and characteristics of low voltage equipment Earthing & testing of electrical installation, Illumination

Lesson 1 : IEE Regulations (see KK's)

Discuss the IEE Regulations for control Distribution a Excess current protection (section A) in your own words. Include Diagrams (5%) of Exam

IEE Table A2 TG Francis
Electrical Installation Work.

Prof Nwodo's office 451321
home 454195

ESUT 451253
ask for DVC

CamScanner

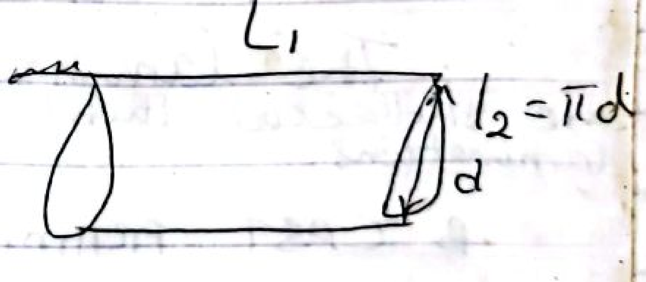
DOCUMENTATION OF THE PRODUCTION PROCESS OF ELECTRIC MOTOR COMPONENT PARTS Including Machines Used and Problems faced.

1 FRAME

This is produced either by rolling or casting.

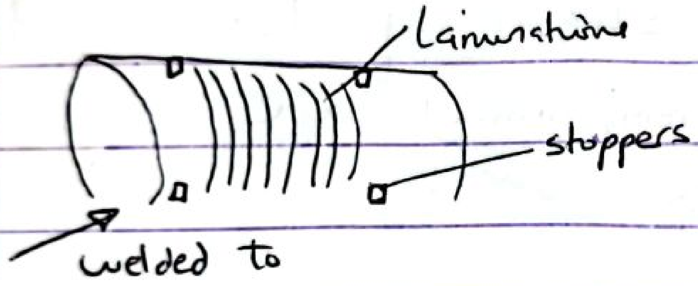
A ROLLED FRAME

Mild steel sheets of the reqd. thickness (3mm; 5mm) are cut to the reqd size [illegible]?



The sheets are then rolled in a rolling machine to form the cassing. PRODA rolling machine is not yet operational but this service can be got from other machine shops in Enugu.

After rolling we had the problems of putting the laminations in the frame. The laminations were clamped together and were put in the frame & the frame welded at the bottom. Stoppers were welded in order to hold the laminations.



The laminations already in the frame are shellacked thinly by pouring shellack over the laminations.

B CAST FRAME

This is useful under the Adaptive Technology programme. The motor frame to be copied is taken to the ceramic production mould making section and using a p.o.p. based mixture (p.o.p, cement and talc) sections of the frame are moulded.

These sections are late joined together to form the mould for the frame. The frame is then cast in aluminium using the mould. Heat treatment and Machining should follow. The one we have tried in PRODA

i cast frame in Al. We have not heat treated nor machined as yet but we hope to do this soon.

ii p.o.p. based mould for a bigger motor.

Heat treatment oven is out of order and needs urgent attention.

The laminations are to be forced into the cast frame. We have not yet done this in PRODA.

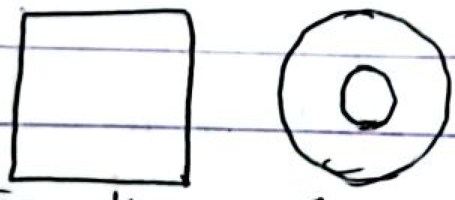
The laminations are pushed into the frame and pinned on three sides.

2A STATOR / ROTOR LAMINATIONS

(see 2B also) The production process is in this order. A die is first produced. Using a press, the required laminations are stamped out.

We did not have a die so we used scrap laminations bought from the market 180 – 200 laminations are usually enough for one electric motor. The laminations are cleaned using a metal brush (iron teeth?) to remove any rust. They are then individually varnish ~~shallacked~~ by dipping them in a thin shallack. They are left to dry. It is usual to turn to the other surface and then allowed to dry.

We tried to produce the rotor laminations ourselves using basic machine shop equipment-



~~This shape was first of all~~

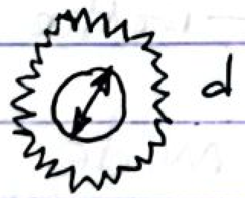
mild steel sheets 0.5mm thickness

were cut to the required size of square to accomodate the circle 70mm diameter.

The pieces of about 200 were ~~clamped~~ drilled in the middle dia = 32mm and then clamped together using a long bolt.

The Lathe machine was used to mill the squares to the reqd circular shape.

This was further clamped on a machine and then ~~used~~ a cutting tool was used to make the reqd teeth.



The teeth were not uniform but we still used it the way it appear for lack of nothing better.

3. SHAFT PRODUCTION

A shaft is produced to the reqd dimension in the Machine shop. to fit the rotor bore. A similar

sized shaft could be copied. Rem-
t. put key & pulley extractor grip. The shaft
was not heat-treated but should be for safety

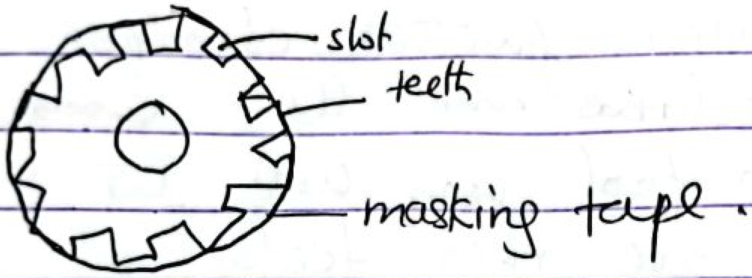
4 ROTOR PRODUCTION

Conductor Embedding.

Stack the laminations on ~~the~~ shaft. ~~clamp pin~~ ~~glass~~ clamp, shellack (thinly). Allow to dry for about 2hrs. Using masking tape cover the teeth so that the slots will be free for conductor embedding.

(ie pour the shellack over the assembly.)

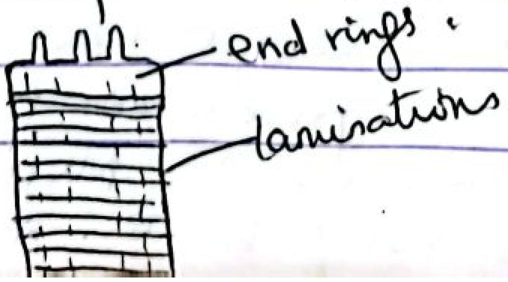
varnish



dip in sand mould — in the foundary

Rem the pop mould made for the end rings.

Make pop mould for the end rings. It is good to copy straight from a similar size of rotor.



~~Thess.~~

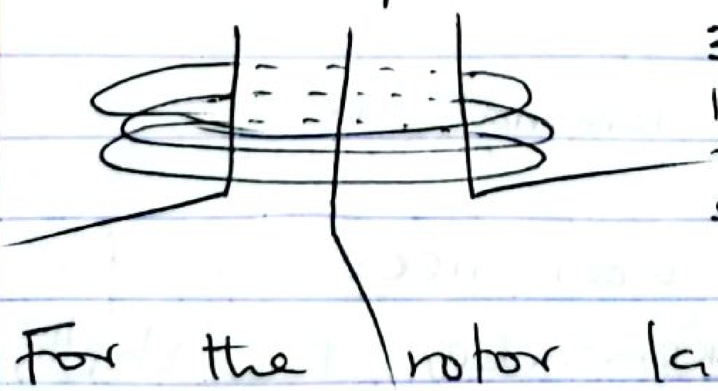
In making of pop mould remember to account for the gate ie where the metal will be poured into and from where it will flow. This is a basic Foundry practice. The aluminium is super heated and then poured (gravity) and left to cool. The ~~stator~~ is dressed and skimmed for

8. ~~[illegible]~~

8B. RE: STATOR / ROTOR LAMINATIONS CONT.

(see 2A)

To stack the stator laminations we used the following method: Used 3 bent rods to fit into 3 slots at 120° apart

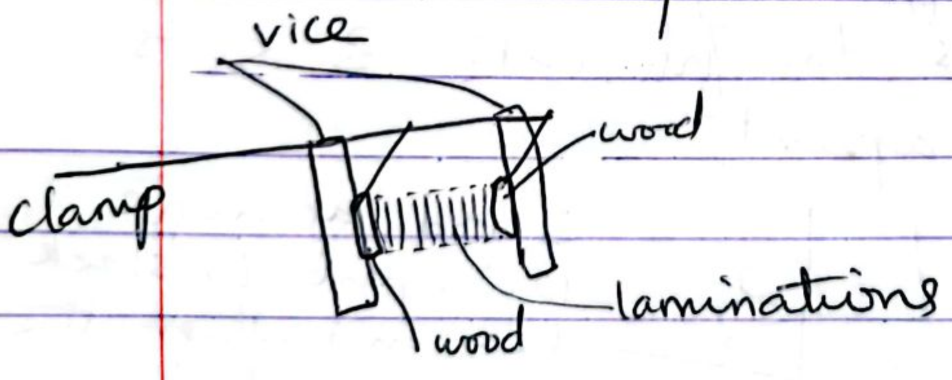


3 rods at angle 120° apart to stack them and allign the slots properly.

For the rotor laminations we

used a scribber to guide it upon the shaft. The other set of laminations produced in PRODA were a tight fit on the shaft and thus had to be guided carefully for proper stacking.
We also placed a ~~placed~~ copper wire or paper or leathroid in the slots to allign them properly.

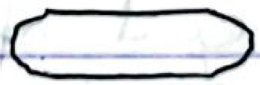
Next we clamped them using 2 clamps. We used wood at each ends to protect the metalic laminations from the vice.



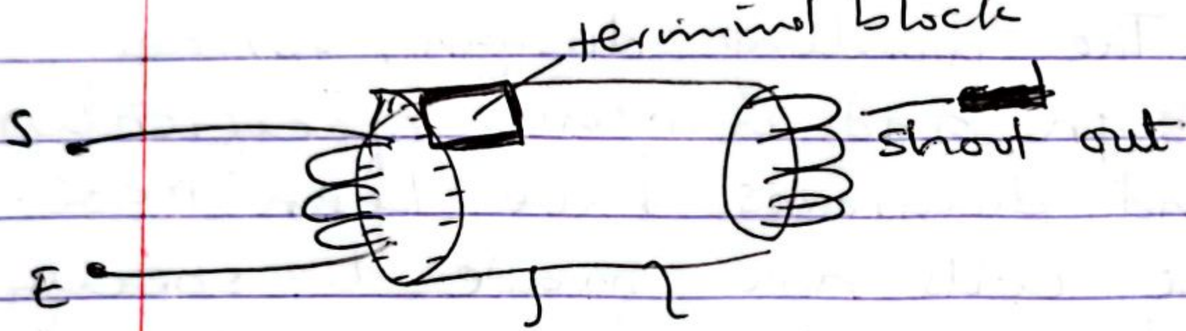
The clamping was necessary for binding. Remember the shellack is poured on this assembly and allowed to dry. Again clamping will reduce air gaps in between laminations and increase efficiency.

5. STATOR WINDINGS.

The winding design, former design and winding specifications and diagrams have been made. The coils are made to specifications using a coil winding machine. We have a manual winding machine incorporating a counter.

The ~~insulated~~ foundation ~~leatheroid~~ Nomex ie base (Nomex) leatheroid is cut and ~~put in~~ used to line the stator slots  this shape has been found better than rectangular. This is used to line the slots and provide insulation between the coils & the laminations.
base of the slots

The coils are slotted in with the terminal block in mind. The end & start wires are to be positioned at the (end) face of the motor having the terminal block.

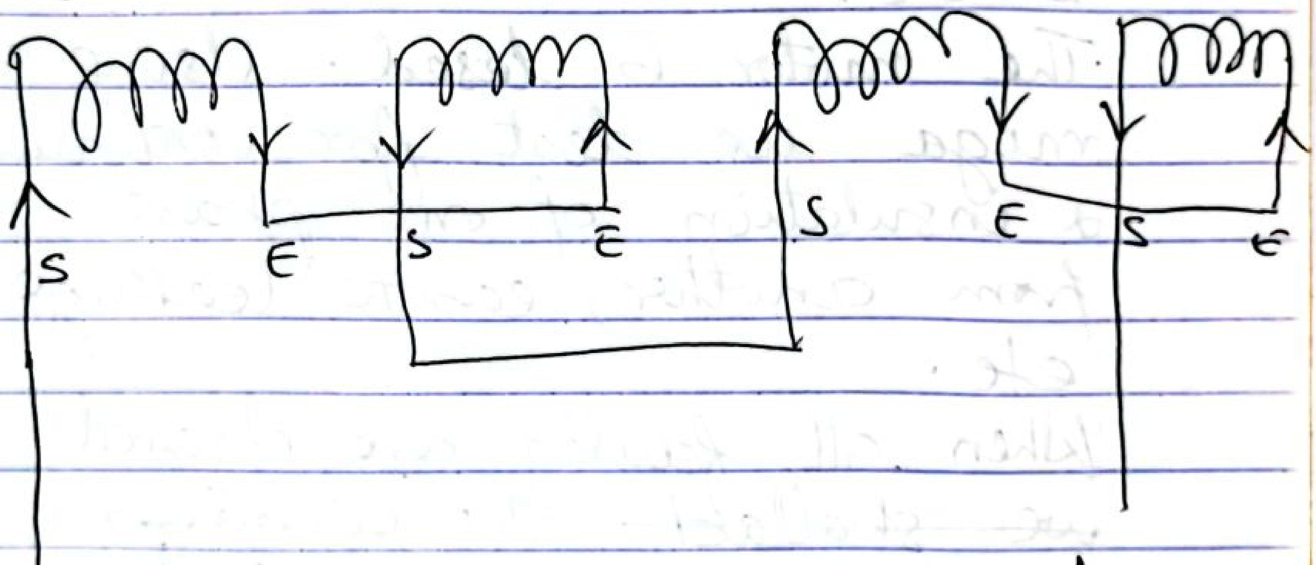


Leathroid is put in again on top of the coils for insulation from the top of the stator teeth. All this is to prevent earth leakage.
The coils are slotted in carefully in a coil of 170 turns, about 20 turns may be put in at a time using a stick for dressing the coils.

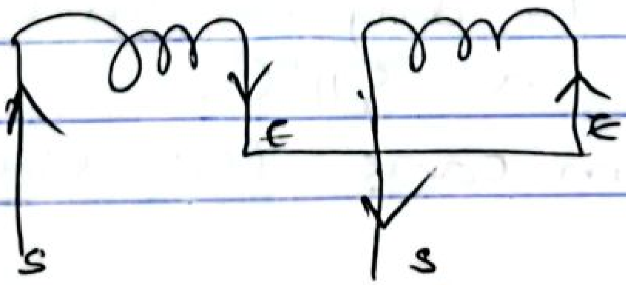
The overhang of the other end is bound. paper myler or thin leathroid is used to insulate each group of coils from the other before binding.

{the end not having start & end wires}

The connections are made usually end - end, start - start.



With 2 leads brought out in each group of coils.
The above is a 4 pole motor
For 2 poles:



For connecting, we first scrape off the resin used to insulate the wires and then use solder. Sleeves are used for further insulation of the connected portions. Cables are ~~used to bring out~~ connected to the relevant wires and brought out ~~the wires~~ to the terminal block.

The motor is tesed. Using a mega we test for continuity, & insulation of one phase from another, earth leakage etc.

When all faults are cleared ~~we shallack the windings~~ we test the motor. If runs & then we disassemble and shallach the windings. Pour thin shallack over the windings and allow to dry in an oven for 6hrs ~ 50°C.

In our own case the oven

was bad so we dried in sunglight ~ 35°C For 2 days.
Assemble for test run.
Is the motor heating? No.
Why? —

WINDING DESIGN a note!

Typical Frame sizes, 50, cycle Motors

FRAME Designation	Outside Diameter of stator Stampings cm. D_o	Gross core length cm L_o	No. of Poles $2P$	Stator Bore cm D	D^2L
A 1	21.0	5.0	2	11.0	600
			4	13.0	845
A 2		7.0	2	11.0	850
			4	13.0	1180
B 1	24.0	6.5	2	13.0	1100
			4	15.0	1460
			6	16.5	1760
B 2		9.0	2	13.0	1520
			4	15.0	2020
			6	16.5	2450
C 1	29.0	9.0	2	15.0	~~2700~~ 2020
			4	18.5	3080
			6	20.0	3600
C 2		12.0	2	15.0	2700
			4	18.5	4100
			6	20.0	4800
D 1	34.5	10.5	2	18.5	3600
			4	22.5	5300
			6	24.5	6300
D 2		14.0	2	18.5	4800
			4	22.5	7100
			6	24.5	8400
E 1	41.5	12.0	4	27.0	8750
			6	29.0	10000
E 2		15.0	4	27.0	11000
			6	29.0	12600
F 1	46.5	12.0	4	31.5	11900
			6	34.0	13800
F 2		16.0	4	31.5	15900
			6	34.0	18500
G 1	53.0	13.0	4, 6	36.0	16800
			8	40.0	20800
G 2		18.0	4, 6	36.0	23300
			8	40.0	29000
H 1	59.0	16.0	4, 6	40.0	25600
			8	45.0	32000
H 2		20.0	4, 6	40.0	32000
			8	45.0	40000

TEXTS

1. Elements of Power System Analysis
by William D. Stevenson

2. Introduction to Electrical Machines
by A.R. Daniels

3. Electric Machinary fundamentals
Stephen J. Chapman

4.
Olle Elgard

Power system planning?

EEE 352
Introduction to Power Systems
(3 credits)

COURSE OUTLINE

✓ Introduction to conventional and
453 renewable energy resources for
power generation ✓
Principles of power generations, hydro
steam plants, gas turbine plant,
? magnetohydrodynamic (MHD) generation ✓
✓ Economic considerations in the
453 text choice of plant types. ✓
? Power supply planning
? System planning in generation
station location and plant size,
high, medium & low voltage
power networks,
? Busbar systems, substation settings
see chap 8 Stevenson Load, voltage and power factor
control, load ~~utilization~~ diversity and
diversity
utilization factor. Maximum demand.

Stevenson chap 9 { System economics, economic loading
choice of machines, tarriffs,

✓ STEVENSON chap 5 overhead lines — long, medium and short lines calculations, power charts. Transmission line efficiency and voltage regulation

Stevenson chap 2 p.u. notation (2.10, 2.11)

TY Francis ? Power cables

✓ STEVENSON Transformers operational characteristics, Loading, losses, efficiency and regulation

✓ winding types & conventions equivalent circuits, three winding transformer, tap changing

? Distribution system

TG Francis? Distribution system planning
Choice of distribution voltages
radial characteristic substation
Subtransmission and distribution substations

Addition : Analysis of Power System performance
Load Flow studies *
Fault Analysis *
Stability studies *

* short description of the above studies.

see ① text (4.3)
② Encyclopaedia
③ Handbook. of EEE.
④ AEPSAP write up. x
⑤ Stevenson
⑥ TG FRANCIS
⑦ OTHER

① Introduction to Conventional & Renewable Energy Resources for Power Generation etc.
② Overhead lines; etc.
③ Per Unit Computations
④ ~~Transformers~~
⑤ Tutorials & ~~Assignment~~ or ~~Test~~
⑤ Transformers
⑥ Tutorials & Assignment ^Test
⑦ Power Supply Planning etc. (Handbook)
⑧ Distribution System etc. (Handbook)
⑨ Power System Economics — economic loading (chap 9)
⑩ Tutorials

EEE 352

Lesson 1 : Introduction to Conventional and Renewable Energy resources for power generation.

In order to generate electrical energy we have to depend on sources, such as coal, natural gas, hydro (water), and nuclear energy. These can be classified as follows:

A Fossil Fuels

① Coal ② Oil
③ Natural gas ④ Substitute fuels eg. coal liquefaction and coal gasification
⑤ Oil from shale
⑥ Oil from tar sands.

B Nuclear Energy

① Fission Reactors
② Breeder Reactors
③ Fusion Reactors

c Natural Sources

Hydro electric power
Geothermal
Wind
Solar - Solar thermal, photovoltaic
Ocean - ocen thermal, ocean currents, tidal.

The convensional energy sources are those that have been in use for over a century and which are considered less risky. Examples are hydroelectric power stations, Fossil fueld power stations.

EEE 352

Introduction to Power System 3 credit

Introduction to conventional and renewable energy resources for Power generation

Principles of Power generations hydro and steam Plants, gas turbine plant, Magnetohydronamic (MHD) generation, economic considerations in the Choice of plant types.

Power supply planing.

- System planning: generating Station Location and plant size, high, medium, low voltage power network, busbar systems, substation sitting, load, voltage and Power factor control load diversity and utilization factors, Maximum demand. System economics - economic loading, Choice of Machines, tariffs overhead lines: long, medium and short line Calculations Power Charts. Transmission line efficiency and voltage regulations P.U. notation

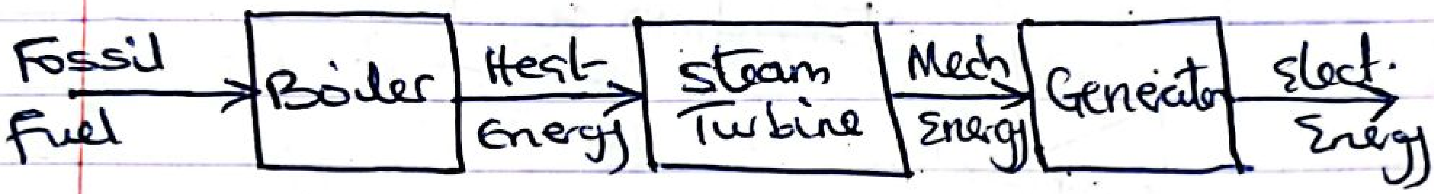
Power Cables

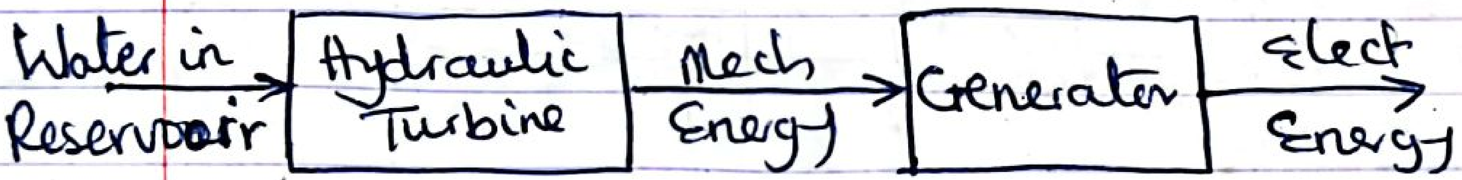
Transformers: Operating Characteristics, loading, losses, efficiency and regulation, winding types and connection equivalent circuits, three winding transformers, tap changing

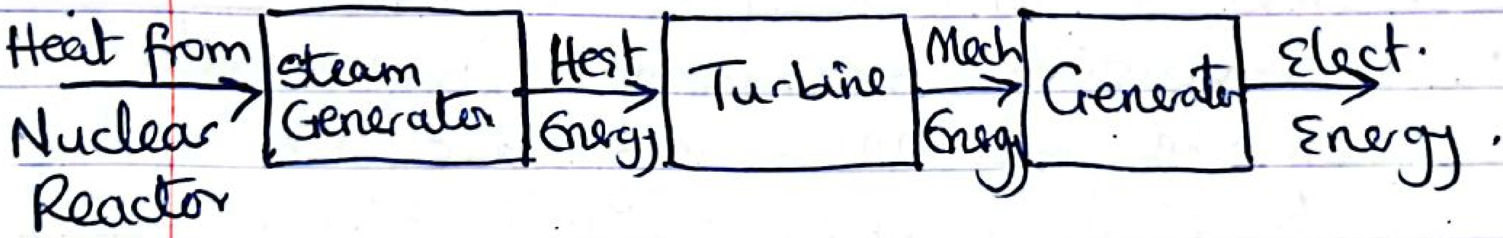
Distribution System
Distribution system planning,
Choice of distribution voltages,
radial characteristics,
Subtransmission & distribution substations.

Electromagnetic wave cause interference
(name of author) superscript.

The following block diagrams highlight the process of energy conversion in the nuclear, fossil fueled and hydro power stations.





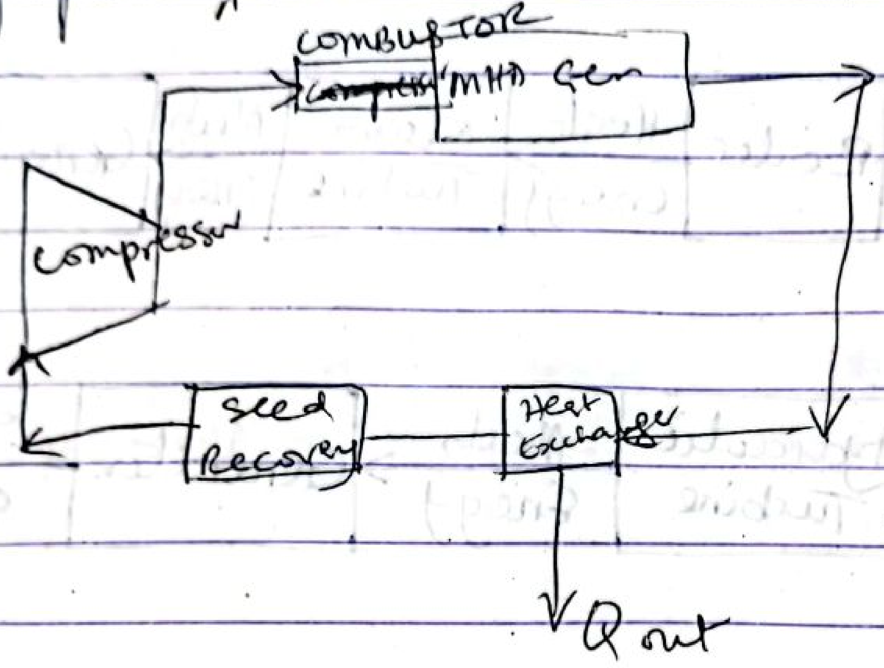


see p. 20 & 21 for diagrams of steam turbine & gas turbine power stations 453 [illegible]

Magnetohydrodynamics

Magnetohydronamics generation

Magnetohydronamics is being activily pursed in order to improve the thermodynamic efficiencies of power generating stations



In a MHD generator, hot combustion gasses moving at a high velocity through the MHD channel are subjected to a strong magnetic field at right-angles to the direction of flow ~~of direction~~. The diagram above is a simplified block diagram of what happens in a magnetohynamic power generating station.

Economic considerations in the choice of plant types

Some Economic Considerations arise when considering the type of power plant to build ~~even the type to a~~ in a particular region or locality. These include:

① Economics of electric power production which will in turn affect the cost of electricity to the consumer. Usually three major areas are compared. These are

ⓐ The Fixed charges are those costs that the utility must pay regardless of the quantity of electric power produced. These charges are usually constant over the lifetime of the plant and are directly related to the capital cost of the power plant and all associated electrical generating equipment.

(b) The Operating and Maintenance costs are those associated with the routine operation & maintenance of the power plant. These include salaries and wages of all cadre of staff and workers, cost of training, cost of consumable supplies ~~...~~ and equipment.

(c) Fuel or Energy Cost. This is the cost of the fuel used for the operation of the power station.

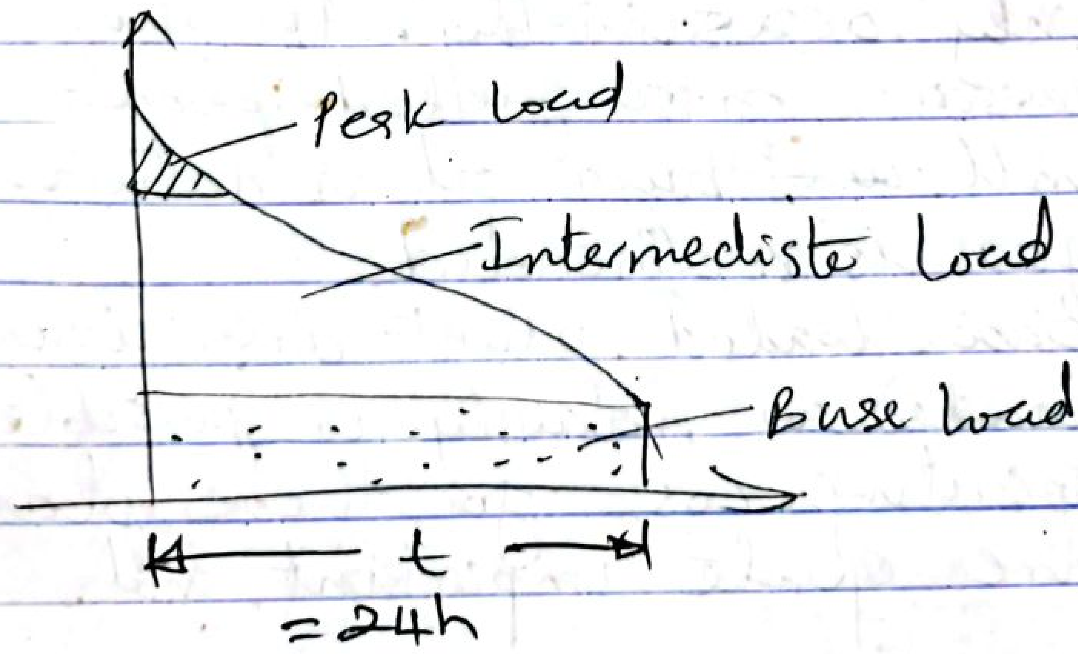
2. Local Availability of Raw Materials
This consideration is quite pertinent in a country such as Nigeria where payment for routine services, fuel, consumable materials should not be made in foreign currency because ~~...~~ it would be much more expensive to do so.

3 Location and Safety Considerations
Hydroelectric power stations are

~~Power supply planning~~ usually encouraged where there is a good waterfall and a dam can be built to enable the water fall through an appropriate head and turn the turbine of the generating plant. The safety of environment & populace is also a major concern in power system economics.

4 Load Consideration

In this regard a load duration curve of the population is usually studied or estimated. Load duration curves are usually divided into three parts as shown in the fig below



The base load is the load below which the demand never falls and is supplied 100% of the time
The peak load is usually seen about 15% of the time.
The intermediate load represents the remaining load region.
Now, peaking load stations are used only a fraction of the time so one desires to minimize their capital costs knowing that even if the fuel cost is high it can be tolorated since the station will be used only occassionally. For this reason, fossil fuelled plants that will ~~use~~ burn oil or natural gas is recomended.
Base loaded plants are usually loaded as heavily as possible, operating costs for these plants are quite important and

should be minimized. Most new coal power stations are base loaded plant

Intermediate load plants tend to find an appropriate medium between base loaded plants & peak loaded plants as seen in the table below

TABLE

BASE LOAD	INTERMEDIATE	PEAK
NEW COAL P.S.	COAL	GAS POWER ST.
HYDRO	HYDRO	PETROLEUM
NUCLEAR		HYDRO

Q ~~A power station is required to produce constant power for the electrolytic smelting of Aluminium (This is a continuous process). Recommend the type of power station required ~~for this~~ to supply this company with constant electricity. Support your argument by making proper load consideration~~

electricity is required for the smelting of Aluminium This is a continuous process by the North Aluminium Company Ltd. Make a proper load designation and recommend the type of power station required to be built to supply electric power to this company. (5%)

should be minimized. Most new coal power stations are base loaded plant
Intermediate load plants tend to find an appropriate medium between base loaded plants & peak loaded plants as seen in the table below

TABLE

BASE LOAD	INTERMEDIATE	PEAK
NEW COAL P.S. HYDRO NUCLEAR	COAL HYDRO	GAS POWER ST. PETROLEUM " HYDRO

Q ~~A power station is required to produce constant power for the Electrolytic smelting of Aluminium (This is a continuous process). Recommend the type of power Station required ~~for this~~ to supply this company with constant Electricity. Support your argument by making proper load consideration~~

electricity is required for the smelting of Aluminium This is a continuous process by the North Aluminium company ltd. Make a proper load designation and recommend the type of power station required to be built to supply electric power to this company. (5%)

2. OVERHEAD LINES

An electric transmission line has four parameters which affect its ability to fulfil its function as part of a power system. These parameters are as follows

i resistance
ii inductance
iii capacitance
iv Conductance

Resistance: The resistance of a transmission line conductors is the most important cause of power loss in a transmission line. The effective resistance of a conductor is

$$R = \frac{\text{power loss in conductor (W)}}{|I|^2 \ (A^2)} \quad \Omega$$

where I is the rms current in the conductor.

The effective resistance is equal to the dc resistance only if the distribution of current throughout the conductor is uniform. In which case the formular below holds

$$R = R_0 = \frac{\rho l}{A} \ \Omega$$

ρ = resitivity of conductor
l = length
A = cross sectional area.

Inductance

To explain inductance, two equations are necessary

(a) $$e = \frac{d\tau}{dt}$$

Ω

e is the induced votage in volts
τ is the number of fluxe linkage of the circuit in weberturns (Wbt)

(5) $$e = L\frac{di}{dt}$$

where

L = constant of proportionality
= inductance of circuit in Henrys

e = induced voltage V

$\frac{di}{dt}$ = rate of chance of current A/s

eqn (4) & (5) combined gives

$$L = \frac{d\tau}{di} \quad (H)$$

3. Capacitance

capacitance of a transmission line is the result of the potential difference between the conductors. Capacitance between two conductors of a two wire line was defined as the charge on the conductors per unit length of line.

$$C = \frac{q}{v} \quad F/m$$

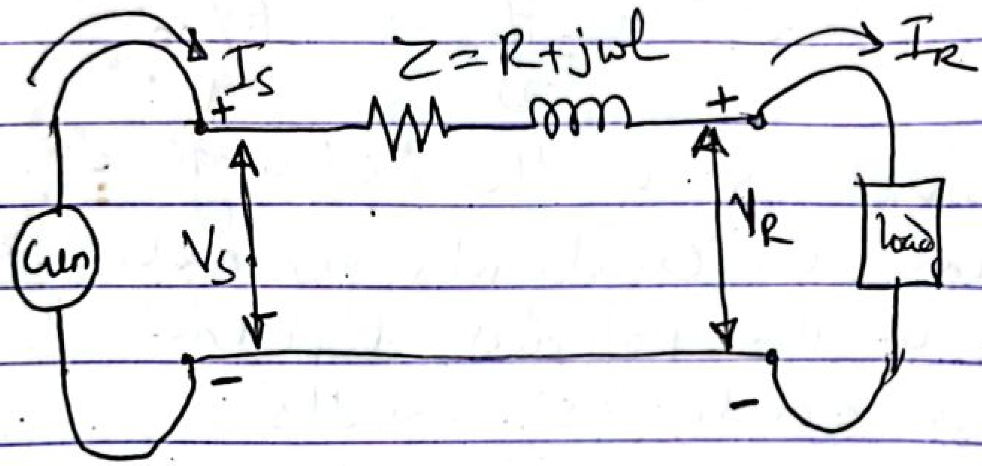
where q is the charge on the line in coulombs per metre and v is the potential difference between the conductors in volts.

4. Conductance

conductance between conductors or between conductors and the ground accounts for the leakage current at the insulators of overhead lines, and ~~through~~ the insulation of cables. Since leakage at insulators of overhead lines is negligible, the conductance between conductors of an overhead line is assumed to be zero.

Representation of lines

1 The short line $l < 80$ km



I_s = sending end current

V_s = sending end line to neutral voltage

V_R = ~~sending~~ Receiving end line to neutral voltage

I_R = receiving end current.

The circuit is solved as a simple ac circuit. Since there are no shunt arms,

$$I_S = I_R$$

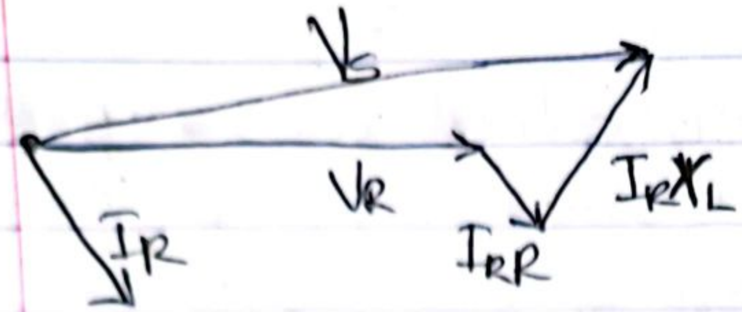
$$V_S = V_R + I_R Z$$

where $Z = zl$ = the total series impedance of the line. (l = length of line)

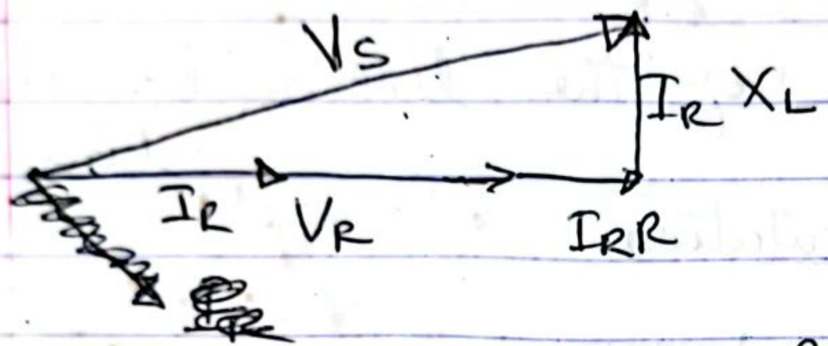
% regulation

$$= \frac{|V_{R,NL}| - |V_{R,FL}|}{|V_{R\,FL}|} \times 100$$

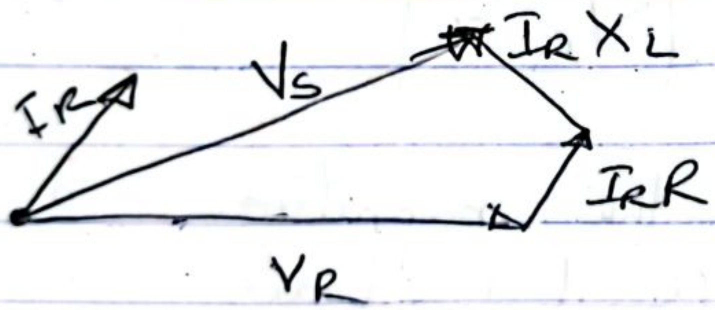
$|V_{R,NL}|$ is the magnitude of receiving end voltage at no load
$|V_{R,FL}|$ is the magnitude of receiving end voltage at full load with V_S held constant.



ⓐ load pf. = 70% lag



ⓑ load pf = 100%

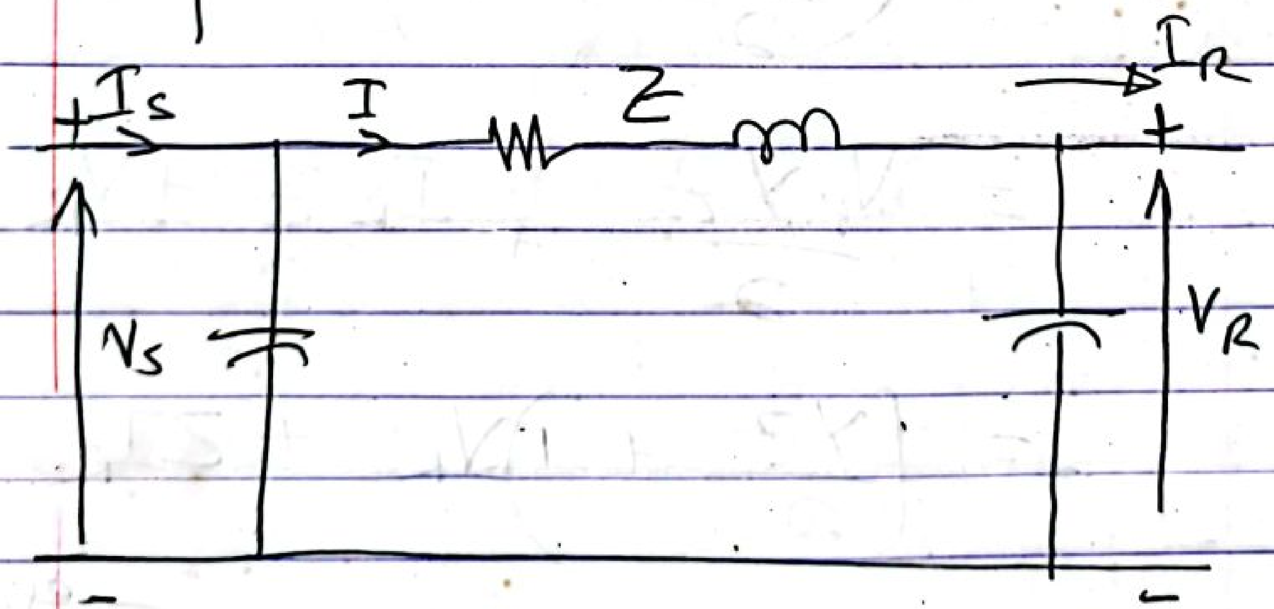


ⓒ load pf = 70% lead

Note from the above phasor diagrams that the regulation is greatest for lagging power factors and least, ~~or~~ even negative for leading power factors.

2 The Medium length line $80 < L < 240$ km

The shunt admittance, usually pure capacitance is usually included in the calculation for a line of medium length as shown in the diagram below.



The current in the capacitance at the receiving end is

$V_R Y/2$.

The current in the series arm is

$$I = \frac{V_R Y}{2} + I_R$$

Hence the voltage V_S is the current in the series arm I multiplied by the impedance Z plus V_R

$$V_S = ZI + V_R$$

$$= \left(\frac{V_R Y}{2} + I_R\right) Z + V_R$$

$$= \frac{V_R Y Z}{2} + I_R Z + V_R$$

$$= \left(\frac{YZ}{2} + 1\right) V_R + Z I_R$$

— eqn p

To get I_S we add the current in the shunt capacitance of the sending end to get

$$I_S = V_S \frac{Y}{2} + V_R \frac{Y}{2} + I_R$$

substituting V_S as given above gives

$$I_S = V_R Y\left(1 + \frac{ZY}{4}\right) + \left(\frac{ZY}{2} + 1\right) I_R$$

eqn. q.

Equations p and q can be written in general form as

$$V_S = AV_R + BI_R$$
$$I_S = CV_R + DI_R$$

where $A = D = \frac{ZY}{2} + 1$

$$B = Z \quad , \quad C = Y\left(1 + \frac{ZY}{4}\right)$$

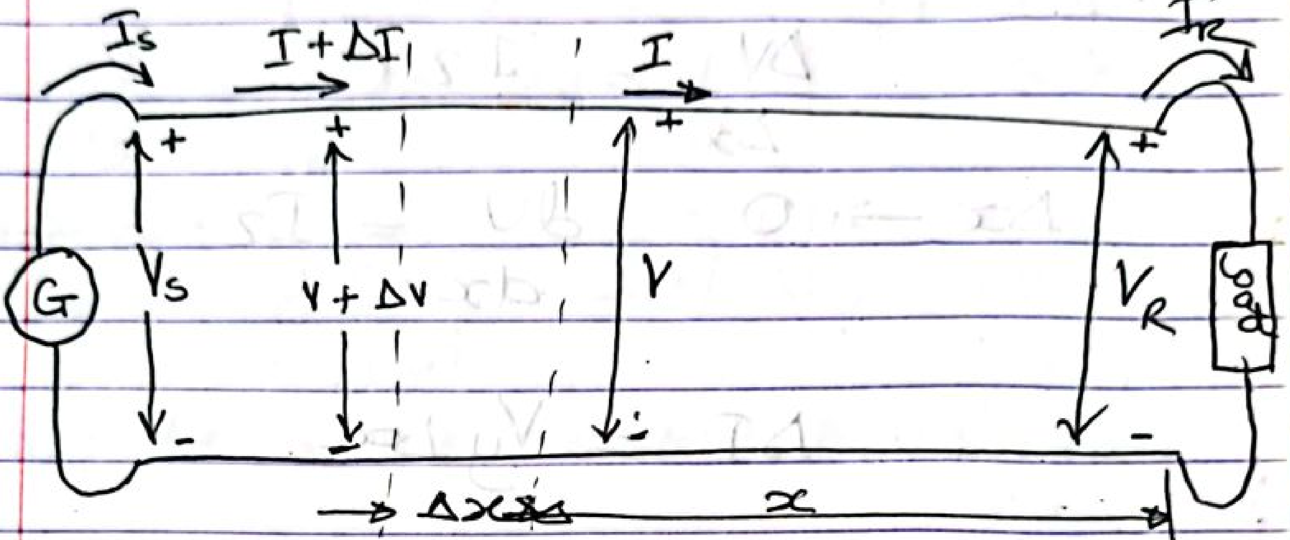
These ABCD constants are sometimes called the generalized circuit constants of the transmission line. The physical meaning of A is that A is the ratio V_s/V_R at no load. Similarly B is the ratio V_s/I_R when the receiving end is short circuited.

percentage regulation is given by

$$\frac{|V_S|/|A| - |V_{R,FL}|}{|V_{R,FL}|} \times 100$$

*3 The long transmission line ($l > 240$ km)

Jump



x = distance measured from the receiving end of the line to the small element of line.

Δx = length of the small element of line; z = series impedance per unit length per phase.

small letter z → $z\Delta x$ = series impedance of the elemental length of the line

$y\Delta x$ = shunt admittance of the same.

V = voltage to neutral at the end of the element towards the load

$V + \Delta V$ = voltage to neutral at the end of the element towards the gen.

$$\Delta V = I_2 \Delta x$$

$$\frac{\Delta V}{\Delta x} = I_2$$

$\Delta x \rightarrow 0$ $\quad \frac{dV}{dx} = I_2$ —— ①

$$\Delta I = V_y \Delta x$$

$$\frac{\Delta I}{\Delta x} = V_y$$

$\Delta x \rightarrow 0$ $\quad \frac{dI}{dx} = V_y$ —— ②

differentiating equations ① & ② wrt x gives

$$\frac{d^2V}{dx^2} = z\frac{dI}{dx} \quad ③$$

$$\frac{d^2I}{dx^2} = y\frac{dV}{dx} \quad ④$$

substitutinp values of $\frac{dI}{dx}$ and $\frac{dV}{dx}$ into eqns ③ & ④ gives

$$\frac{d^2V}{dx^2} = zVy \quad ⑤$$

$$\frac{d^2I}{dx^2} = yIz \quad ⑥$$

noticing that The only variables in eqn 5 are V and x and the only variables in eqn 6 are I and x, the solution to these equations sugest an exponiental expression which wen differentiated twice will give the original expression multiplied by constants.

e

ASIDE :

Let $h = e^{at}$

$$\frac{dh}{dt} = ae^{at}$$

$$\frac{d^2h}{dt} = a^2e^{at}$$

In the same manner, let

~~$V = A_1 \exp$~~

$$V = A_1 e^{(\sqrt{yz})x} + A_2 e^{(-\sqrt{yz})x}$$

$$\frac{d^2V}{dx^2} = yz\left[A_1 e^{\sqrt{yz}x} + A_2 e^{-\sqrt{yz}x}\right]$$

$\therefore$ eqn above is the solution of eqn (5)

Similarly

$$I = \frac{1}{\sqrt{z/y}} A_1 e^{\sqrt{yz}\,x} - \frac{1}{\sqrt{z/y}} A_2 e^{-\sqrt{yz}\,x}$$

The constants A_1 and A_2 can be evaluated ~~found~~ by using the conditions at the receiving end of the line when $x = 0$, $V = V_R$, and $I = I_R$ to get

$$V_R = A_1 + A_2 \qquad I_R = \frac{1}{\sqrt{z/y}}(A_1 - A_2)$$

let $Z_c = \sqrt{z/y}$; $A_1 = \frac{V_R + I_R Z_c}{2}$

$$A_2 = \frac{V_R - I_R Z_c}{2}$$

Let $\gamma = \sqrt{yz}$ we obtain for equations (5) & (6) after due substitution

* only gave them these formulas

$$V = \frac{V_R + I_R Z_c}{2} \varepsilon^{\gamma x} + \frac{V_R - I_R Z_c}{2} \varepsilon^{-\gamma x}$$

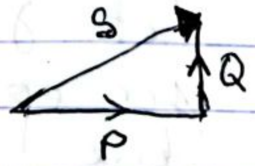
$$I = \frac{V_R/Z_c + I_R}{2} \varepsilon^{\gamma x} + \frac{V_R/Z_c - I_R}{2} \varepsilon^{-\gamma x}$$

where $Z_c = \sqrt{y/z}$ is called the characteristic impedance of the line and $\gamma = \sqrt{yz}$ is called the propagation constant.

POWER IN A TRANSMISSION LINE

$$S = P + jQ$$

$$S_R = P_R + jQ_R$$



$$S_S = P_S + jQ_S$$

CONTD *

$\varepsilon^{-\gamma x}$

$\varepsilon^{-\gamma x}$

$$P_R = |V_R| \cdot |I_R| \cos \theta_R$$

$$Q_R = |V_R| \cdot |I_R| \sin \theta_R$$

θ_R is the phase angle by which the voltage leads the current.

CONT'D * Transmission line Transients

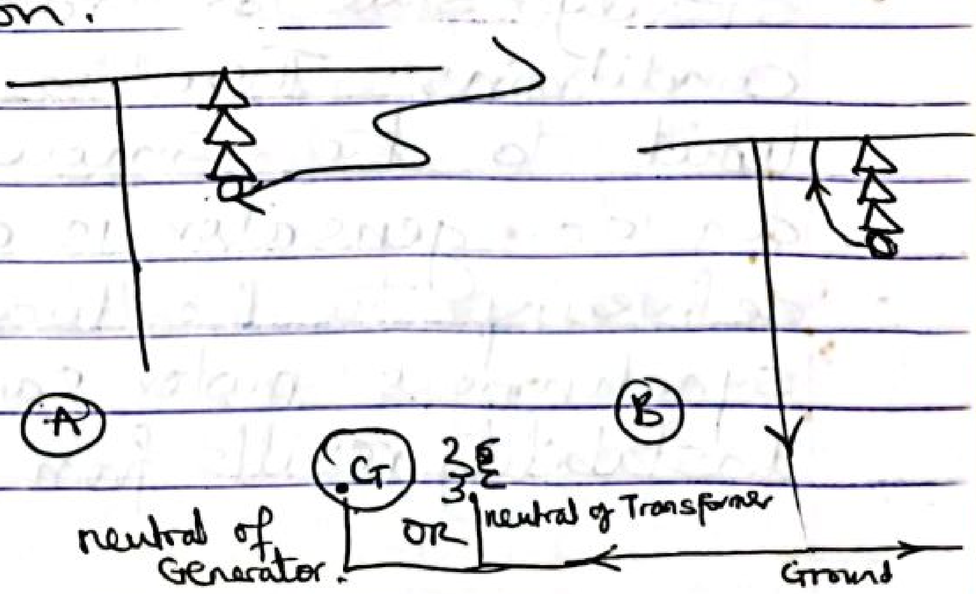
The transient over voltages which occur in a power system are either of external origin (eg lightning discharge) or are generated internally by switching operations. In general the transients on transmission systems are caused by any sudden change in the operating condition ~~and~~ or ~~opera~~ configuration of the system. The starting of induction motors

draw a surge of current from the power system and are also a factor in the stability of the power system.
The planning of power systems will take into consideration the following studies

① Load Flow Studies
A load flow study is the determination of the voltage, current, power and power factor or reactive power at various points in an electric network under existing or contemplated conditions of normal operation.
Load flow studies are essential in planning the future development of the system because satisfactory operation of the system depends on knowing the effect of interconnections

with other power systems, of new loads, new generating stations, and new transmission lines before they are installed.

② Fault Calculations:
A fault in a circuit is any failure which interferes with the normal flow of current.
70% - 80% of transmission line faults are single line to ground faults which arise from flashover of only one line to the tower and ground. Flashover could be caused by lightning especially in tropical Africa where lightning is common.



The smallest number of faults include all three phases. These are called three phase faults. Other types of faults are line to line faults (which do not involve earth) and double line-to ground faults. All the above faults except the three phase faults are unsymmetrical and cause an inbalance between the phases.

③ Stability studies

Stability studies are classified according to whether they involve steady-state or transient conditions. There is a definite limit to the amount of power an a.c. generator is capable of delivering to the load which a synchronous motor can carry. Instability results from attempting to increase the mechanical input to a generator or the mechanical load on a motor beyond this definite amount of power called the stability limit. Disturbances on a system caused by suddenly applied loads (especially induction motor loads (starting)), by the occurrence of faults, by the loss of excitation in the field of a generator, and by switching may cause loss of synchronism. The limiting value of power is called the transient stability limit or the steady-state stability limit according to whether the point of instability is reached by a sudden or a gradual change in conditions of the system.

? Voltage stability studies on the other hand refer to the stability of asynchronous load such as induction motors. The voltage across the load controls the stability of the load such that it does not become unstable and stall. There is therefore a certain critical value below which the voltage may not fall in order to retain stability.

(* Jump & Teach after Short ckt Test befor Exc 4.3)

3. PER-UNIT QUANTITIES

The per-unit value of any quantity is defined as the ratio of the quantity to its base value expressed as a decimal.

Voltage, current, kilovoltamperes and impedance are so related that the selection of the base values for any two of them determines the base values for the remaining two.

$$\text{Base Current, A,} = \frac{\text{base kVA}_{1\phi}}{\text{base Voltage kV}_{LN}}$$

L-N
One phase

$$\text{Base Impedance, Z,} = \frac{\text{base Voltage V}_{LN}}{\text{Base Current A}}$$

$$\text{Base Impedance, Z} = \frac{\text{base (Voltage kV}_{LN})^2 * 1000}{\text{base kVA}_{1\phi}}$$

$\therefore$ Base Impedance, $Z = \dfrac{(\text{base voltage}, KV_{LN})^2}{\text{Base } MVA_{1\phi}}$

Base power KW = base $KVA_{1\phi}$
Base power MW = base $MVA_{1\phi}$

Per Unit Impedance (of a cct element) $= \dfrac{\text{Actual Impedance } \Omega}{\text{base Impedance } \Omega}$

To change from per unit impedance on a given base to per unit impedance on a new base the following equation applies

$$\text{Per Unit } Z_{new} = \text{per-unit } Z_{given} \left(\frac{\text{Base } KV_{given}}{\text{Base } KV_{new}}\right)^2 \left(\frac{\text{Base } KVA_{new}}{\text{Base } KVA_{given}}\right)$$

Note that this expression has nothing to do with transfering the ohmic value of impedance from one side of the transformer to the others.

4. ~~TRANSFORMERS~~

Advantages of Per Unit Computations

~~Making com~~

1. Manufacturers usually specify the impedance of a piece of apparatus in per cent or per unit on the base of the nameplate rating
2. The per unit impedances of machines of the same type and widely different rating usually lie within a narrow range though the ohmic values differ materially for machines of different ratings. For this reason, when the impedance is not known definitely, it is generally possible to select from tabulated average values a per-unit impedance which will be reasonably correct. Experience in working with per-unit values brings familiarity with the proper values of per-unit impedance for different types of apparatus.
3 When impedance in ohms is specified in an

equivalent circuit, each impedance must be refered to the same circuit by multiplying it by the square of the ratio of the rated voltages of the two sides of the transformer connecting the reference circuit and the circuit containing the empedance. The per-unit impedance once it is expressed on the proper base is the same referred to either side of the transformer

4. The way in which transformers are connected in three phase circuits does not affect the per unit impedances of the equivalent circuit although the transformer connection does determine voltage bases on the two sides of the transformer

I NEED A SCIENTIFIC CALCULATOR

4. ~~TRANSFORMERS~~

~~The ideal transformer~~

TUTORIALS

1 The ABCD constants of a three phase transmission line are

$A = D = 0.936 + j\,0.016 = 0.936 \angle 0.98^{\circ}$

$B = 33.5 + j\,138 = 142.0 \angle 76.4^{\circ}\ \Omega$

$C = (-5.18 + j\,914) \times 10^{-6}\ \mho$

The load at the receiving end is 50MW at 220KV with a pf of 0.9. lagging. Find the magnitude of the sending end voltage and the voltage regulation. Assume the magnitude of the sending end voltage remains constant.

$P_R = VI\cos\phi$

$V_R = 220KV$, $P_R = 50MW$

$$I_R = \frac{50 \times 10^6}{220 \times 10^3 \times 0.9}$$

$I_R = 252.525$

power factor = $\cos\theta$; $\cos\theta = \cos(-\theta)$

$V_R = 220\angle 0^\circ$ KV

$= 220 \times 10^3 \angle 0$

$I_R = 252.525 \angle \cos^{-1}(0.9)$

$\cos^{-1}(0.9) = 25.8149$ since the current is lagging the voltage, Actual angle is -25.8149.

$I_R = 252.525 \angle -25.8149$ (.8419)

$V_s = AV_R + BI_R$

$= 0.936\angle 0.98 * 220\angle 0 * 10^3 + 142.0\angle 76.4^\circ * 252.525\angle -25.8149$

$= 205920\angle 0.98^\circ + 35858.55\angle 50.5851$

$= 205889.8793 + j\,3521.93 + 22780.77 + j\,27692.45$

$= 228670.653 + j\,31214.38$

$= 230799.242\angle 7.776^\circ$

$= 230.780\angle 7.776^\circ$ KV

voltage regulation $= \dfrac{\frac{|V_S|}{|A|} - |V_{R\,FL}|}{|V_{R\,FL}|} * 100$

$= \dfrac{\frac{230.780\angle 7.776^\circ}{0.936\angle 0.98^\circ} - 220\angle 0^\circ}{220\angle 0^\circ}$

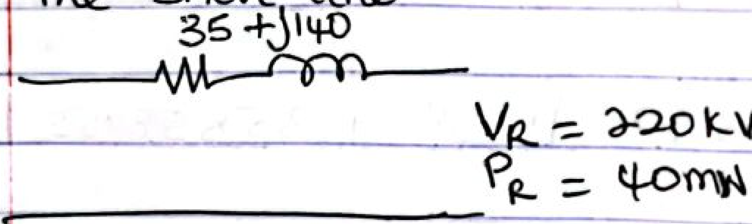
JUST MAGNITUDE, NOT ANGLE

$= \dfrac{\frac{230.780}{0.936} - 220}{220} * 100\% = 12.08$

2 A 50Hz 3-phase transmission line ~~has~~ is 250km long. It has a total series impedance of $35 + j140\ \Omega$ and shunt admittance of $930 \times 10^{-6} \angle 90°\ \Omega$. It delivers 40MW at 220 KV with 90% power factor lagging. Find the voltage at the sending end by

(a) the short line approximation
(b) the nominal π approximation
(c) The long line equation

(A) The short line



$$I_R = \frac{40 \times 10^6}{220 \times 10^3 \times 0.9}$$

$$= 202.02\ A \angle -25.8419$$

[Aside
$\cos^{-1}(0.9)$
$= 25.8419$
Since lagging
$\theta = -25.8419$]

$I_S = I_R$

$V_S = V_R + I_R Z$

$= 220 \times 10^3 + j0 + \left[(181.8595 - j87.9727)(35 + j140)\right]$

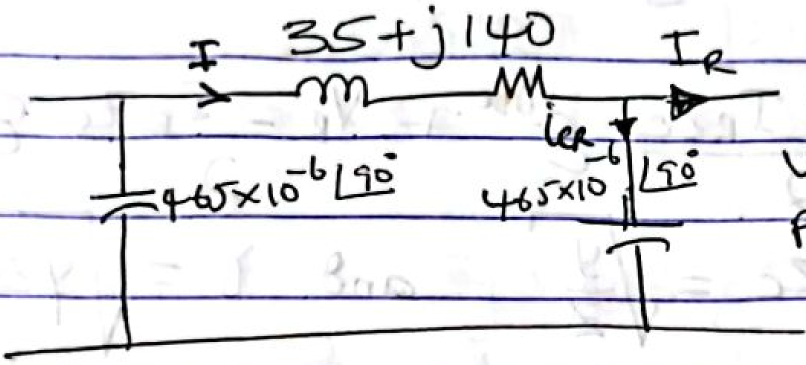
$= 220 \times 10^3 + j0 + 18681.2885 + j22381.2785$

$= 238681.2885 + j22381.2785$

$239.74 \angle 5.35$ kV

$= 239.7283 \angle 5.356^\circ \times$ kV

(b)



$V_R = 220$ kV

$P_R = 40$ mW

$I_R = 202.02 \angle -25.8449$ A

$i_{CR} = 10^3 \times 220 \angle 0 * 465 \times 10^{-6} \angle 90^\circ$

$= 102.3 \angle 90^\circ$ A

$I = I_R + i_{CR} = 102.3 \angle 90^\circ + 202.02 \angle -25.84$

$= j102.3 + 181.8595 - j87.97268$

$= 181.8595 + j14.3273$

$= 182.423 \angle 4.5^\circ$

$V_s = ZI + V_R$

$= (35+j140)(181.8595+j14.3273)$

$+ 220 \times 10^3 + j0$

$= 224.359 + j25.961$ kV

$= 225.858 \angle 6.6$ kV

(c) From the long line equation,

$$V = \frac{V_R + I_R Z_c}{2} \varepsilon^{\gamma x} + \frac{V_R - I_R Z_c}{2} \varepsilon^{-\gamma x}$$

where $Z_c = \sqrt{\frac{y}{z}}$ and $\gamma = \sqrt{yz}$

$$Z_c = \sqrt{\frac{930 * 10^{-6} \angle 90^\circ}{35 + j140}} =$$

$$= \sqrt{6.252 + j1.563 \times 10^{-6}}$$

$$Z_c = \sqrt{6.444\ 10^{-6} \angle 14^\circ}$$

$$Z_c = 2.538 \times 10^{-3} \angle 7^\circ$$

$$\gamma = \sqrt{yz} = \sqrt{930 * 10^{-6} \angle 90 * 35 + j140}$$

$$= \sqrt{-0.1302 + j0.03255}$$

$$= \sqrt{0.1342 \angle 165.96}$$

$$= 0.336 \angle 165.96/2$$

$$0.336 \angle 82.98^\circ$$

$$I_R Z_c = 202.02 \angle -25.8149 * 2.538 \times 10^{-3} \angle 7^\circ$$

$$= 0.5127 \angle -18.8149^\circ$$

$$= 0.4853 - j0.1653$$

$$V = \frac{220 \times 10^3 + 0.4853 - j0.1653}{2} \varepsilon^{0.336} +$$

$$\frac{220 \times 10^3 - 0.4853 + j0.1653}{2} \varepsilon^{-0.336}$$

$$= \frac{220000.4853 - j0.1653}{2} \varepsilon^{0.336} +$$

$$\frac{219999.5147 + j0.1653}{2} \varepsilon^{-0.336}$$

$$= \frac{(220000.4853 - j0.1653)(1.3993)}{2} +$$

$$\frac{(219999.5147 + j0.1653)(0.71462)}{2}$$

$$= 153923.3395 + j0.115652 +$$

$$78608.0266 + j0.5906$$

$$= 232531.3661 + j0.474948$$

$$= 232.531 \angle 0.00012^\circ \text{ kV}$$

What is a transformer?
Develope the practical transformer concept ~~using~~ starting from the ideal transformer analysis

4 TRANSFORMERS

Transformers are devices which consists of two or more coils placed so that they are linked by the same flux

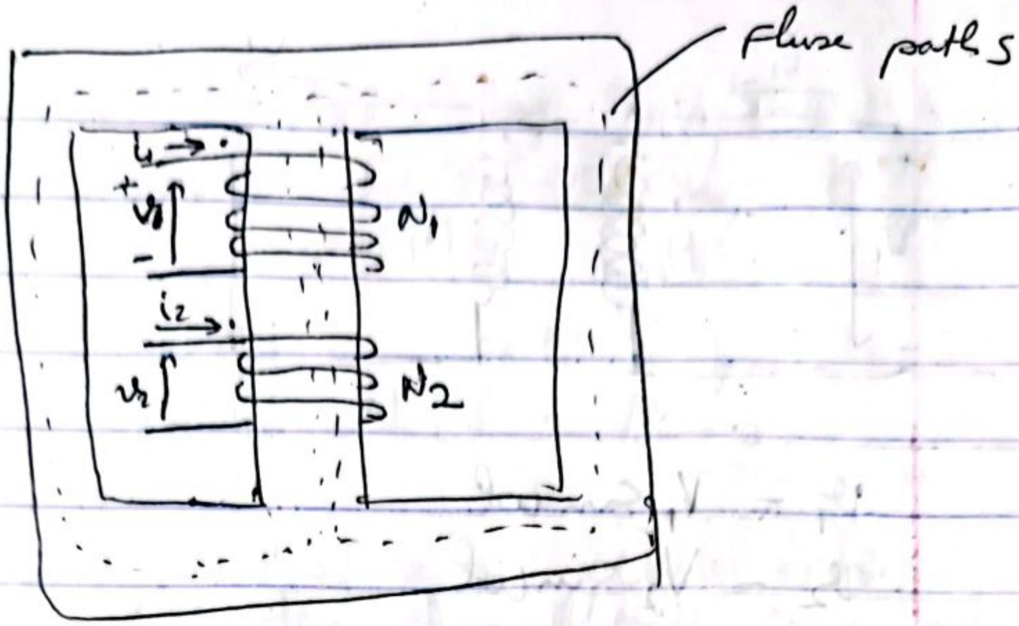
The ideal transformer. To achieve ideal transformer analysis we assume the following

i the permeability μ of the core is infinite

ii the resistance of the windings is zero

iii the flux varies sinusoidally in the core.

iv With infinite permeability of the core, all the flux is confined to the core and therefore links all the turns of both windings.



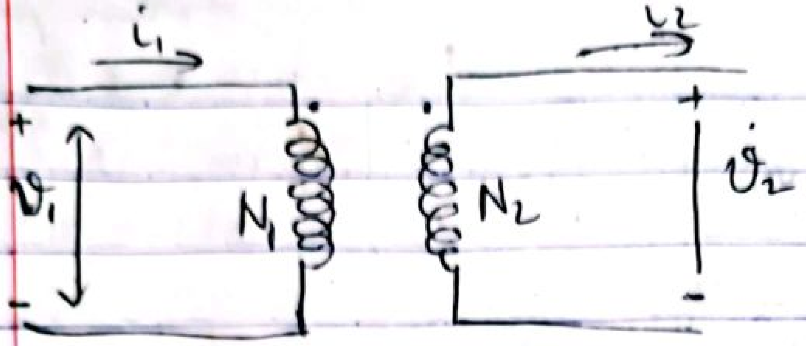
An ideal 2-winding transformer

Since the winding resistance is zero, the voltage e induced in each winding by the changing flux is also the terminal voltage of the winding since the winding resistance is zero.

$$v_1 = e_1 = N_1 \frac{d\phi}{dt}$$

$$v_2 = e_2 = N_2 \frac{d\phi}{dt}$$

where ϕ is the instantaneous value of flux
N_1, N_2, number of turns on winding 1 and 2.



$v_1 = V_1 \sin \omega t$

$v_2 = V_2 \sin \omega t$

$$\frac{v_1}{v_2} = \frac{V_1}{V_2} = \frac{N_1}{N_2}$$

Imp: Usually, in order to know the direction in which transformers are wound a dot is placed at the end of each winding such that all dotted ends of windings are positive at the same time.

Amperes law & magnetomotive force arround a closed path is given by

$$\oint H \, ds = i$$

i = current enclosed by the line integral of the field intensity H arround the path.

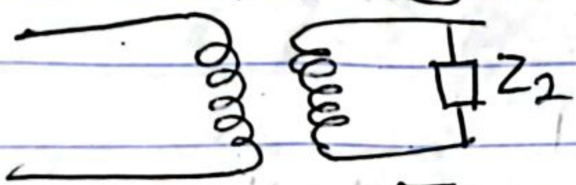
$$\oint H \cdot ds = N_1 i_1 - N_2 i_2$$

The integral of the field intensity H arround the closed path is zero when permeability is infinite.
So upon converting to phasor form we have

$$N_1 I_1 - N_2 I_2 = 0$$

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

If an impedance Z_2 is connected across winding 2 of the circuit



$$Z_2 = \frac{V_2}{I_2}$$

$$= \frac{(N_2/N_1) V_1}{(N_1/N_2) I_1}$$

Let $\frac{V_1}{I_1} = Z_2'$

$$\therefore Z_2' = \frac{V_1}{I_1} = \left(\frac{N_1}{N_2}\right)^2 Z_2$$

This means that the impedance of the secondary winding when referred to the primary must be multiplied by the square of the ratio of primary to secondary no of turns OR primary to secondary voltage.

Note that in an ideal transformer

$$V_1 I_1 = V_2 I_2$$

$$V_1 I_1^* = V_2 I_2^*$$

✓ Example A.1

If $N_1 = 2000$ and $N_2 = 500$ in the circuit below and if $V_1 = 1200\angle 0^\circ$ V and $I_1 = 5\angle -30^\circ$ A:

with an impedance Z_2 connected across the winding 2. Find V_2, I_2 and Z_2 and the impedance Z_2' which is defined as the value of Z_2 referred to the primary side of the transformer.

$$V_2 = \frac{500}{2000}(1200\angle 0^\circ) = 300\angle 0^\circ \text{ V}$$

$$I_2 = \frac{2000}{500}(5\angle -30^\circ) = 20\angle -30^\circ \text{ A}$$

$$Z_2 = \frac{V_2}{I_2} = \frac{300\angle 0^\circ}{20\angle -30^\circ} = 15\angle 30^\circ \,\Omega$$

$$Z_2' = 15\angle 30^\circ \left(\frac{2000}{500}\right)^2 = 240\angle 30^\circ \,\Omega$$

OR

$$Z_2' = \frac{1200\angle 0^\circ}{5\angle -30^\circ} = 240\angle 30^\circ \,\Omega$$

The practical transformer

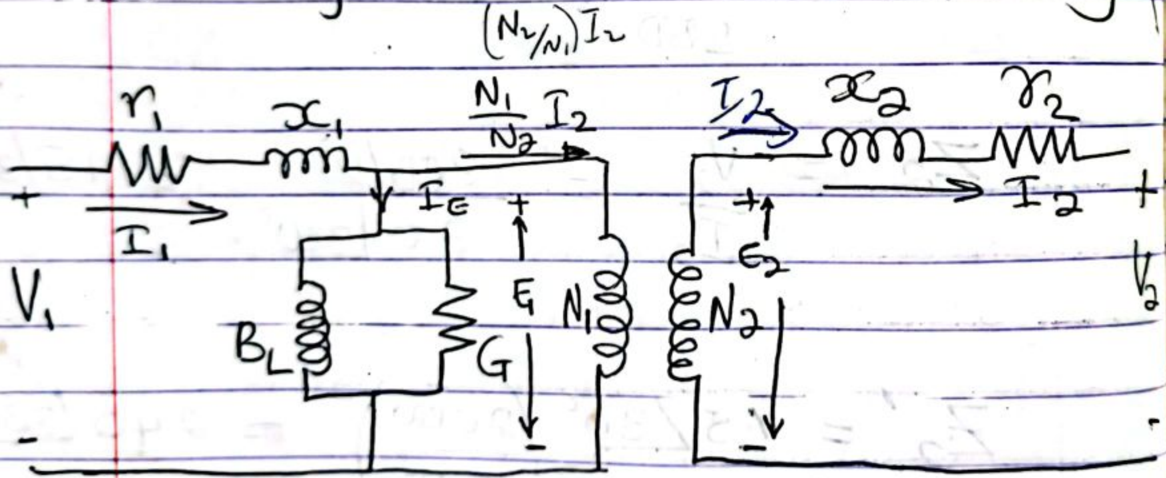
In this case the following observations hold:

i The permeability of the core is not infinite

ii Winding resistance is present

iii Losses occur in the iron due to the cyclic changing of direction of the flux (hysteresis loss & eddy current losses) and also due to circulating currents in the core (I^2R losses or eddy current losses)

iv Not all the flux linking one winding links the other winding.



Transformer equivalent circuit

In a practical two winding

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I_E is

transformer, some of the flux linking the primary winding does not link the secondary. This flux is proportional to the primary current and causes a voltage drop that is accounted for by an ~~leakage~~ inductive reactance x_1, called leakage reactance. Similarly in the secondary winding a leakage reactance x_2 is accounted for. r_1 and r_2 refer to the winding resistances which are present in a practical transformer.

...osses) and circulating the core
...R losses or
...dy current losses

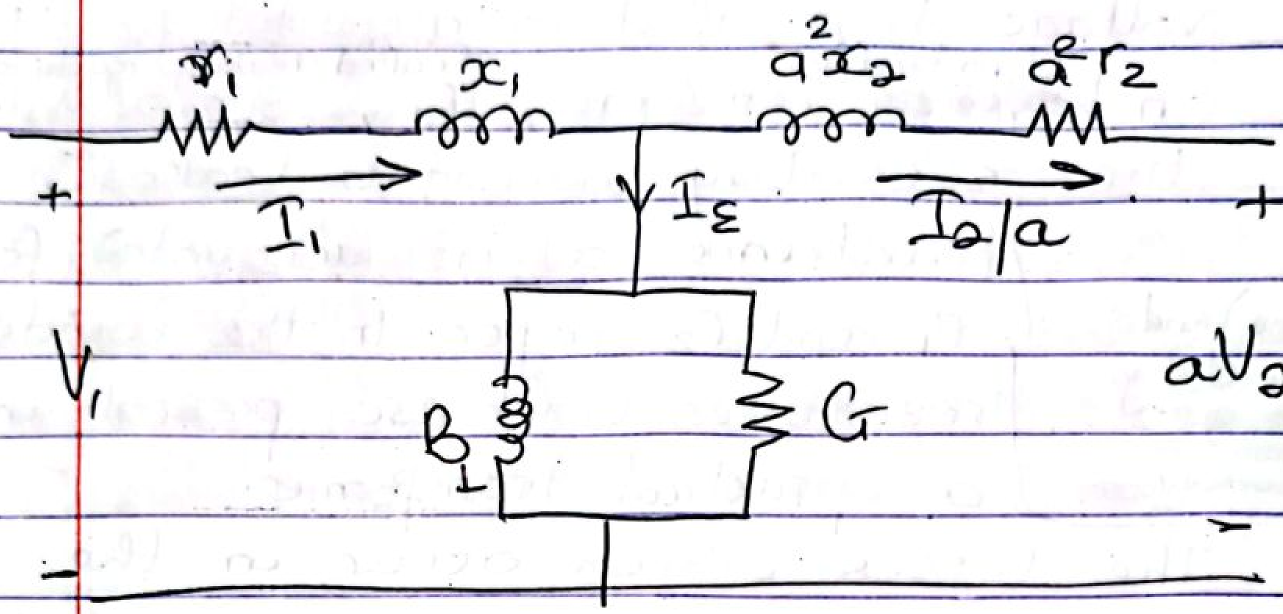
The losses which occur in the core are taken care of by the introduction of an inductive susceptance B_L in parallel with a conductance G.

I_E is the magnetising current

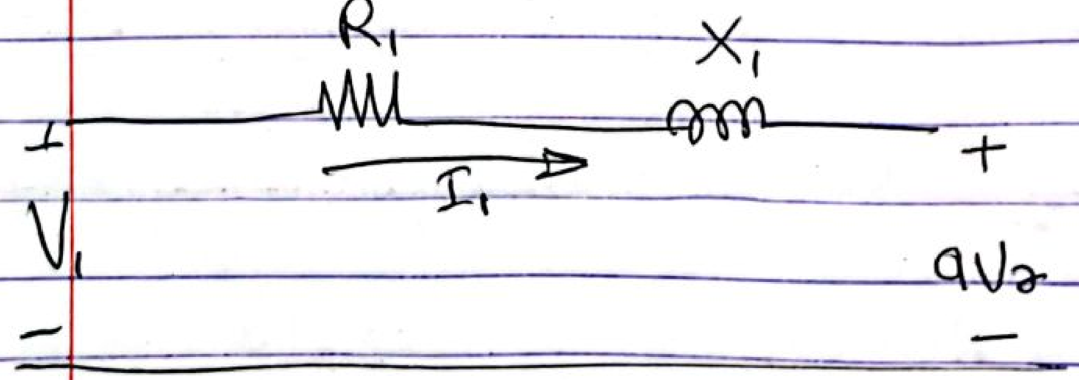
Let $a = \frac{N_1}{N_2}$

$R_1 = r_1 + a^2 r_2$

$X_1 = x_1 + a^2 x_2$



neglecting the magnetising current I_E which is very small compared to I_1 & I_2, we have the cct below



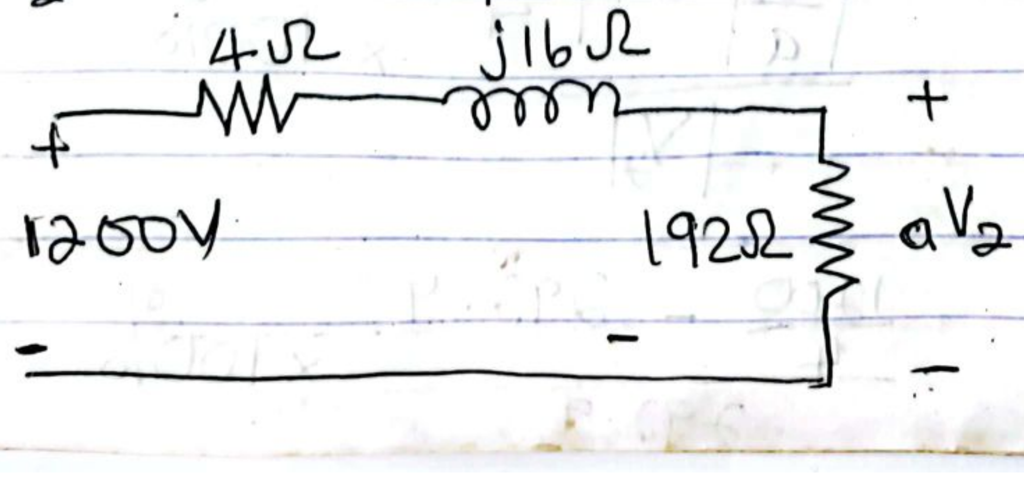
* see practical transformer equivalent cct - over back leaf *

Example 4.2

A single phase transformer has 2000 turns on the primary winding and 500 turns on the secondary. Winding resistances are $r_1 = 2.0\Omega$ and $r_2 = 0.125\Omega$. Leakage reactances are $x_1 = 8.0\Omega$ and $x_2 = 0.5\Omega$. The resistance load Z_2 is 12Ω. If applied voltage at the terminals of the primary winding is 1200V, find V_2 and the voltage regulation. Neglect magnetising current.

$$a = \frac{N_1}{N_2} = \frac{2000}{500} = 4$$

$$R_1 = 2 + (0.125)(4^2) = 4\Omega$$
$$X_1 = 8 + 0.5(4^2) = 16\Omega$$
$$Z_2' = 12 \times 4^2 = 192\Omega$$



$$I_1 = \frac{1200}{192 + 4 + j16} = 6.10 \angle -4.67^\circ$$

$$aV_2 = I_1 Z_2'$$

$$= 6.10 \angle -4.67^\circ \times 192$$

$$= 1171.6 \angle -4.67^\circ$$

$$V_2 = \frac{aV_2}{a} = \frac{1171.6 \angle -4.67^\circ}{4}$$

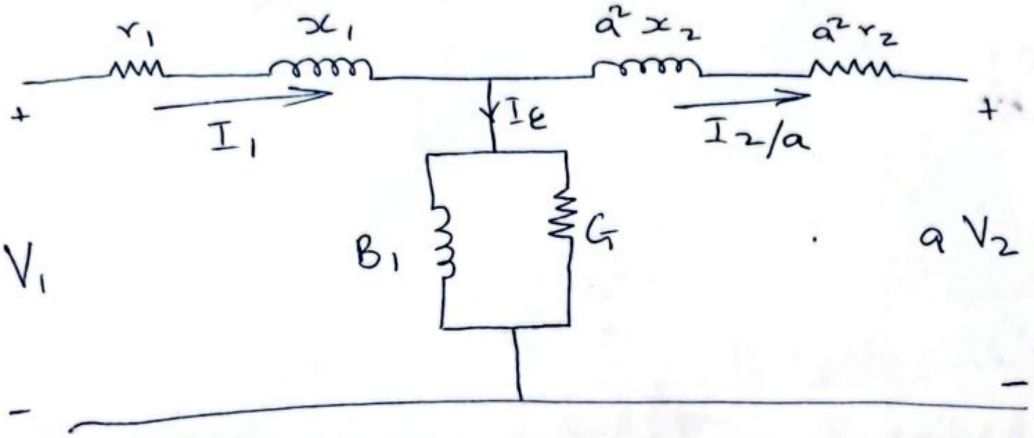
$$= 292.9 \angle -4.67^\circ$$

voltage regulation — This compares the transformer output voltage at no load with the output voltage at full load. $\frac{V_{2nl} - V_{2fl}}{V_{2fl}}$

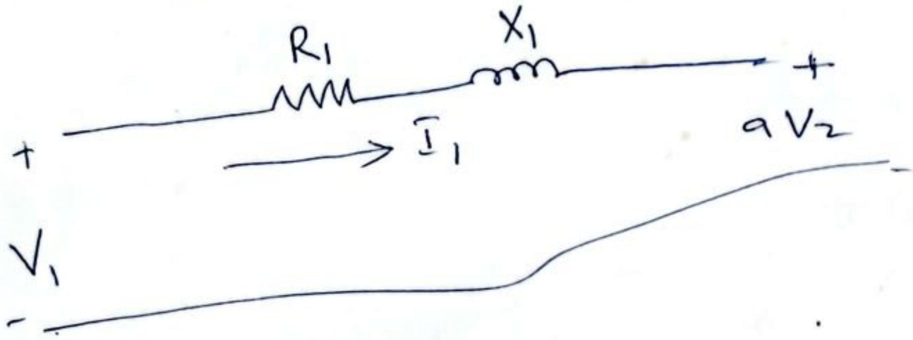
$$\frac{\left|\frac{V_1}{a}\right| - |V_2|}{|V_2|} \times 100\%$$

$$\frac{\frac{1200}{4} - 292.9}{292.9} \times 100\%$$

Note:
The diagram below is the equivalent circuit of a transformer



If we neglect the magnetising current I_E which is very small compared to I_1 & I_2 we have the circuit below.



ignoring magnetization

$R_1 = r_1 + a^2r_2$

$X_1 = x_1 + a^2 x_2$

This is a simplification.

Notice that the secondary has been referred to the primary while the magnetizing branch has been ignored.

As a result of voltage drop in impedance when current flows, $V_1 = aV_2$ only when I_1 is zero ie on open circuit.

when current flows, there is voltage drop

$aV_2 = I_1 Z_2'$ ie the voltage drop across a load Z_2 connected across V_2 as seen or referred to the primary.

$$V_2 = \frac{aV_2}{a}$$

Note that in an ideal case, $\frac{N_1}{N_2} = a = \frac{V_1}{V_2}$

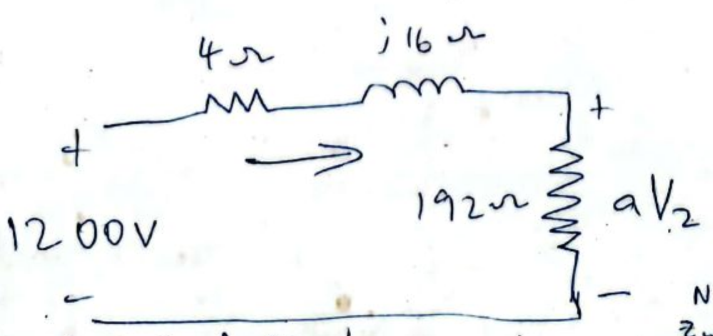
this is also the case at no load when the current is zero.

However, when there is current flow, you have to take into consideration the winding impedance [resistance & leakage reactance] as well as the magnetizing path and load. These would affect the voltages & verse versa. Hence the equivalent circuit is used to calculate the voltages & ~~curr~~ current appropriately.

In the voltage regulation, we used the magnitude

$$\frac{\left|\frac{V_1}{a}\right| - |V_2|}{|V_2|} \times 100\%$$

w — winding
L — load



NB:

$V_1 = I_1 Z_w + I_1 Z_L$
$= I_1 Z_w + I_1 Z_L$
$= I_1 Z_w + aV_2$

NB in an ideal transformer $Z_w = 0 \Rightarrow V_1 = aV_2$

at No load, $I_1 = 0 \Rightarrow V_1 = aV_2$.

However, in a practical transformer,
$I_1 Z_L = aV_2$ & $V_2 = \frac{aV_2}{a}$

$aV_2 = I_1 Z_2'$ ie the voltage drop across a load Z_2 connected across V_2 as seen or referred to the primary.

$$V_2 = \frac{aV_2}{a}$$

Note that in an ideal case, $\frac{N_1}{N_2} = a = \frac{V_1}{V_2}$
this is also the case at no load when the current is zero. However, when there is current flow, you have to take into consideration the winding impedance [resistance & leakage reactance] as well as the magnetizing path and load. These would affect the voltages & verse versa : Hence the equivalent circuit is used to calculate the voltages & current appropriately.

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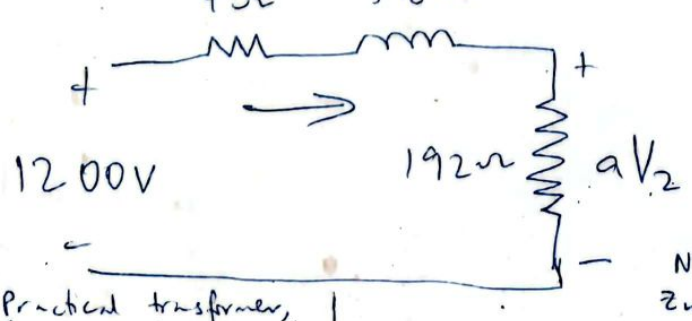
$$\frac{\left|\frac{V_1}{a}\right| - |V_2|}{|V_2|} \times 100\%$$

w – winding
L – load



NB:

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$= I_1 Z_w + I_1 Z_L$
$= I_1 Z_w + aV_2$

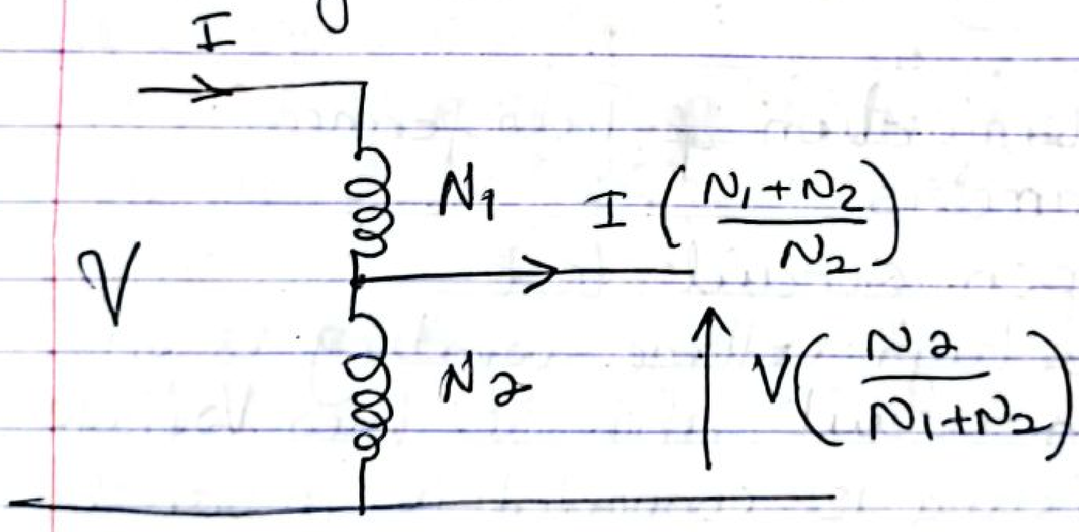
NB in an ideal transformer $Z_w = 0 \Rightarrow V_1 = aV_2$
at No load, $I_1 = 0 \Rightarrow V_1 = aV_2$.

However, in a Practical transformer,
$I_1 Z_L = aV_2$ & $V_2 = \frac{aV_2}{a}$

$= 2.42\%$

The Autotransformer.

This differs from the ordinary transformer in that the windings of the autotransformer are electrically connected as well as being coupled by mutual flux

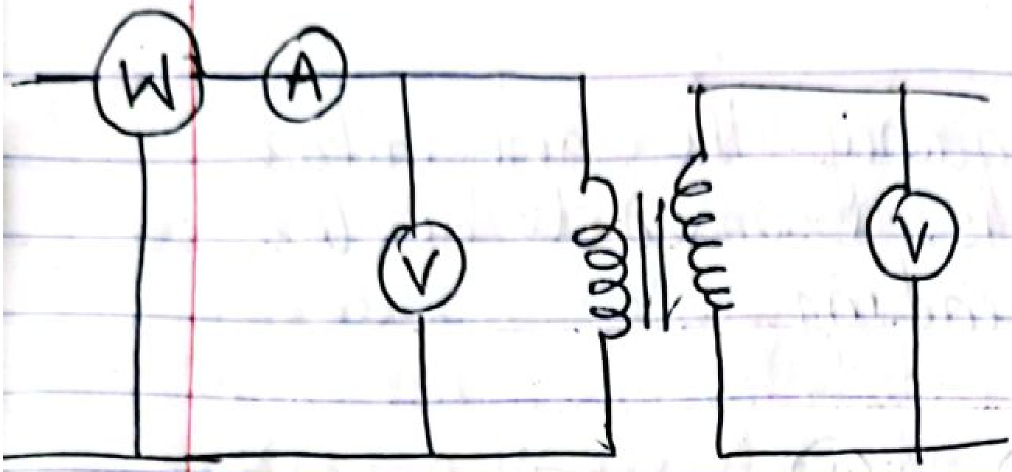


There is a type of autotransformer called a VARIAC which is used to regulate the voltage applied to a particular device from 0 to a certain maximum value V_{max}. In the starting of induction motors variacs are used to start IM's of rating 5hp and above. This is in order to limit the high surge of current (starting current) which usually occurs when the motor is started direct-on-line. Induction motors of low horse powers hp<5 are usually started direct-on-line.

Determination of Transformer Parameters

ⓐ open circuit test

The high voltage winding is on open circuit and the low Voltage winding is connected to a variable voltage supply, at normal frequency. The primary is assumed to be the low voltage winding



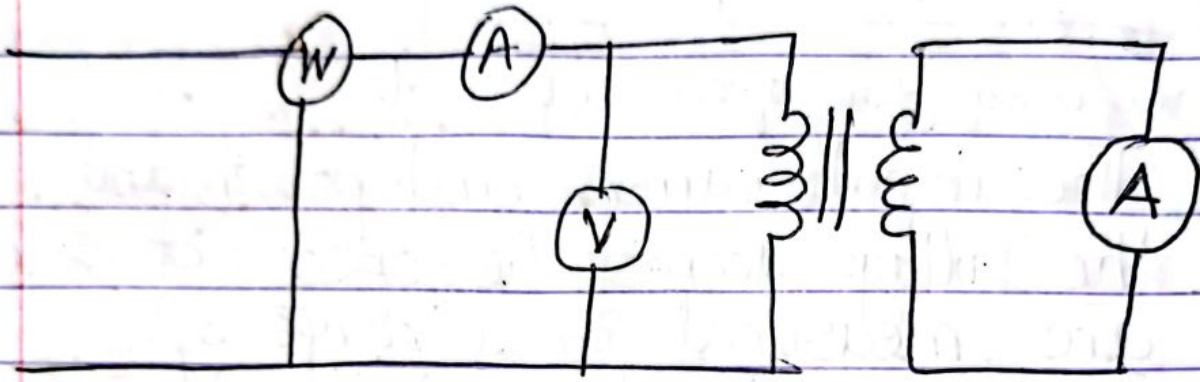
connections for open cct test

The input current and power and the voltage accross the open cct winding are measured for a range of applied voltages up to 125% of the rated voltage.

Then at rated voltage
Iron losses $P_i = V^2 g$ ie $g = P_i / V^2$
open cct admittance $y = I / V$
magnetising susceptance $b = \sqrt{y^2 - g^2}$

(b) short circuit test
The low voltage winding is short circuited through an ammeter and the high voltage winding is connected to a variable voltage supply at

normal frequency. The high voltage winding is assumed to be the primary winding.



connections for short cct. test

~~Copper loss $P_c = I^2R$ Total resis~~

The input current, power, voltage accross the high voltage winding are measured for a range of short circuit currents up to 125% of the rated current

Copper loss $P_c = I^2R$; Total resistance $R = P_c / I^2$

Short circuit impedance $Z = V/I$

Total leakage reactance $X = \sqrt{Z^2 - R^2}$

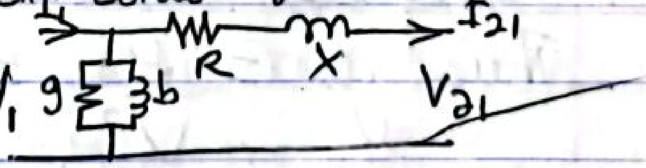
* PER UNIT QUANTITIES *

Example 4.3

The results of the open-circuit and short circuit tests of a 230/100 V 10kVA single phase transformer are as follows

	primary	secondary
open cct test	open cct	100V 6A 154W
short cct test	18V, 43.5A, 240W	short-circuit

Determine the parameters of the approximate equivalent circuit of the figure below and express these quantities as per unit values



Solution

From the short cct test

$R = R_1 + R_{21} = \frac{P}{I^2} = \frac{240}{43.5^2} = 0.127\Omega$

$Z = \frac{V}{I} = \frac{18}{43.5} = 0.414\Omega$

R_{21} is the secondary resistance referred to the primary

$$X = X_1 + X_{21} = \sqrt{Z^2 - R^2} = 0.394\ \Omega$$

Since the open circuit test was performed with the primary on open circuit the results of this tests must be referred to the primary if parameters applicable to ~~the~~ an equivalent circuit referred to the primary are to be obtained. The results of the open cct tests become

$$\frac{100 \times 230}{100} = 230\text{V}, \quad 6 \times \frac{100}{230} = 2.61\text{A},$$

154W

Thus $g = \frac{P}{V^2} = \frac{154}{(230)^2} = 0.00291$ mho

$$y = \frac{I}{V} = \frac{2.61}{230} = 0.01136 \text{ mho}$$

$$b = \sqrt{y^2 - g^2} = 0.01094 \text{ mho}$$

$$Z_{pu} = \frac{Z}{Z_b} \qquad Z_b = \frac{V_r}{I_r} = \frac{V_r^2}{(VA)_r}$$

$$= \frac{230^2}{10 \times 10^3} = 5.28$$

$$R_{pu} = \frac{R}{Z_b} = \frac{0.127}{5.28} = 0.024$$

$$X_{pu} = \frac{X}{Z_b} = \frac{0.394}{5.28} = 0.0784$$

$$Y_b = \frac{I_r}{V_r} = \frac{1}{Z_b} = 0.189$$

$$g_{pu} = \frac{0.00291}{0.189} = 0.0154$$

$$b_{pu} = \frac{0.01094}{0.189} = 0.058$$

Efficiency

The losses in a transformer are limited to the following :

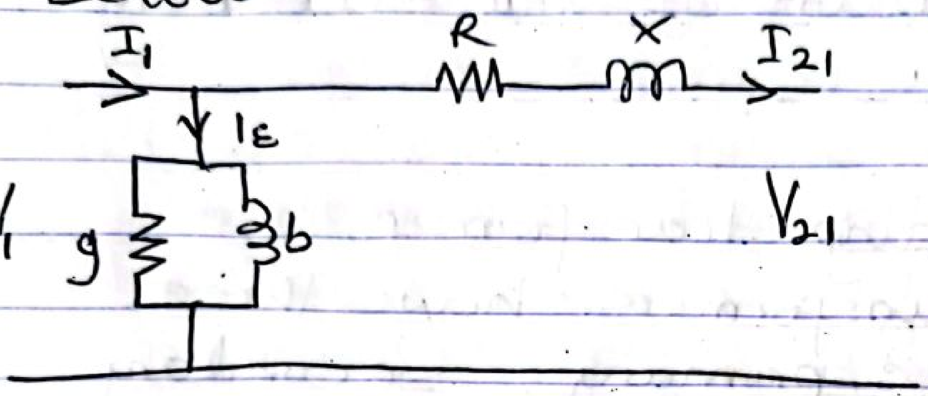
1. Copper loss in the resistance of the windings which is variable with load current
2. Iron loss in the core made up of component hysteresis and eddy current losses which are usually considered to be constant
3. Stray loss produced by stray flux producing eddy current losses in the conductors
4. Dielectric loss in the insulating material which is appreciable only in the particular case of high voltage transformers

{NOTE that apart from live transformers we also have instrument transformers & welding transformers.}

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

$$= \frac{\text{Output}}{\text{output} + \text{losses}}$$

For the approximate epuivalent cct below



$$\text{Efficiency pu} = \frac{V_{21pu} I_{21pu} \cos\phi}{V_{21pu} I_{21pu} \cos\phi + I_{21pu}^2 R_{pu} + V_{1pu}^2 g_{pu}}$$

Three phase transformers.

Three phase transformers usually have all three phases on one iron structure and can be connected in Y – Δ (Star – Delta) or Δ – Y (Delta – Star). other possible connections are Y – Y and Δ – Δ where the first symbol refers to the connection of the primary windings and the second symbol refers to the connection of the secondary windings.

Three winding transformers.

Some transformers have three windings : primary, secondary and tetiatry windings.

It is possible to measure three impedances by the standard short circuit tests as follows

Z_{ps} = leakage impedance measured in primary with secondary short circuited and tetiary open

Z_{pt} = leakage impedance measured in primary with tetiary short-ctted and secondary open

Z_{st} = leakage impedance measured in secondary with tetiary short circuited and primary open we note that

$$Z_{ps} = Z_p + Z_s$$
$$Z_{pt} = Z_p + Z_t \qquad \text{eqn } *$$
$$Z_{st} = Z_s + Z_t$$

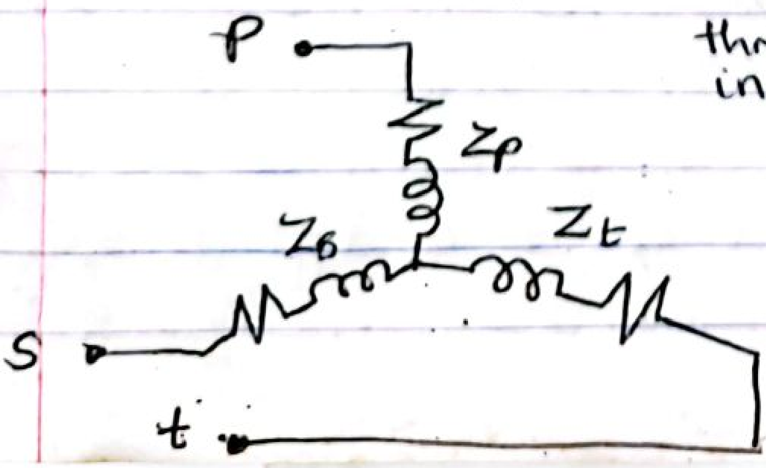
where Z_p, Z_s and Z_t are the impedances of the primary, seconday & tetiary windings refered to the primary cct and Z_{ps}, Z_{pt}, Z_{st} are the measured empedances refereed to the primary cct.

Solving eqn * simultaneously will then yield

$$Z_p = \frac{1}{2}(Z_{ps} + Z_{pt} - Z_{st})$$

$$Z_s = \frac{1}{2}(Z_{ps} + Z_{st} - Z_{pt})$$

$$Z_t = \frac{1}{2}(Z_{pt} + Z_{st} - Z_{ps})$$



The impedances of the three windings are conected in star to represent the equivalent cct of a three wending transformer with magnetising current neglected.

Example 4.4

The three phase ratings of a three winding transformer are

primary Y connected, 66 kV; 15 MVA
secondary Y connected, 13.2 kV, 10 MVA
Tertiary Δ connected, 2.3 kV, 5 MVA

Neglecting resistance, the leakage impedances are

Z_{ps} = 7% on 15 MVA 66 kV base
Z_{pt} = 9% on 15 MVA 66 kV base
Z_{st} = 8% on 10 MVA 13.2 kV base

Find the per unit impedance of the star connected equivalent circuit for a base of 15 MVA, 66 kV in the primary cct.

~~Solution~~

{ NB. In Electrical Power Systems, when PU is used & a base is chosen for Power, it is the same on all sides of the elements of the system eg transformers, gen etc. However, for voltage quantities the base value changes when a transformer is encountered depending on the turns ratio. See earlier notes on PU. }

Hint: With a base of 15 MVA, 66 kV in the primary circuit the proper bases for the per-unit impedances of the equivalent circuit are 15 MVA, 66 kV for primary circuit quantities, 15 MVA, 13.2 kV for secondary cct quantities and 15 MVA 2.3 kV for tertiary circuit quantities.

Solution:

Z_{ps} and Z_{pt} were measured in the primary circuit and are therefore already expressed on the proper base for the equivalent circuit. No change of voltage base is required for Z_{st}. The required change in base kVA for Z_{st} is made as follows

$$Z_{st} = 8\% \times \frac{15}{10} = 12\%$$

$$Z_p = \frac{1}{2}(j0.07 + j0.09 - j0.12) = j0.02_{pu}$$

$$Z_s = \frac{1}{2}(j0.07 + j0.12 - j0.09) = j0.05_{pu}$$

$$Z_t = \frac{1}{2}(j0.09 + j0.12 - j0.07) = j0.07_{pu}$$

The great advantage of using per unit values is that no computations are necessary to refer an impedance from one side of a transformer to the other. The following points should be kept in mind:

1. A base kilovolts and base kilovoltamperes are usually selected in one part of the system. The base values for a three phase system are usually line to line kilovolts and three phase kilovoltamperes or megavoltamperes.
2. For the other parts of the system, that is, on the other sides of transformers, the base kilovolts for each part is determined according to the line-to-line voltage ratios of the transformers. The base kilovoltamperes will be the same in all parts of the system. It will be helpful to state the base kilovolts of each part of the system and mark it on

the diagram

3. Impedance information available for three-phase transformers will usually be in per unit or percent on a base determined by the ratings.

Transformer Taps & Voltage Regulators

In almost all real distribution transformers, there are a series of taps in the windings to permit small changes in the turns ratio of the transformer after it has been built. These taps cannot normally be changed while power is being applied to the transformer. There are however special transformers called Tap Changing Under Load (TCUL) transformers or Voltage Regulators. A TCUL transformer is a transformer with the ability to change taps while power is connected to it. A voltage regulator is a TCUL transformer with built-in voltage sensing circuitry that automatically changes taps to keep the system voltage constant. Such special transformers are very common in modern power systems.

You will learn more about this in your power system analysis.

Transformers are important to modern life mainly because they are used in a power system to step up voltages for transmission and step them down for local distribution. The use of a transformer to step up the voltage for transmission over long distances reduces the losses because the current is very low and thus the power loss which is proportional to the square of the current is also very low.

Recall in an ideal transformer

$$V_1 I_1 = V_2 I_2$$

$\therefore$ high V_2 will result in low I_2 to maintain the equation.

POWER SUPPLY & DISTRIBUTION

Voltage Structure of the Electric Energy System

The U.S. Standard operating voltages are given below

Voltage class	Nominal line voltage
low	120/240V single phase
	208V
	240V
	480V
	600V
medium	2.4kV
	4.16kV
	4.8 kV
	|
	69.0kV
High	115KV
	138KV

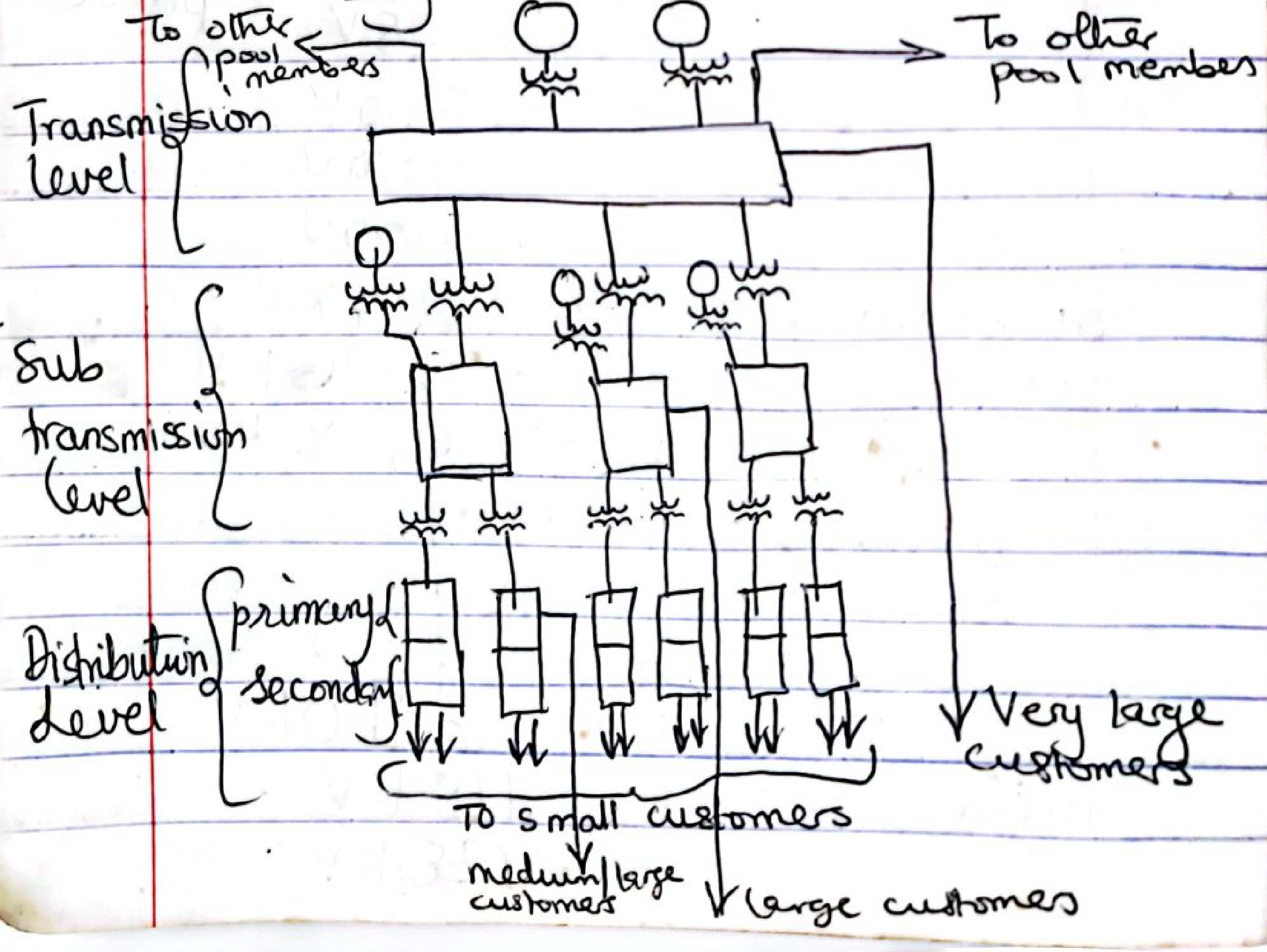
~~230kV~~

230 kV

Extra high 345 kV

765 kV

Power system structure



① Distribution level

ⓐ The primary or feeder voltage (eg [illegible]kV)

ⓑ The secondary or consumer voltage 120/240 V

② Subtransmission level

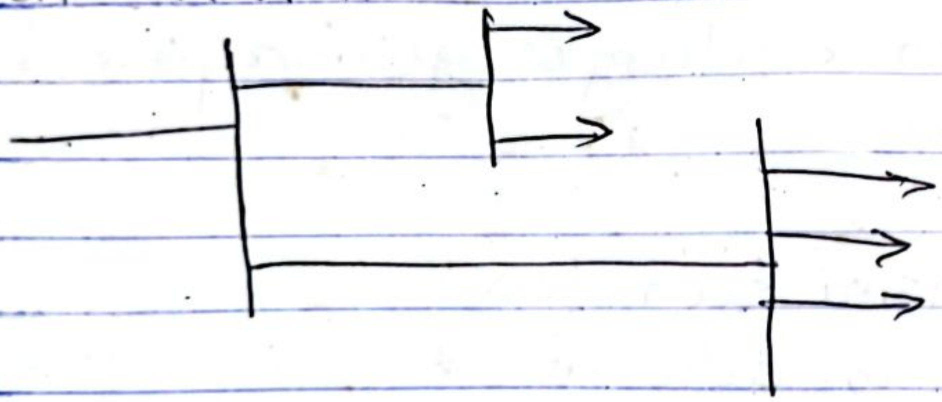
The sub transmission circuit distributes energy to a number of distribution networks and serves a larger geographical area

③ Transmission level

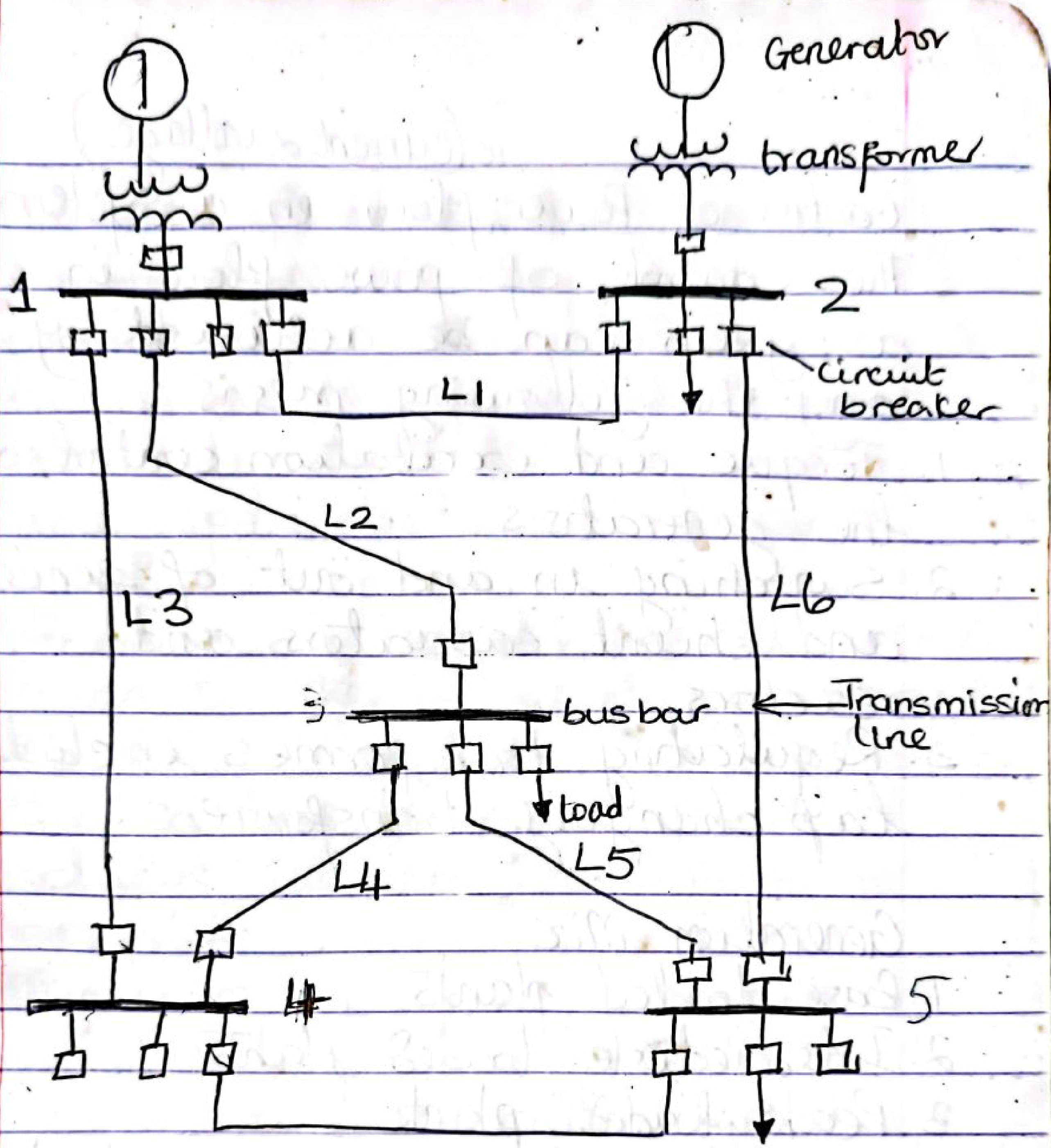
This is different both in operation & characteristics from the distribution & subtransmission systems.

It handles the largest blocks of power; It interconnects all the generator stations and all the major loading points in the system. Usually energy can be routed in any desired direction on the various links of the transmission system in a way that corresponds to the best overall operating economy or best serves a technical objective.

The network structure of subtransmission and distribution systems are usually radial in nature



while the network structure for the transmission system tends to be of a loop structure



One line diagram of power system.

A bus is a nodal point of a transmission network.

NODE = JUNCTION = CORNER = POINT
WHERE CONNECTIONS ARE MADE

ie (current & voltage)

Control of Power flow in a system.

The control of power flow in a system can be achieved by ~~any~~ the following means:

1. Torque and excitation control of the generators
2. Switching in and out of series and shunt capacitors and reactors
3. Regulating transformers including tap changing transformers.

Generation Mix

1. Base loaded plants
2. Intermediate loaded plants
3. Peak loaded plants
3. Reserve units/plants are plants installed in order to meet unforseen emergencies.

Maintaining a proper generation mix is a most important requirement for a power company. The operating

success of a utility company such as NEPA depends to a great extent upon the ability optimally to match the generation to the load not only over the 24hour daily time span but over seasons and years.
Economic dispatch is the name given to the process of apportioning the total load on a system between the various generating plants to achieve the greatest economy of operation
Minimum economic generation cost is a relevant criterion and power systems are typically operated so as to achieve minimum overall cost. Optimum dispatch equations are usually derived and solved in order to know the optimum generator megawatt setting for the generating units. The problem arises in the

implementation of the ODE solutions in "real time". This is achieved by the following methods.

1. Automatic Voltage Regulator control loop which controls the magnitude of the terminal voltage, V.
2. The Automatic load - frequency control loop which regulates the megawatts output and frequency (speed) of the generator. Normally these

~~see diagram on p. of Elgerd.~~

have sensors that senses the voltage or frequency as the case may be and automatic controls that adjusts the settings to achieve the desired values.

An example in Complex power?

END!

RG FORM 1997/97
₦500.00 Bank draft
+ about 160.00 to pay
for the draft
₦550.00 cash

Total ₦1210.00 estimated

Explain briefly

(10) 1a ~~What are~~ the parameters of an electric transmission line. ~~which enable it to fulfil its function as part of a power system~~

(25) b A 50Hz 3 phase transmission line has a total series impedance of 25 + j 120 Ω and shunt admittance of $970 \times 10^{-6} \angle 90°$ ℧. It delivers 50 MW at 220 kV with 90% power factor lagging. Find the voltage at the sending end by

(a) The short line approximation.

~~(b) The nominal π approximation~~

(5) 2a What is a transformer?

(10) b Develope the practical transformer concept starting from the ideal transformer analysis

(10) c Mention and write about two types of transformers you know?

3. A single phase transformer has 2000 turns on the primary and 500 turns on the secondary. Winding resistances are $r_1 = 2.5\Omega$ and $r_2 = 0.15\Omega$. Leakage reactances are $x_1 = 8.0\Omega$ and $x_2 = 0.25\Omega$. The resistive load Z_2 is 12Ω. If the applied voltage at the primary winding is 1500V, Find V_2 and the voltage regulation. Neglect magnetising current.

(25)

4. (a) Using block diagrams, highlight and explain the processes of energy conversion in the nuclear, fossil fueled and hydro power stations

(9)

pix 2
exp 1

(b) What are the economic considerations that arise ~~when~~ in

(6)

3 considerations
2 marks each

The planning of a power station:

1 — 25%
2 — 25%
3 — 25%
4 — 15%
Assignment — 10%

TRY AND MAKE IT a 2hr paper to save time.

WK 7 22 - 26

Winding design Interpretation and circuit connection diagrams.

Three days of lectures

MON , WED , FRI

Recommended Text

1. Alternating Current Machines; SAY, M.G
2. Electric Machinery fundamentals SJ Chapman
3. Electrical Machine Design Balbir Singh

INTRODUCTION

Basically electric motors are devices which convert electrical energy to mechanical energy. In this regard they are seen as prime movers or drives. All rotating electrical equipment have one form of electric motor or the other.

The magnetic field.

Magnetic fields are the fundamental mechanisms by which energy is converted from one form to another in motors generators and transformers.

There are 4 basic principles

(1) A current carring wire produces a

magnetic field in the area around it. This is ampere's law

$$\oint H \cdot dl = I_{net}$$

H = magnetic field intensity
I_{net} = current

μ of air is quite low
μ of silicon steel is high

$$B = \mu H$$

μ = magnetic permeability of the material
B = resulting magnetic flux density produced.

② A time-changing magnetic field induces a voltage in a coil of wire if it passes through that coil (This is the basis of the transformer action)

(3) A current carrying wire in the presence of a magnetic field has a force induced on it. This is the basis of the motor action.

The force induced on the conductor is given by the equation

$$F = i(L \times B)$$

i = magnitude of current in wire
l = length of wire (vector)
B = magnetic flux density (vector)

$$= i l B \sin \theta$$

where θ is the angle b/w the wire and the flux density vector.

④ A moving wire in the presence of a magnetic field has a voltage induced in it. This is the basis of the generator action

INDUCTION MOTORS

① Wound Rotor induction motor (also called slip ring I.M.)

② SQUIRREL CAGE induction motor.

Basic Concepts.

When a three-phase voltage is applied to the stator of an induction motor and a three-phase current is flowing, these currents produce a magnetic field. The speed of the magnetic field is given by

$$N_{sync} = \frac{120 f_e}{P}$$

f_e = System frequency in Hertz

P = no of poles in the

machine.

The rotor or shaft of the electric motor does not move at the synchronous speed N_{sync} but at a speed slightly less than that it (N_m)

$$N_{slip} = N_{sync} - N_m$$

N_{slip} = slip speed

$$\text{Slip } s = \left(\frac{N_{sync} - N_m}{N_{sync}}\right) \times 100\%$$

The less the slip the more efficient the machine but the slip can never be zero. This is because the rotor frequency is ~~given b~~ never equal to the stator frequency. So we have the eqn:

$$f_r = s f_s$$

f = rotor frequency

The windings of an induction motor are what determine the performance of the motor in terms of speed, hp, starting torque, etc. This means that we must correctly interprete the winding design, and follow the correct winding & finishing procedures to achieve efficient and long lasting electric motors.

Winding Types
① MUSH (1 per slot)
② LAP including DOUBLE LAYER LAP (WAVE)
③ CONCENTRIC including DOUBLE LAYER CONCENTRIC

Need for Documentation
* Because of the various types of windings employed in single phase & 3 phase motors, there is an absolute need to

keep records of all the electric motors we come across as electric motor rewinders. We know that a Winding Design hase 2 portions,

① - the drawing

② - The specifications (detailed)

eg NO OF SLOTS

NO of TURNS

WINDING TYPE

COIL SPAN etc.

Again the nameplate of the electric motor contain relevant information for documentation eg.

1. Output power

Voltage

Current

Power factor

Speed

Nominal efficiency

NEMA design class

Starting code

Since there is a relationship

between the winding arrangement and the output (performance) of the electric motor, we need to document these 2 groups of data for each electric motor re-wound.

This data and information would serve as a guide when we meet similar motors either having their coils striped or so burnt out that one cannot possitly dertermine correctly the parameters of the motor, OR one rewound in a place where such care is not taken and may have been rewound incorrectly.

Remember that an electric motor was first of all designed by some ~~one~~ ~~befo~~ people — both the magnetic cct, the windings, the shaft etc. before being wound.

For eg this equation below is the output equation for an 3-ph induction motor

$$= 3 (E_{ph})(I_{ph}) \times 10^{-3}$$

$$KVA = 3\left[k_{w1} (4.44)\left(\frac{P}{2} \times n\right) N \left(\frac{B \pi D L}{P}\right)\right] \times \left(\frac{q \pi D}{6N}\right) \times 10^{-3}$$

$$= 1.11 k_{w1} \pi^2 (Bq)(D^2 L n) \times 10^{-3}$$

KVA = input to the motor in kVA

k_{w1} = winding factor

B = average flux density (wb/m^2)

q = amp-cond per unit air gap circumference (in amp cond/m)

L = stator length (m)

D = stator bore diameter (m)

n = synchronous speed (rps)

P = no of poles

N = No of Turns per phase

$$q = \frac{\text{total ampere conductors}}{\pi D}$$

$$= \frac{\text{CURRENT} \times \text{Total conductors}}{\pi D}$$

$$\text{Total conductors} = \frac{q * \pi D}{I}$$

$$= C_T$$

$$\text{Conductors / slot} = \frac{C_T}{S_1}$$

~~C_s~~ =

$$= C_s$$

S_1 = no of stator slots

~~For~~ The no of conductors / slot is equivalent to the number of Turns per slot in the winding design specifications.

Furthermore ~~Conductors/phase = ...~~

* WORKSHOP PRACTICE
* WINDING DESIGN INTERPRETATION
* PRACTICAL ACHIEVEMENT OF THE DESIRED NO OF POLES.

→ MUSH, LAP, CONCENTRIC.

2/9/17 ELETRIC MOTOR for REWINDING
LEROY-SOMER
Frame LS80L1 No 63714 IP44
Hp 0.55 - 0.75
eff (cosθ) 0.75 - 0.68
RPM 1400
Hz 50
ph 3
Insulation Class B
ΔV } 240 V, 2.62 A
λV } 415 V, 1.51 A

P.T.O.

Masters in Industrial Relations pg course
ESUT or
Personnel management (MFA)

CONCENTRIC
COIL SPAN 1-6-8
NO OF TURNS 140
NO OF SLOTS 24
SIZE OF COILS SWG (24)
DIAGRAM

The Chairman
ESUT Research Grant
Through Prof Nwodo

Date:

CS CamScanner

MODEM Problems

configuration

ERROR message while atempting to deliver mail

* We most likely have not configured the Mail service or Modem settings properly in the Mail service Dialogue.

WHAT TO DO

check modem. log file
RFD mail prof exec.

MODEM
PREFERENCES

Redial : 5
Connect 45
Modem
Int Strg (press :) ie shift 

AT&F/AT&C1&D2
(*no spacing b/w characters)

Default service
rmrdc

We checked the modem.log file (using file manager. First Associate with Text files (NOTEPAD.EXE)
To get the following Info

Notepad MODEM.LOG

ATDT095326035

BUSY
ATDT095326035

BUSY
ATDT095326035
P
BUSY
ATDT095326035

BUSY
ATDT095326035

BUSY

↓ etc.

We checked the modem.log file (using file manager. First Associate with Text files (NOTEPAD.EXE)

To get the following Info

Notepad MODEM.LOG

ATDT095326035

BUSY

ATDT095326035

BUSY

ATDT095326035

BUSY

ATDT095326035

BUSY

ATDT095326035

BUSY

↓ etc.

Thinking It Over

- Pray in the morning (early)
  Say 3am or 4am or 5am

- Pray at noon
  say • 12noon or 1pm or 2pm

- Pray At night
  say 9pm or 10pm or 11 pm

By the grace of God.

It's not by might, it's not by power but by the Spirit of the LORD.

Assignment

1) Discuss NEPA and its attempts to provide electricity for the whole country. What do you think are her constraints

2) The three main compon
Fixed charges, O & M, fuel or energy cost, Explain them.

Expansion of the Armour of God. [THROUGH CONFESSION]

i Grid your loins with truth
ii Put on the breastplate of righteousness
iii Shod your feet with the gospel
iv Take up the shield of faith
v Put on the helmet of salvation
vi Use the sword of the spirit

Expansion on Prayer

Use all manner of prayer

- confession & cleansing
- * Consecration → submission or dedication to the will of God.
- prayer of faith
- Intercession
- petition
- agreement
- Binding and Loosing
- commitment of your way unto Him & casting of Burden upon Him
- * worship and praise
- * Thanksgiving for answered prayer received by faith.

The crux of the matter is knowing His will and praying for it

What do you want us to do O Lord?

See Matt 6 : 33
But seek ye first the kingdom of God and His righteousness and all these things shall be added unto you.

Psalm 27 : 4
One thing have I desired of the LORD, that will I seek after; that I may dwell in the house of the LORD all the days of my life to behold the beauty of the LORD and to inquire in his temple.

MESSAGE : WATCH & PRAY

PRAYER POINTS (RISE EARLY!)
For myself.
(* confession of sins)

1 Praise & Worship
ⓐ Thanksgiving
ⓑ Praises — songs, choruses, hymns.

② Pray for the Day
ⓐ Commit the day into His hands.
ⓑ Pray not to enter into temptations
* ⓒ Confess sins (if convicted of any)
ⓓ Present my body as a living sacrifice unto Him
lay down my own will
lay down my own desires
lay down my own ways
& accept His own. my own being esp my members (hands, feet etc)

ⓔ Ask for the filling of the Holy Spirit

(R) Submit to the authority of a church (local New Testament church)

(F) Put On the whole armour of God Ephesians 6:13-18
Fight against the real enemy — the devil behind the scenes. spiritual wickedness in high places, the prince of darkness, the prince of the power of the air, all principalities & powers.
Cast out all fear, lust, pride, jelousy, anger, malice, contempt, evil thinking, wandering thougths etc.

13 Pray for Others
(a) For their salvation
(b) For progress both spirictual and material
(c) For specific gifts such as children, His protection

1997 TAX INFO

Spouse Mr Kesandu Uchenyi
Lecturer (Civil Servant)

dependent Relatives

Mr Henry Osakwe, Abakpa	70	₦13500	₦1
Mrs Lucy Uchenyi, Abakpa	61	₦12000	

Children

Uzoamaka	1994	—
Chioma	1996	—
* Grinme Ogbonnaya	1985	Abakpa P
* Nnenna Ogbonnaya	1981	Commercial School Abak (BASIC)

* Mr & Mrs Ogbonnaya
Trader Abakaliki

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ENGR. UCHENYI KESANDU

Association of Electrical and Electronics
Engineering Students,
Faculty of Engineering, AC campus,
ESUT, Enugu.
15th February, 2017.

Dear Sir,

LETTER OF INVITATION TO THE INAUGURATION OF NEW DEPARTMENTAL EXCOS

Owing to the just concluded departmental elections of new executives as well as the departmental fellowship executives for the 2016/2017 academic year, the Association of Electrical and Electronics Engineering students wishes to use this letter to officially invite you to the handover/inauguration and thanksgiving ceremony of the newly elected executives of the two bodies.

The program is scheduled to take place as follows:

- Venue : Power lab (ASEEES 400level classroom),
- Time: 12:00 noon prompt.
- Date: 17^{th} Feb. 2017

We will be glad if you grace the occasion, because your presence will be one which will send a positive signal of success to both the students and the department at large. Thank you.

Yours Faithfully,

....

NNAMANI CHIZOBA
(PRESIDENT ELECT ASEEES)