}$

Z ✓ cartesian

$|Z| = \sqrt{R^2 + X^2} = V$

$\phi = \tan^{-1}\left(\dfrac{V_L}{V_R}\right) = \_\_$

$Z = \_\_ \angle \_\_$

V leads I by ϕ

capacitive / Inductive

series $Z_{eq} = Z_1 + Z_2 + \cdots$

parallel $\dfrac{1}{Z_{eq}} = \dfrac{1}{Z_1} + \dfrac{1}{Z_2} + \cdots$

$Y = \dfrac{1}{R} + \dfrac{1}{j\omega L} + \dfrac{1}{\frac{-j}{\omega C}}$

$= \dfrac{1}{R} + j\left(\dfrac{-1}{\omega L} + \omega C\right)$

$\tan\phi = \dfrac{\omega C - \frac{1}{\omega L}}{1/R}$

R-L series $Z = R + j\omega L$

R-C series $Z = R - \dfrac{j}{\omega C}$

series resonance

L-C series $Z = 0 + j\left(\omega L - \dfrac{1}{\omega C}\right)$

RLC series $Z = R + j\left(\omega L - \dfrac{1}{\omega C}\right)$

series resonance ω_r: $\omega L = \dfrac{1}{\omega C}$

* $Z_{min} \rightarrow I_{max}$

RLC // $Y = \dfrac{1}{R} + j\left(-\omega C + \dfrac{1}{\omega L}\right)$

shunt resonance $\omega C = \dfrac{1}{\omega L}$

* $Z_{max} \rightarrow I_{min}$

R-L parallel $Y = \dfrac{1}{R} + \dfrac{j}{\omega L}$

R-C // $Y = \dfrac{1}{R} - j\omega C$

L-C // $Y = 0 + j\left(-\omega C + \dfrac{1}{\omega L}\right)$

shunt resonance

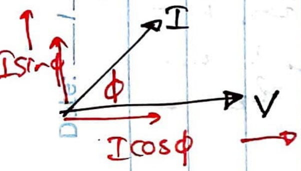
Power factor ($p.f = \cos\phi$) mention leading/lagging w.r.t V

L/C → reactance (X) → reactive power (Q) → var (volt ampere reactive) } no net work done, goes back & forth btw. force

apparent power (S) → VI → VA (volt amperes)

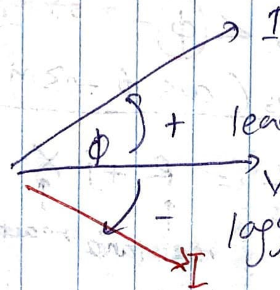
active power (true) (P) → $VI\cos\phi$ → W (watt)

$VI\sin\phi = Q$ (reactive)



$I\cos\phi$ → $P = VI\cos\phi$ (active)

I w.r.t. V



+ leading power factor } mention lagging/leading

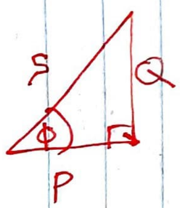
- lagging power factor

high V transmission

$P = IV$ ...

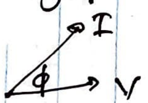
↓loss $= I^2R$

economical



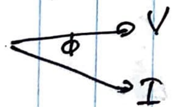
- power factor $= \cos\phi = \frac{P}{S}$

leading power factor



capacitive

lagging power factor



inductive

$\underline{Y} = 0.0154 - j0.0151$

capacitor parallel (pure reactance)

for p.f. → 1 $\phi = 0$ → $\underline{Y}$ = real

then susceptance needed $= +j0.0151$ → capacitive reactance needed $= \frac{1}{j0.0151} = 66.2252\ \Omega$

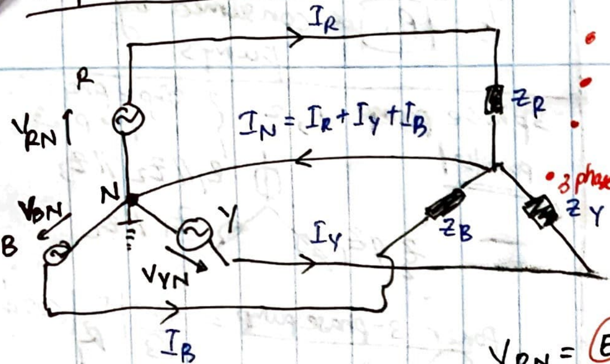
$|C\omega| = 0.0151$

$C =$ ✓

p.f↓ more current drawn from source → wire cost, power loss

more I reqd transfer same P with p.f < 1

3-phase balanced system



- 3 phase
- 4 wires (RYBN)
- Star(Y) connected load
- 3 phase balanced source

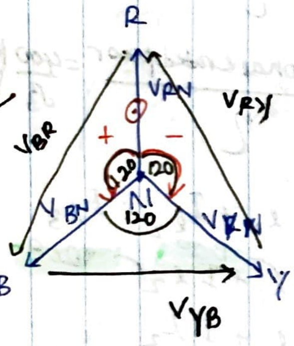
Line / $\sqrt{3}$

$V_{RN} = E\angle 0°$

$V_{YN} = E\angle -120°$

$V_{BN} = E\angle +120°$

phasor diagram balanced



KCL: $I_N = I_R + I_Y + I_B$

$= \frac{E\angle 0°}{Z_R} + \dots$

cvt phase ← lines at load

load balanced $Z_R = Z_Y = Z_B = Z$

$\Rightarrow I_N = 0$ neutral wire is optional

400 230

$V_{line-line} = \sqrt{3}\,|V_{line-neutral}|$

RY, RB, YB — used line voltages

phase voltage: RN, YN, BN

$V_\ell = \sqrt{3}\, V_{phase}$

always line V given — converts to phase

eg: 400V, 50Hz, 22kW, 3-phase motor

400V: line-line V; 22kW: rated output mechanical power

- Why 3 phase needed over single phase? 2V
- Why N needs to be earthed at the source? ref, earth fault

---

[1] line voltage → phase voltage = phase current in star(Y) connected loads

[2] line current $\frac{E}{Z}$ = 92 A (no angles mentioned); Z = load + line losses

- I_N = ? 0 ⇒ no power loss

[3] line loss per phase $= I_{line}^2 R$ — line resistance

[4] total line loss $= 3 \times (I_{line}^2 R)$ } if no current in N

[5] Power delivered by source per phase $= |V_{phase}||I| \cos\theta$ — θ b/w I_{phase} & E_{phase}

[6] total power delivered by source $= 3|V||I|\cos\theta$

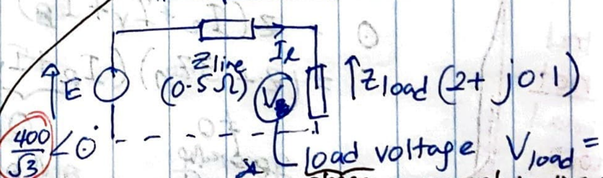
[7] Power consumed by load per phase = Power delivered by source per phase − line loss / power loss per phase

$= |V_{load}||I|\cos(\alpha)$ — α b/w V_{load} & I

[8] total power consumed by load = 3 × power consumed by load per phase

[9] power transmission efficiency $= \frac{\text{Power delivered / consumed to load}}{\text{Power delivered by source}} \times 100\%$

per-phase equivalent cct.



- calculations done using phase voltages
- answers given using line voltages

load voltage $V_{load} = I \times Z$ phase → convert to line voltage at the load

In balanced 3 phase → N is optional even there's an non negligable impedence in N wire

↳ total power delivered $= 3|V_p||I_p|\cos\theta$

$= 3\frac{|V_\ell|}{\sqrt{3}}|I_\ell|\cos\theta$

$= \sqrt{3}|V_\ell||I_\ell|\cos\theta$ } active power; $\cos\theta$: p.f.

kVA → $\sqrt{3}|V_\ell||I_\ell|$ apparent

only when balanced otherwise find power in each phase and add up

3 phase power in balanced load/sys.

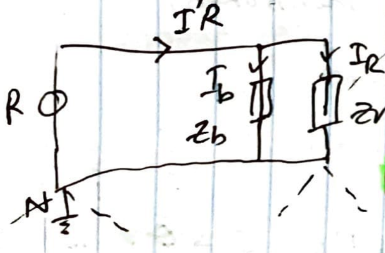
take voltage as 0°

In load balanced 3-phase N → no current, no voltage ⇒ No power loss

total → remember to multiply by 3

- mention neutral wire loss

3 phase unbalanced



p.f → $\angle$? I & V ϕ

7kW, 230V, p.f 1.0 boiler

boiler single phase load

$P = |V||I|\cos\phi$

$7\times10^3 = \frac{400}{\sqrt{3}} |I_b|$

then $I_R' = I_{R(org)} + I_b$

$= 134.72\angle-41.41 + I_b\angle 0^\circ$

balanced power $= \sqrt{3}|V_\ell||I_\ell|\cos\phi$

$I_N = I_{R(org)} + I_b + I_Y + I_B$ ($I_{R(org)} + I_Y + I_B = 0$)

$= I_b$ (neutral wire will carry the return current)

Neutral is not optional now

impedence(R) $Z_b = \dfrac{\frac{400}{\sqrt{3}}\angle 0^\circ}{I_b}$ $Z_M = \dfrac{\frac{400}{\sqrt{3}}\angle 0^\circ}{I_R}$

$Z_b // Z_m$

Show neutral wire is optional

balanced → $P = \sqrt{3}|V_\ell||I_\ell|\cos\phi$

$I_R = I_\ell\angle(-\phi)$ $V_\ell\angle 0^\circ$, $I_R\angle-\phi$

then $I_Y = I_\ell\angle(-\phi-120^\circ)$

$I_B = I_\ell\angle(-\phi+120^\circ)$

then KCL $I_N = I_R + I_Y + I_B$

$= 0$ ✓

When neutral wire impedence cannot be neglected, show sys is still balanced

KVL to R loop KCL → $I_N = I_R + I_Y + I_B$

$E\angle 0^\circ = I_R Z + I_N(Z_N)$

+ Y, B Loop

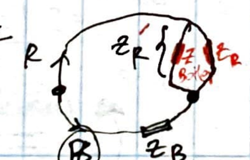
$0 = Z(I_R + I_Y + I_B) + 3Z_n(I_R + I_Y + I_B)$

$= \underbrace{(Z+3Z_n)}_{\neq 0 \text{ generally}}\underbrace{(I_R+I_Y+I_B)}_{0 \text{ still balanced}}$

without N wire system unbalanced

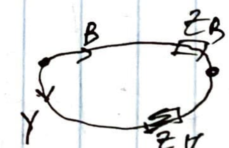
KCL $I_R' + I_Y + I_B = 0$ —(1)

KVL



$\frac{400}{\sqrt{3}}\angle 0^\circ - \frac{400}{\sqrt{3}}\angle+120^\circ =$

$I_R' Z_R' - I_B Z_B$ —(2)



$\frac{400}{\sqrt{3}}\angle 120^\circ - \frac{400}{\sqrt{3}}\angle-120^\circ =$

$Z_B I_B - Z_Y I_Y$ —(3)

$\eta = \dfrac{P_o}{\boxed{P_i}}$ — P_o rated power (given), P_i consumed by pumps

3phase pump 1, 2 } single phase pump 3

parallel ϕ $Z_1 // Z_2 // Z_3$

$Z_1 // Z_2$ $Z_1 // Z_2$

Power 3-phase pump $= \dfrac{\frac{400}{\sqrt{3}}|I_{R_1}|\cos\phi}{\eta}$

(3) Single phase rated power $= \dfrac{\frac{400}{\sqrt{3}}|I_{\ell_3}|\cos\phi}{\eta}$

$I_R = I_{\ell_1} + I_{\ell_2} + I_{\ell_3}$

$I_Y = I_{\ell_1}\angle-120^\circ + I_{\ell_2}\angle-120^\circ$

$I_B = I_{\ell_1}\angle+120^\circ + I_{\ell_2}\angle+120^\circ$

since 3-phase motors are balanced loads I_N = 1 phase current

$= I_R + I_Y + I_B$ ✓

find I_R', I_Y, I_B

Phase voltages at the load

→ $Z_R' I_R'$

$Z_B I_B$

$Z_Y I_Y$

motor currents are original current $I_R = \dfrac{Z_R I_R'}{Z_m}$

No :
Date: / /

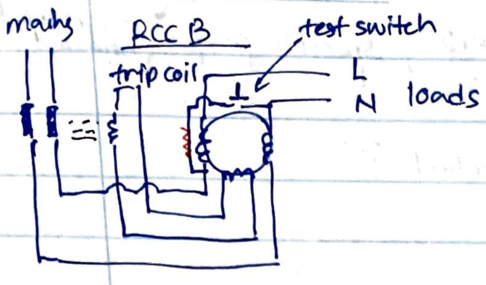
Electrical installation ? combination of e. equip, specific purp., coordinated characteristics

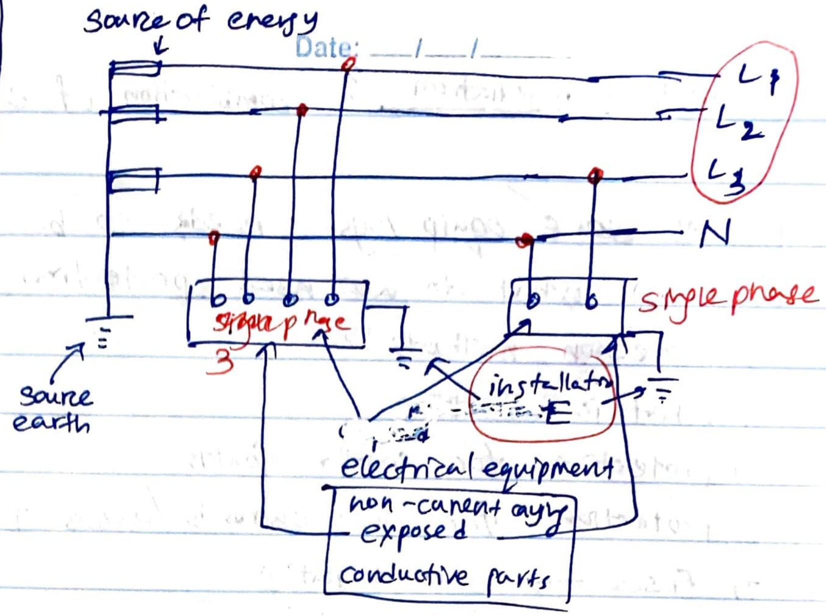
1) why E equip./sys. needs to be protected ?
2) From what do we need protection
3) protection methods (3)
4) what is earthing
5) protection for earth faults → CB → ELCB, RCCB
6) protection for over currents / excess I → CB → MCB, Fuses
7) fuses → current rating
fusing current
fusing factor
8) types of fuses   disadvantages   advantages
re-wirable / semi enclosed
* cartridge
* HRC (high rupturing capacity)
9) MCB → types of mechanism and for what protection
10) adv. of MCB over fuses
11) types of earth leakage prot.   type of operation   remarks
ELCB
RCCB
* 12) types of earthing   regulations ? → neutral equipment
13) types of earthing arrangements
TN   N → direct electrical connection of the exposed conductive parts of consumer to supply earthed point (in AC → neutral)
TT   first T, second T
IT   I → isolated (All live parts are isolated from E / one point is connected to E through high Z)
14) Domestic installation → equip. belong to utility side / service provider
consumer
15) Socket outlet wiring types
16) electric shock

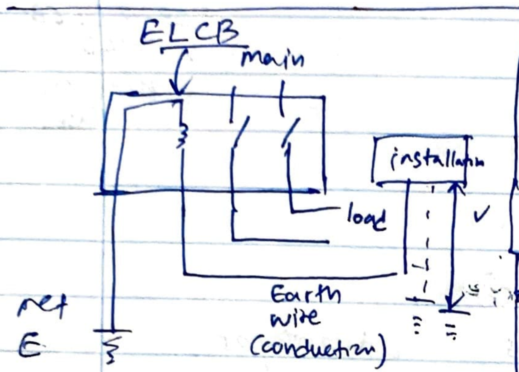
Atlas

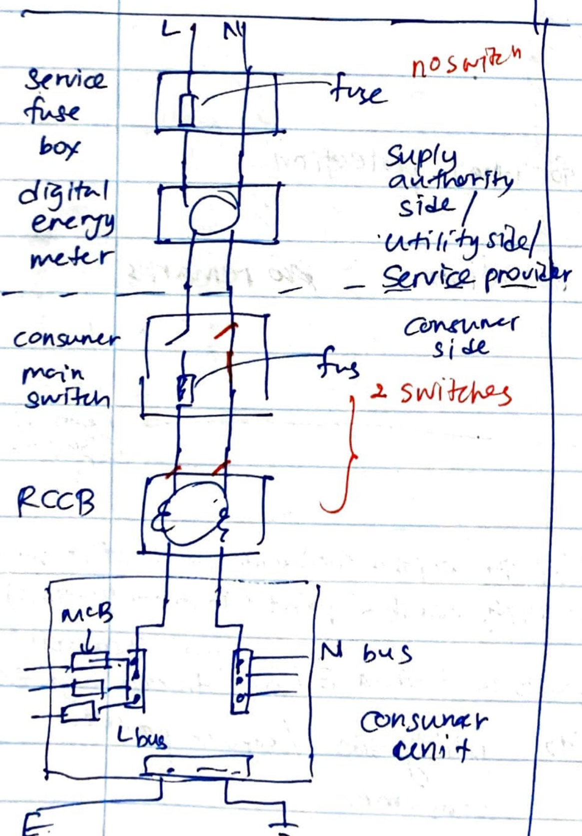
No :

Date: / /









electrical installation tests,

- continuity test $L\ N\ G$
- insulation test $L \leftrightarrow L$, $L \leftrightarrow E$

N has Z ~~if~~ $I_N \neq 0$

$V_N \neq 0$