Pb A 250 MVA, 25 KV 3ϕ STEAM TURBINE GENERATOR HAS A SYNCHRONOUS REACTANCE OF 1.6 PU AND A TRANSIENT REACTANCE X_d' OF 0.23 P.U. IT DELIVERS IT'S RATED OUTPUT AT A POWER FACTOR OF 100%. A SHORT CIRCUIT SUDDENLY OCCURS ON THE LINE CLOSE TO GENERATING STATION.

CALCULATE (a) BASE IMPEDANCE

(b) RATED VOLTAGE DROP

(c) TRANSIENT REACTANCE

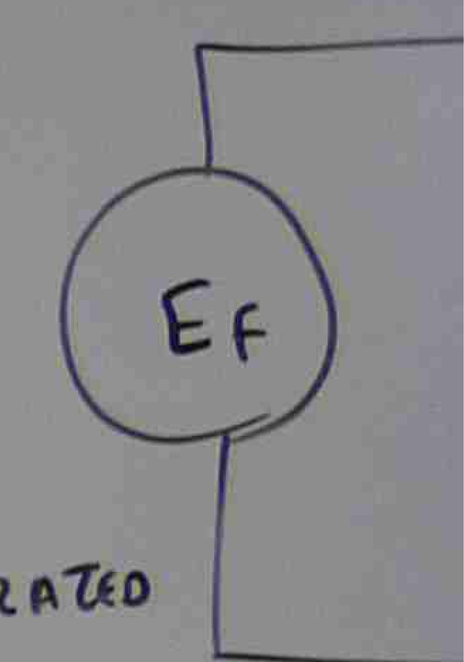
(d) INITIAL SHORT CIRCUIT CURRENT

(e) STEADY VALUE OF CURRENT AT SHORT CIRCUIT.

(a) $$\text{BASE IMPEDANCE} = \frac{E_{BASE}^2}{S_{BASE}} = \frac{(25000)^2}{250 \times 10^6}$$

$$= 2.5\Omega$$

(b) RATED VOLTAGE DROP = RATED CURRENT $\times$ IMPEDANCE



E_F = GENERATED VOLTAGE

I_{RATE}

$X_s =$

=

=

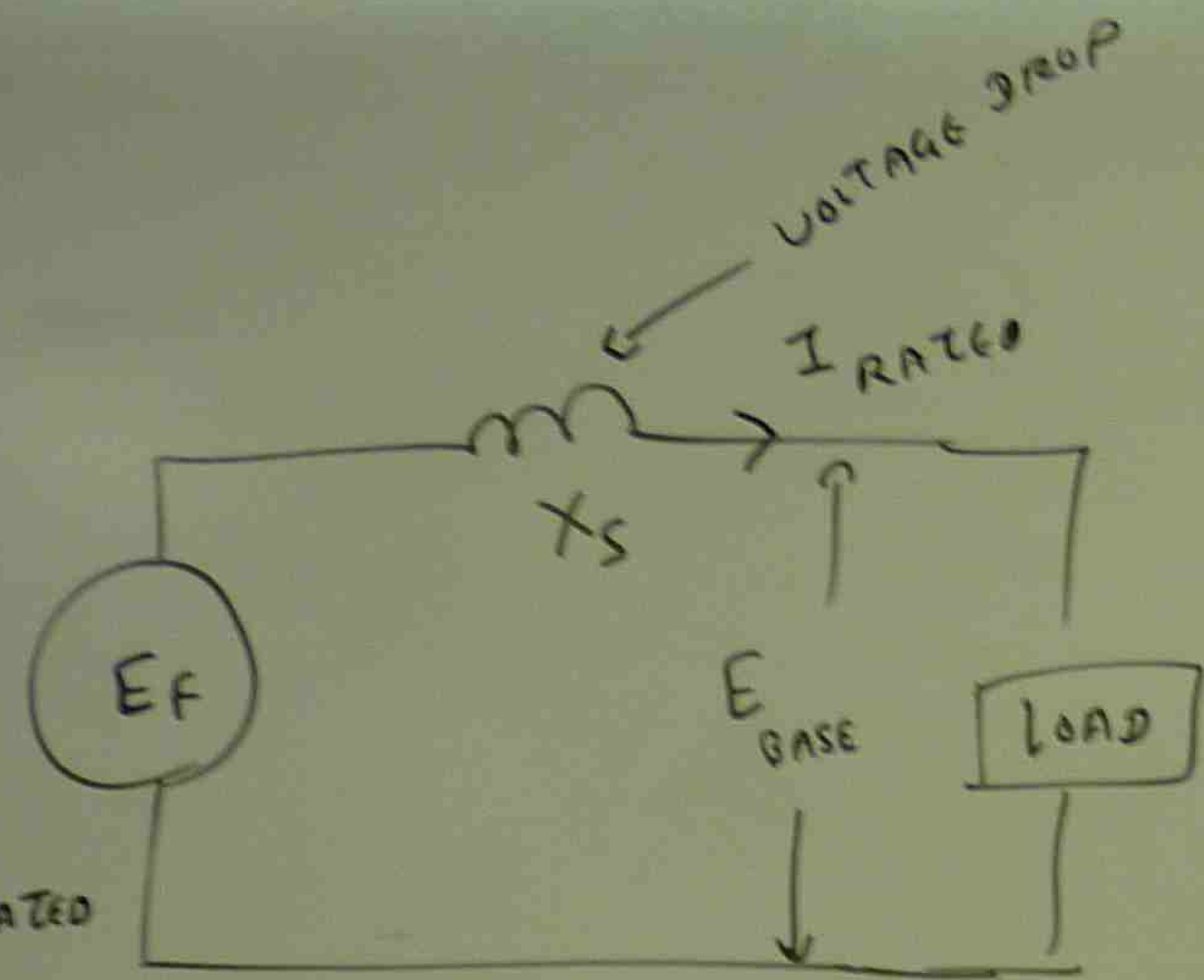
HAS A
ACTANCE
AT A
ON THE

LT.

$$\frac{(25000)^2}{250\times10^6}$$

2.5Ω

IMPEDANCE



E_F = GENERATED VOLTAGE

$$I_{RATED} = \frac{S_{BASE}}{\sqrt{3}\times E_{BASE}}$$

$$= \frac{250\times10^6}{1.7321\times 25\times10^3}$$

$$= 5771 \text{ Amp}$$

$X_S = 1.6$ P.U ← BASE IMPEDANCE

$= 1.6\times 2.5$

$= 4\Omega$

RATED VOLTAGE DROP $= I_{RATED} \times X_S$

$= 5771 \times 4$

$= 23100V$

$= 23.1kV$

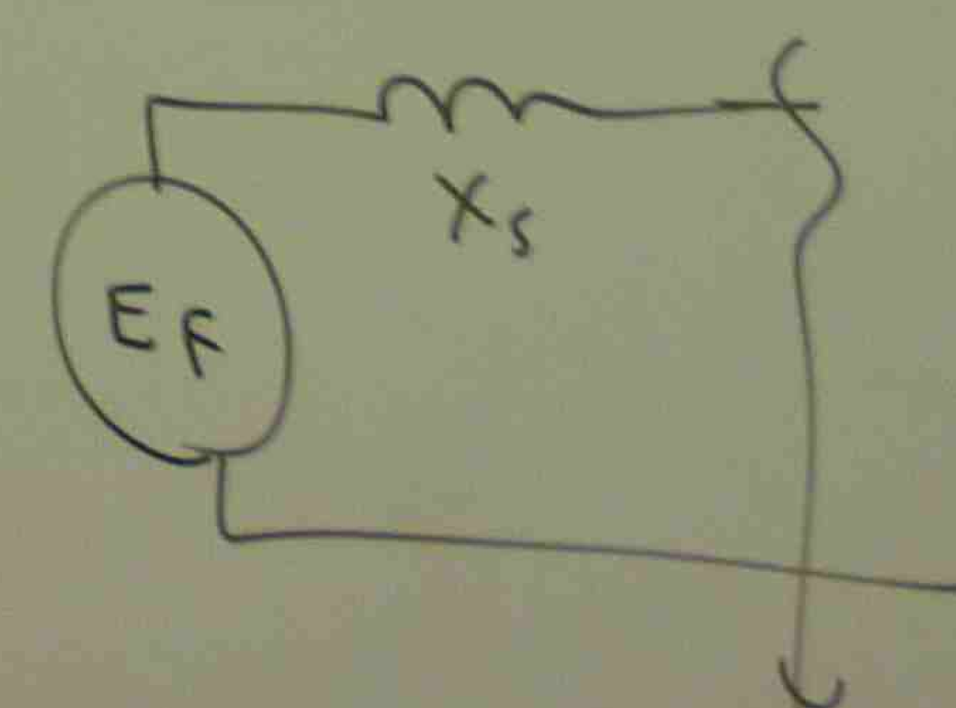
(c) TRANSIENT REACTANCE

$X_d' = X_d'(\text{p.u}) \times Z_{BASE}$

$= 0.23 \times 2.5\Omega$

$= 0.575\Omega$

(d) SHORT CIRCUIT



$E_F = ?$

$E_f =$

INIT

(e) ST

SH

$$E_{BASE(ph)} = \frac{E_{BASE}}{\sqrt{3}} = \frac{25\,kV}{\sqrt{3}} = 14.4\,kV$$

$E_f = ?$

$$E_f = \sqrt{(E_{BASE\,ph})^2 + (I X_{s\,ph})^2}$$

$$= \sqrt{(14.4)^2 + (23.1)^2}$$

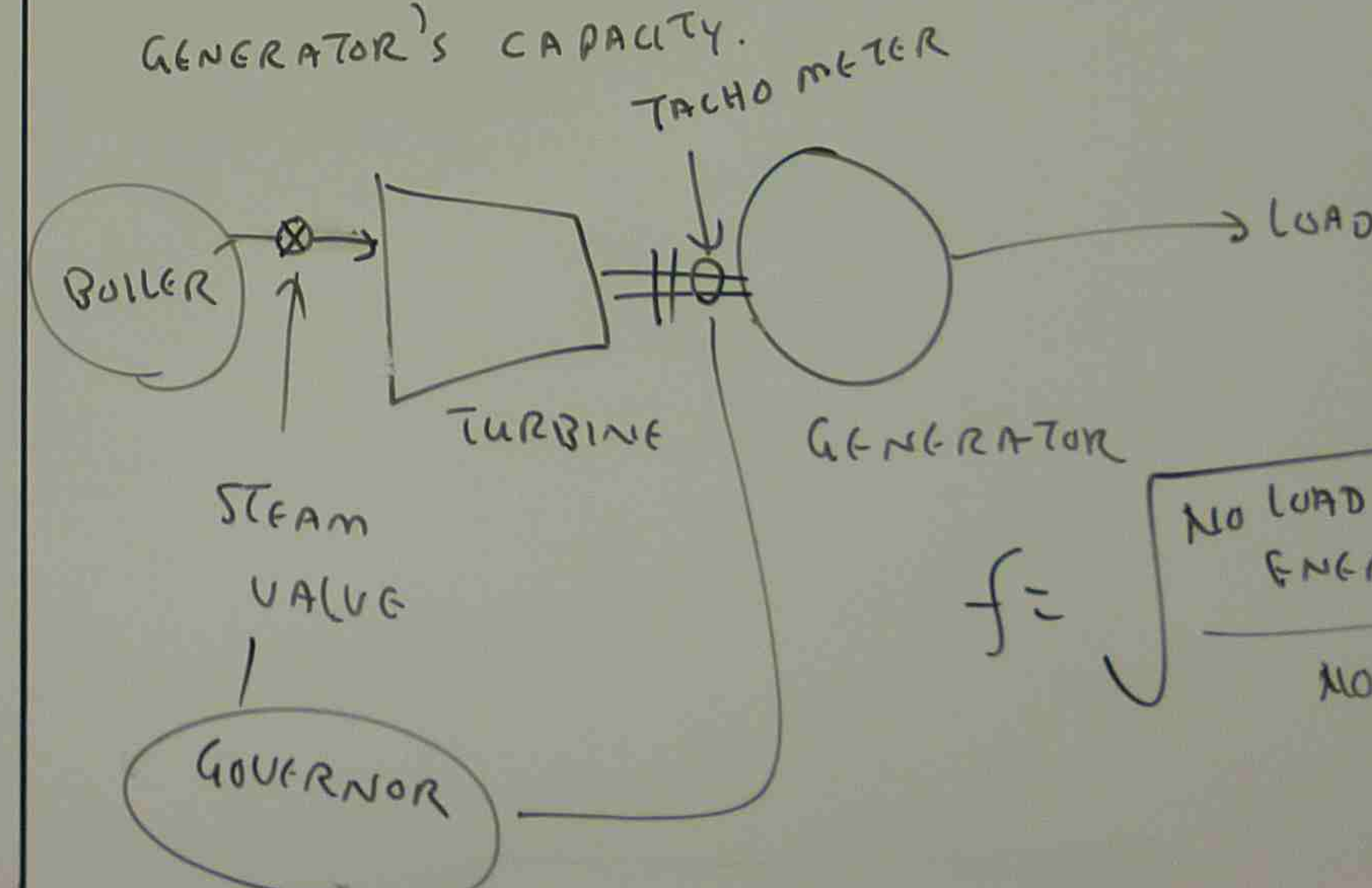
$$= 27.2\,kV$$

$$\text{INITIAL SHORT CIRCUIT CURRENT} = \frac{E_f}{X_d'} = \frac{27.2 \times 10^3}{0.575} = 47300\,A = 47.3\,kA$$

(c) $$\text{STEADY STATE SHORT CIRCUIT CURRENT} = \frac{E_f}{X_s} = \frac{27.2 \times 10^3}{4} = 6800\,A = 6.8\,kA$$

GENERATOR CONTROL LOAD FLOW

pb AN ISOLATED 75 MVA SYNCHRONOUS GENERATOR FEEDS IT'S OWN LOAD AND OPERATES INITIALLY AT NO LOAD AT 3000 RPM, 50 HZ. A 20 MW LOAD IS SUDDENLY APPLIED AND THE STEAM VALVE TO THE TURBINE COMMENCE TO OPEN AFTER 0.5 SEC DUE TO THE TIME LAG IN THE GOVERNOR SYSTEM. CALCULATE THE FREQUENCY TO WHICH THE GENERATED VOLTAGE DROPS BEFORE THE STEAM FLOW MEETS THE NEW LOAD. THE STORED ENERGY FOR THE MACHINE IS 4 KW-S PER KVA OF GENERATOR'S CAPACITY.



$$f = \sqrt{\frac{\text{NO LOAD STORED ENERGY} - \text{APPLIED LOAD ENERGY}}{\text{NO LOAD STORED ENERGY}}} \times \text{RATED FREQUEN[CY]}$$

$$E_{BASE(ph)} = \frac{E_{BASE}}{\sqrt{3}} = \frac{25\,kV}{\sqrt{3}} = 14.4\,kV$$

$$(E_{BASE\,ph})^2 + (I X_{S\,ph})^2$$

$$(14.4)^2 + (23.1)^2$$

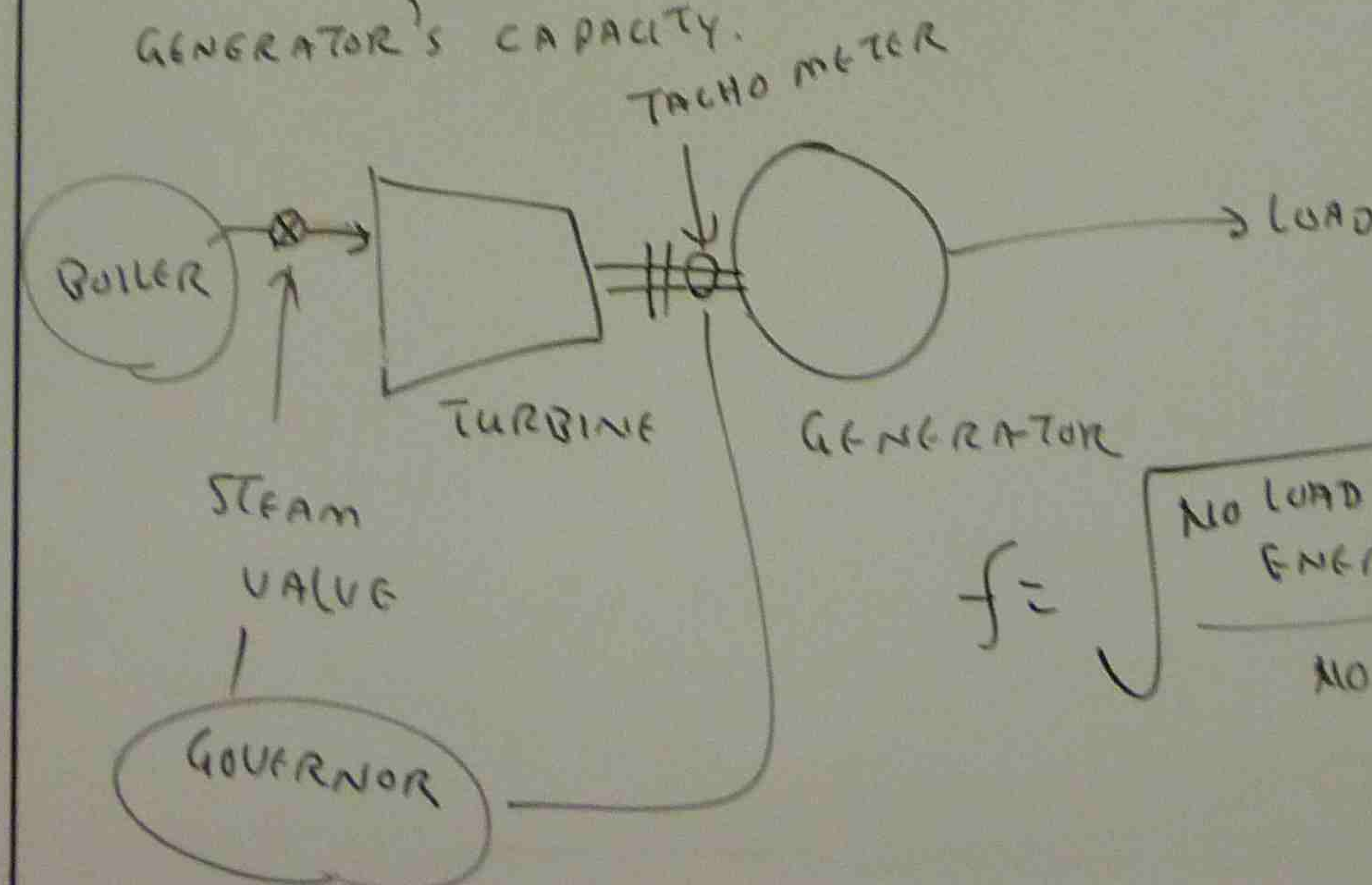
.2 kV

$$\text{RT CIRCUIT } \ldots T = \frac{E_F}{X_d'} = \frac{27.2\times10^3}{0.575} = 47300\,A = 47.3\,kA$$

$$\ldots TE \ldots \text{UIT} = \frac{E_F}{X_s} = \frac{27.2\times10^3}{4} = 6800\,A = 6.8\,kA$$

GENERATOR CONTROL LOAD FLOW

pb/ AN ISOLATED 75 MVA SYNCHRONOUS GENERATOR FEEDS IT'S OWN LOAD AND OPERATES INITIALLY AT NO LOAD AT 3000 RPM, 50 Hz. A 20 MW LOAD IS SUDDENLY APPLIED AND THE STEAM VALVE TO THE TURBINE COMMENCE TO OPEN AFTER 0.5 SEC DUE TO THE TIME LAG IN THE GOVERNOR SYSTEM. CALCULATE THE FREQUENCY TO WHICH THE GENERATED VOLTAGE DROPS BEFORE THE STEAM FLOW MEETS THE NEW LOAD. THE STORED ENERGY FOR THE MACHINE IS 4 KW-S PER KVA OF GENERATOR'S CAPACITY.



$$f = \sqrt{\frac{\text{NO LOAD STORED ENERGY} - \text{APPLIED LOAD ENERGY}}{\text{NO LOAD STORED ENERGY}}} \times \text{RATED FREQUENCY}$$

NO LOAD STO…

APPLIED LO…

f

...ERATOR FEEDS IT'S OWN LOAD

...T 3000 RPM, 50 HZ.

...AND THE STEAM VALVE

... AFTER 0.5 SEC DUE TO

...YSTEM.

... THE GENERATED VOLTAGE

... THE NEW LOAD. THE

4 KW-S PER KVA OF

→ LOAD

$$\frac{\text{NO LOAD STORED ENERGY} - \text{APPLIED LOAD ENERGY}}{\text{NO LOAD STORED ENERGY}} \times \text{RATED FREQUENCY}$$

$$\text{NO LOAD STORED ENERGY} = \frac{\text{KW-S}}{\text{KVA}} \times \text{MACHINE CAPACITY KVA}$$

$$= 4 \times 75 \times 10^3 \text{ KVA}$$

$$= 300 \times 10^3 \text{ KVA}$$

TIME LAG IN GOVERNOR SYSTEM

$$\text{APPLIED LOAD ENERGY} = \text{POWER OF APPLIED LOAD} \times \text{TIME}$$

$$= 20 \times 10^3 \text{ KW} \times 0.5$$

$$= 10 \times 10^3 \text{ KW}$$

$$f = \sqrt{\frac{(300 \times 10^3 - 10 \times 10^3)}{300 \times 10^3}} \times 50$$

$$= 49.2 \text{ HZ}$$

$$\sqrt{\frac{300-10}{300}} \times 50$$

$$\sqrt{\frac{290}{300}} \times 50$$

pb) Two ...

ENDS O...

AND WI...

IS TO ...

CALCULA...

OF CUR...

POWER TR...

PER P...

VOLTAGE D...

DUE TO P...

TRANSF...

CAPACITY

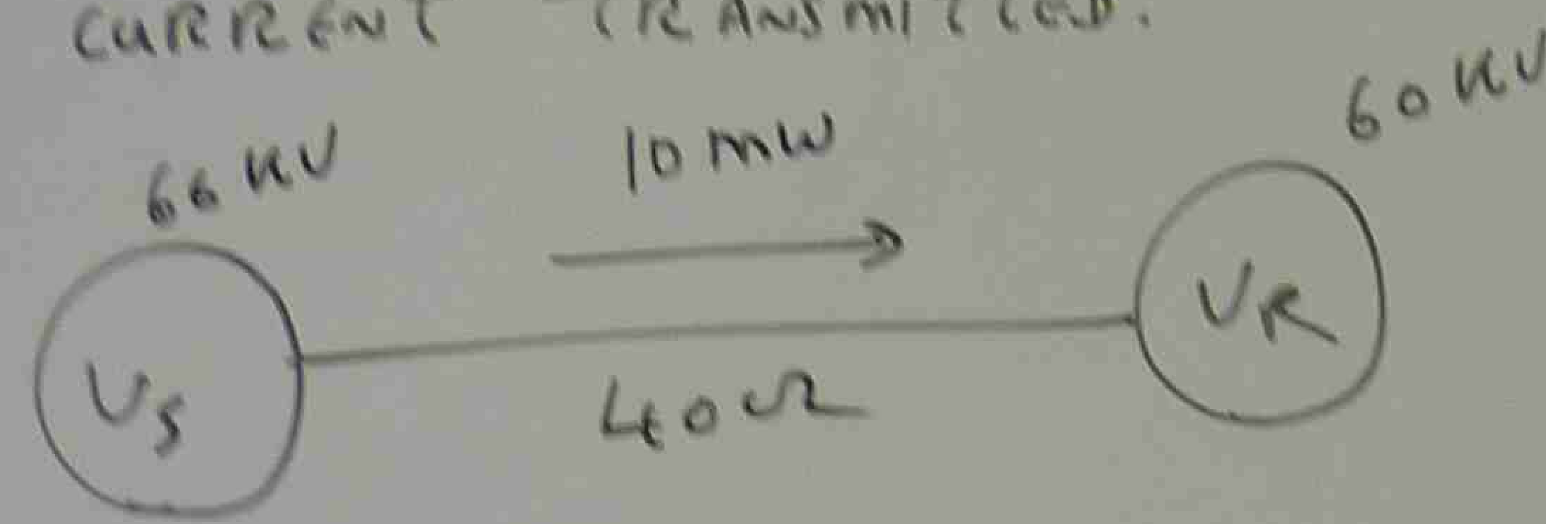
VA

TIME LAG IN GOVERNOR SYSTEM

$$\sqrt{\frac{300-10}{300}} \times 50$$

$$\sqrt{\frac{290}{300}} \times 50$$

Pb. TWO UNITS OF GENERATION MAINTAIN 66 KV AND 60 KV LINE AT THE ENDS OF AN INTERCONNECTOR OF INDUCTIVE REACTANCE PER PHASE OF 40 Ω AND WITH NEGLIGIBLE RESISTANCE AND SHORT CAPACITANCE. A LOAD OF 10 MW IS TO BE TRANSFERRED FROM THE 66 KV UNIT TO THE OTHER END. CALCULATE THE NECESSARY CONDITION BETWEEN TWO ENDS INCLUDING P.F OF CURRENT TRANSMITTED.



POWER TRANSFER PER PHASE (ΔP) $= \dfrac{10 \times 10^6}{3} = 3.33 \times 10^6$ WATT

VOLTAGE DIFFERENCE DUE TO POWER TRANSFER $= V_Q = \dfrac{X \times \Delta P}{V_{R(ph)}} =$

$$= \frac{40 \times 3.33 \times 10^6}{\frac{60 \times 10^3}{\sqrt{3}}}$$

$$= 3840\ V$$

POWER ANGLE

$$\sin\delta = \frac{\Delta V_Q}{V_S} = \frac{3840}{\frac{66,000}{\sqrt{3}}} = 0.101$$

$$\delta = \sin^{-1} 0.101 = 5.44^\circ$$

REACTIVE POWER TRANSFER

$$\Delta Q = \frac{E_{S(ph)} \times E_{R(ph)}}{X}$$

$$= \frac{\frac{66,000}{\sqrt{3}} \times \frac{60000}{\sqrt{3}}}{40}$$

$$= 33 \times 10^6\ VAR$$

$$\tan\phi = \frac{\Delta Q}{\Delta P}$$

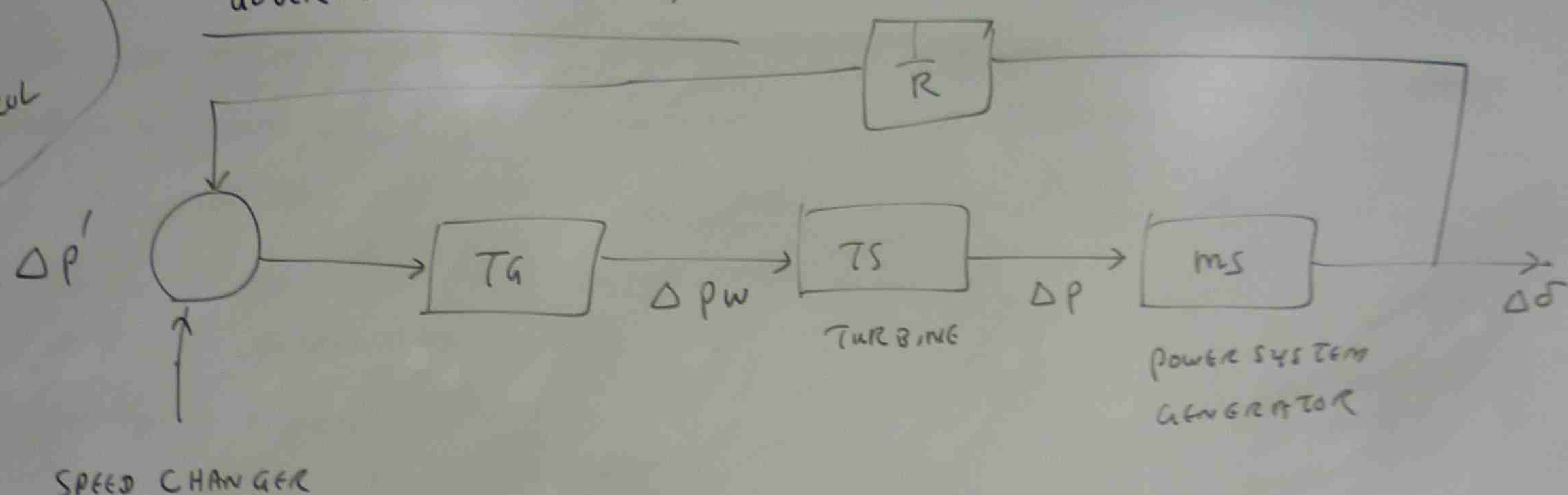
$$= \frac{33 \times 10^6}{3.33 \times 10^6} = 10$$

$$\phi = \tan^{-1} 10 = 84.2$$

$$PF = \cos\phi = \cos 84.2$$
$$= 0.1$$

FREQUENCY + SPEED CONTROL

GOVERNOR CONTROL SYSTEM



$\Delta P'$ = CHANGE IN SPEED CHANGER SETTING

TG - SPEED GOVERNING SYSTEM

ΔP_w = STEAM POWER CHANGE

T_S = TURBINE

ΔP = CHANGE IN TURBINE MECHANICAL POWER OUTPUT

M_S - GENERATOR INERTIA

$\Delta\delta$ = CHANGE IN POWER ANGLE → SPEED

R = SPEED REGULATION (OR) GOVERNOR DROP

$S\delta = $ — M

K = CONST

$\Delta P_L =$

$S\delta =$

S

EGULATION

ERNOR DROP

$$S\delta = \frac{1}{Ms + K}(\Delta P - \Delta P_L)$$

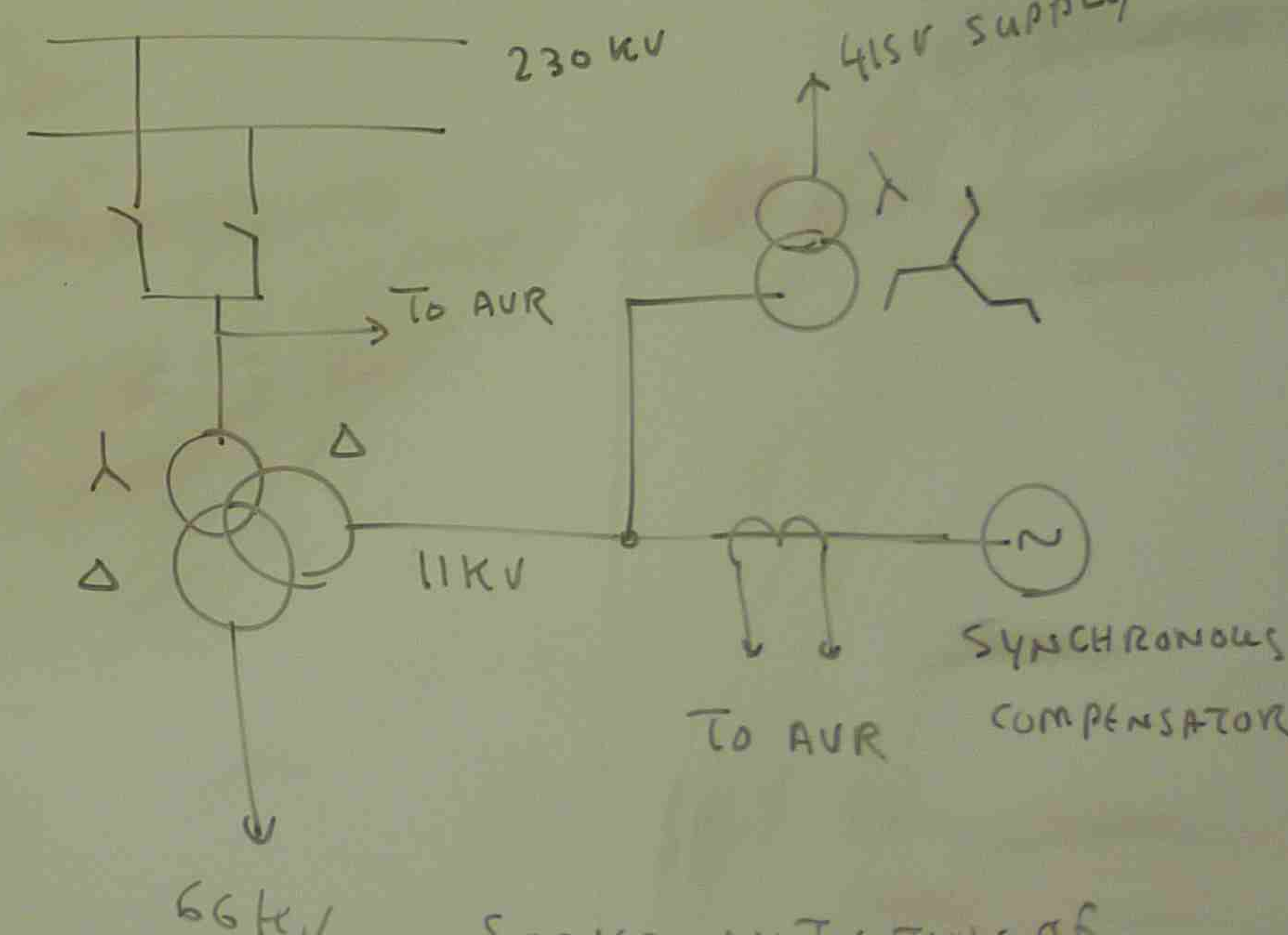
K = CONSTANT

ΔP_L = CHANGE IN PRIME MOVER AND LOAD POWER

$S\delta$ = CHANGE FROM NORMAL SPEED (OR) FREQUENCY

METHODS OF VOLTAGE CONTROL

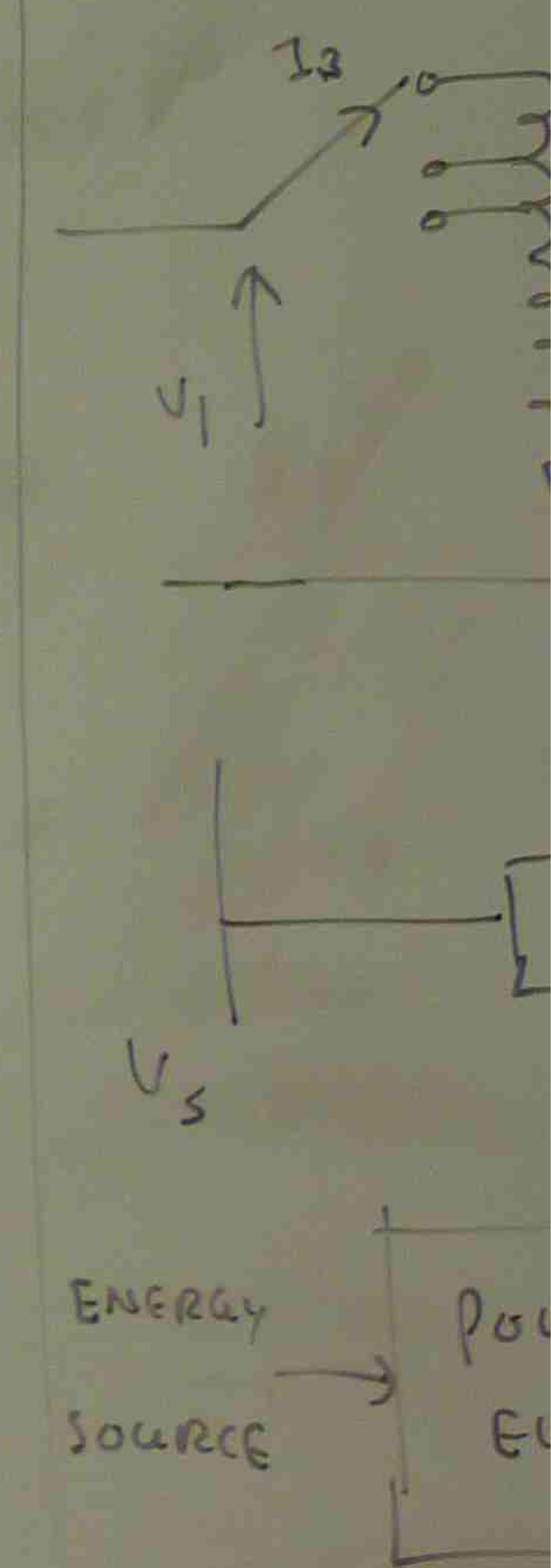
(i) INJECTION OF REACTIVE POWER
(ii) SHUNT CAPACITORS AND REACTORS
(iii) SERIES CAPACITOR
(iv) SYNCHRONOUS COMPENSATOR



SERIES INJECTION OF REACTIVE POWER

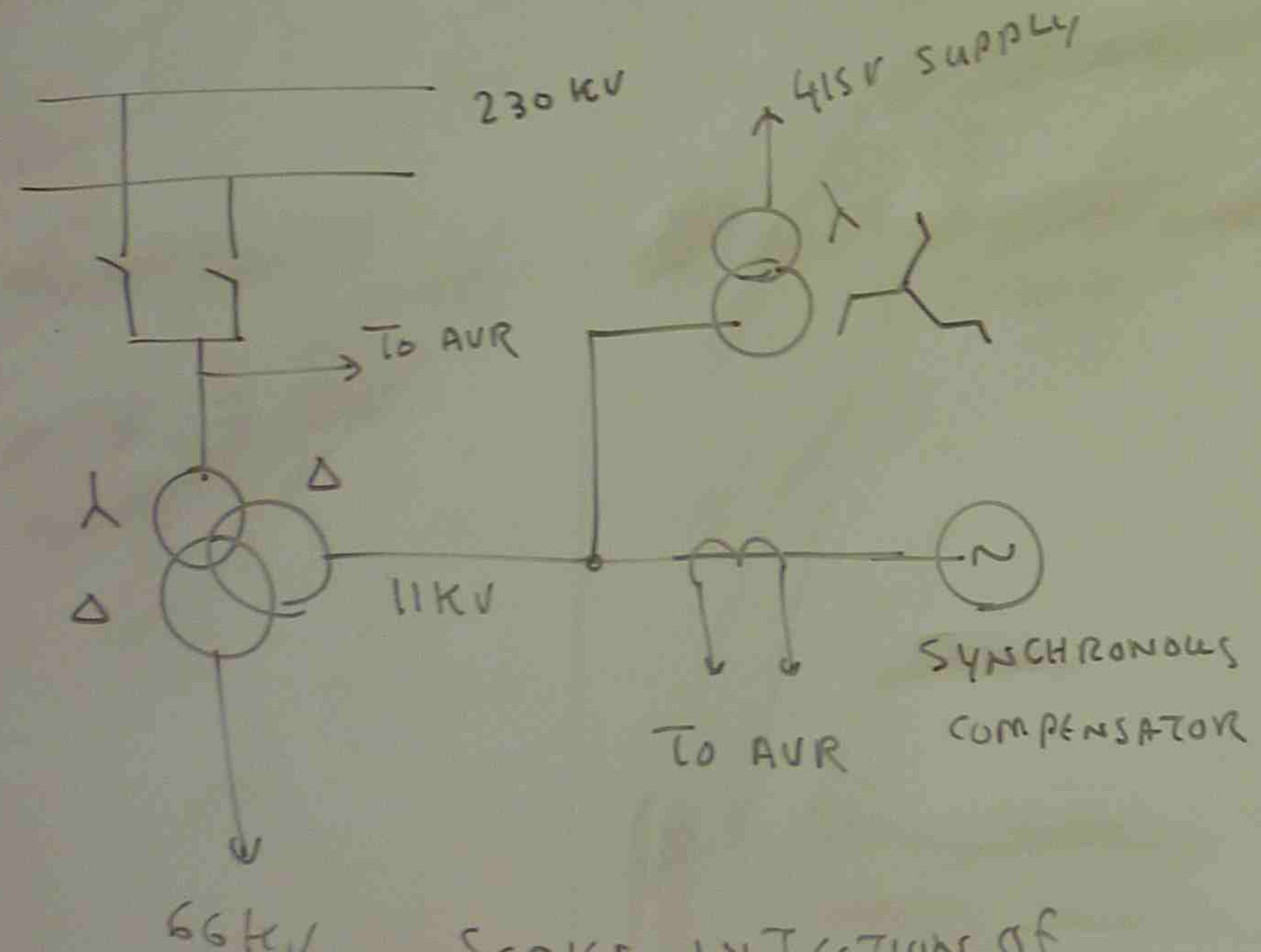
AVR - AUTOMATIC VOLTAGE REGULATOR

TAP CHANGI



METHODS OF VOLTAGE CONTROL

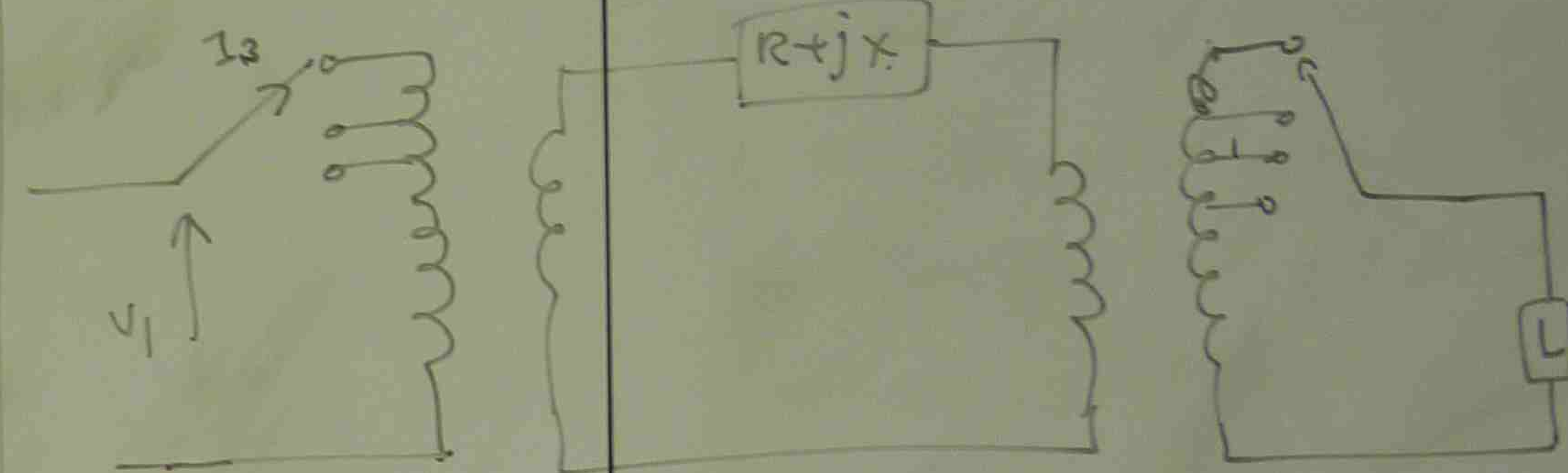
(i) INJECTION OF REACTIVE POWER
(ii) SHUNT CAPACITORS AND REACTORS
(iii) SERIES CAPACITOR
(iv) SYNCHRONOUS COMPENSATOR

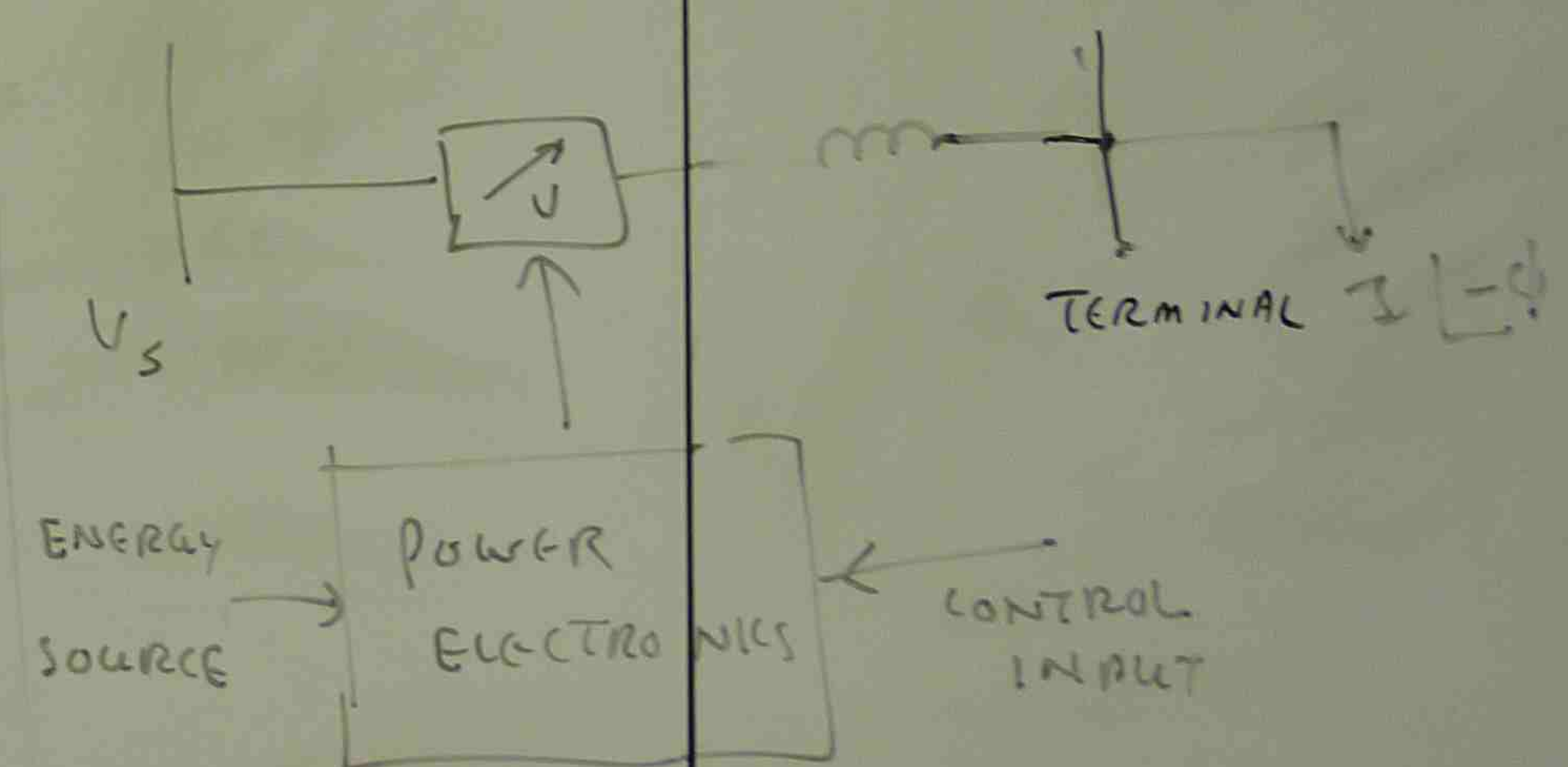


SERIES INJECTION OF REACTIVE POWER

AVR - AUTOMATIC VOLTAGE REGULATOR

TAP CHANGING TRANSFORMER





PL)

E

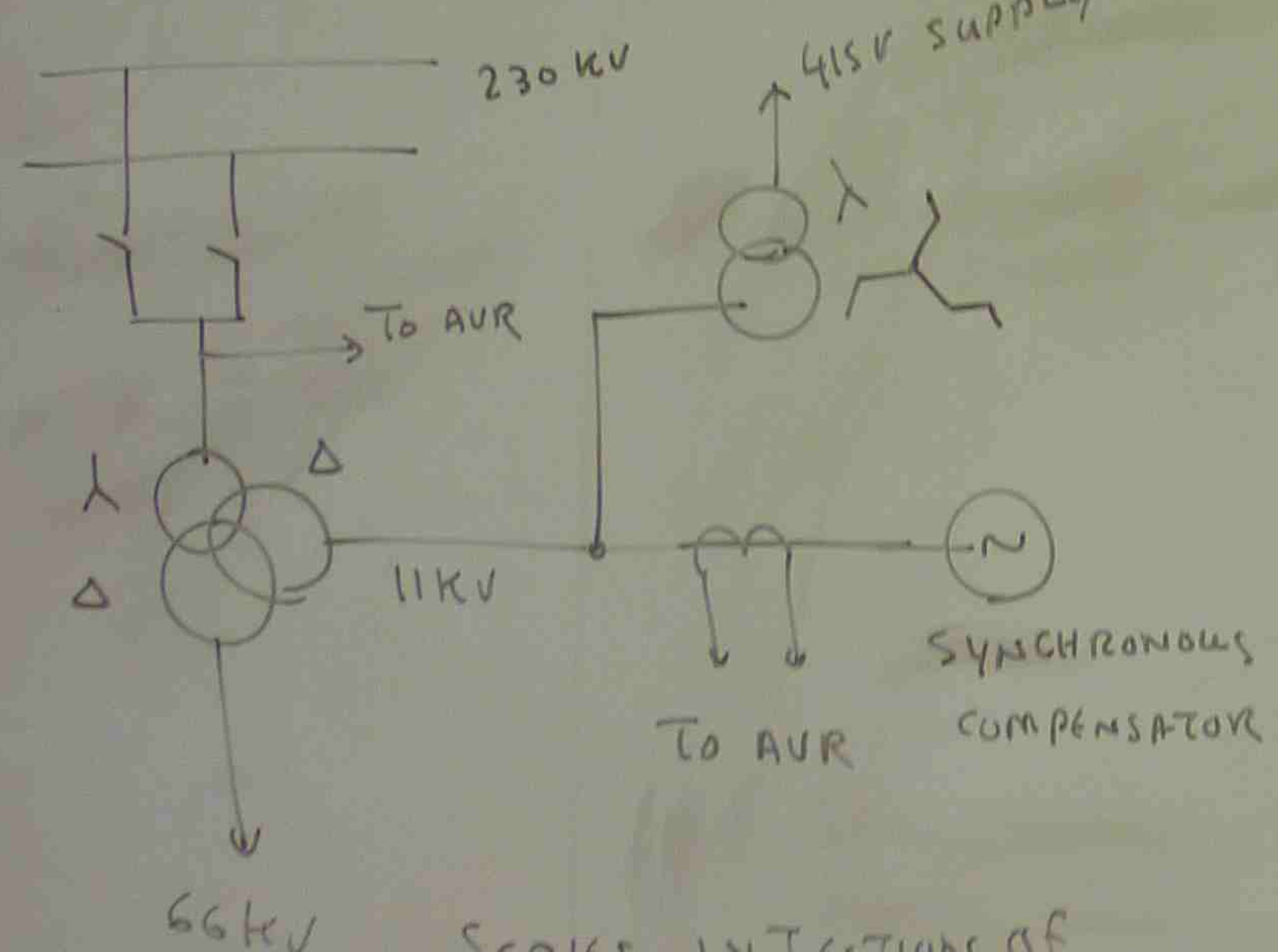
WER

RMAL

ENCY

METHODS OF VOLTAGE CONTROL

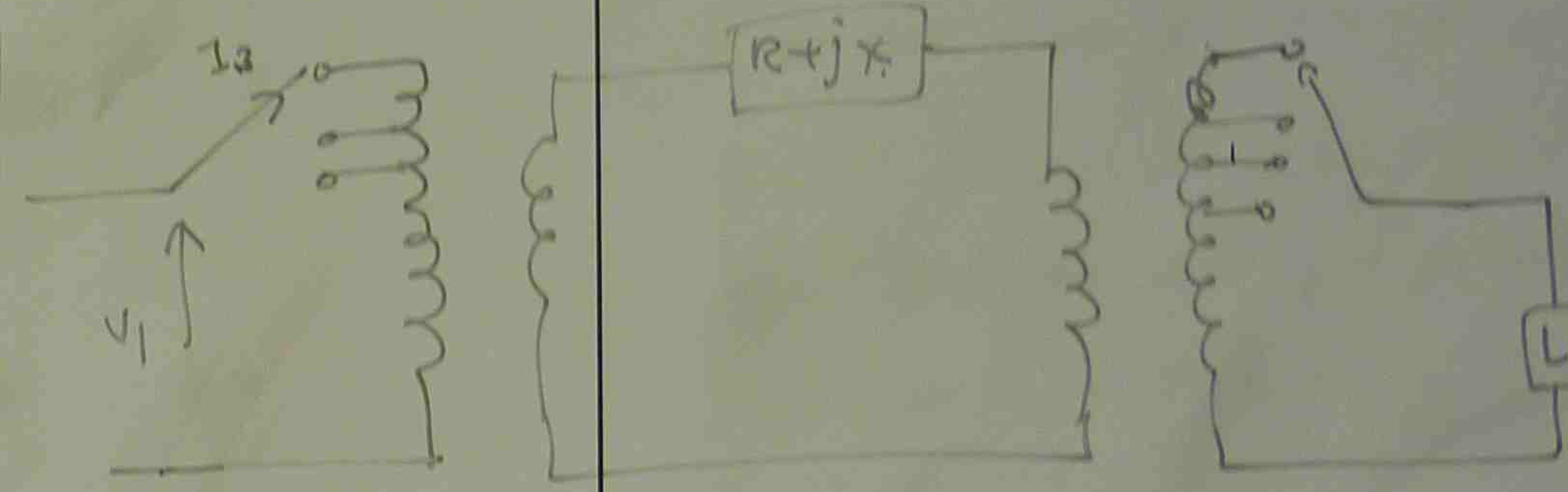
(i) INJECTION OF REACTIVE POWER
(ii) SHUNT CAPACITORS AND REACTORS
(iii) SERIES CAPACITOR
(iv) SYNCHRONOUS COMPENSATOR

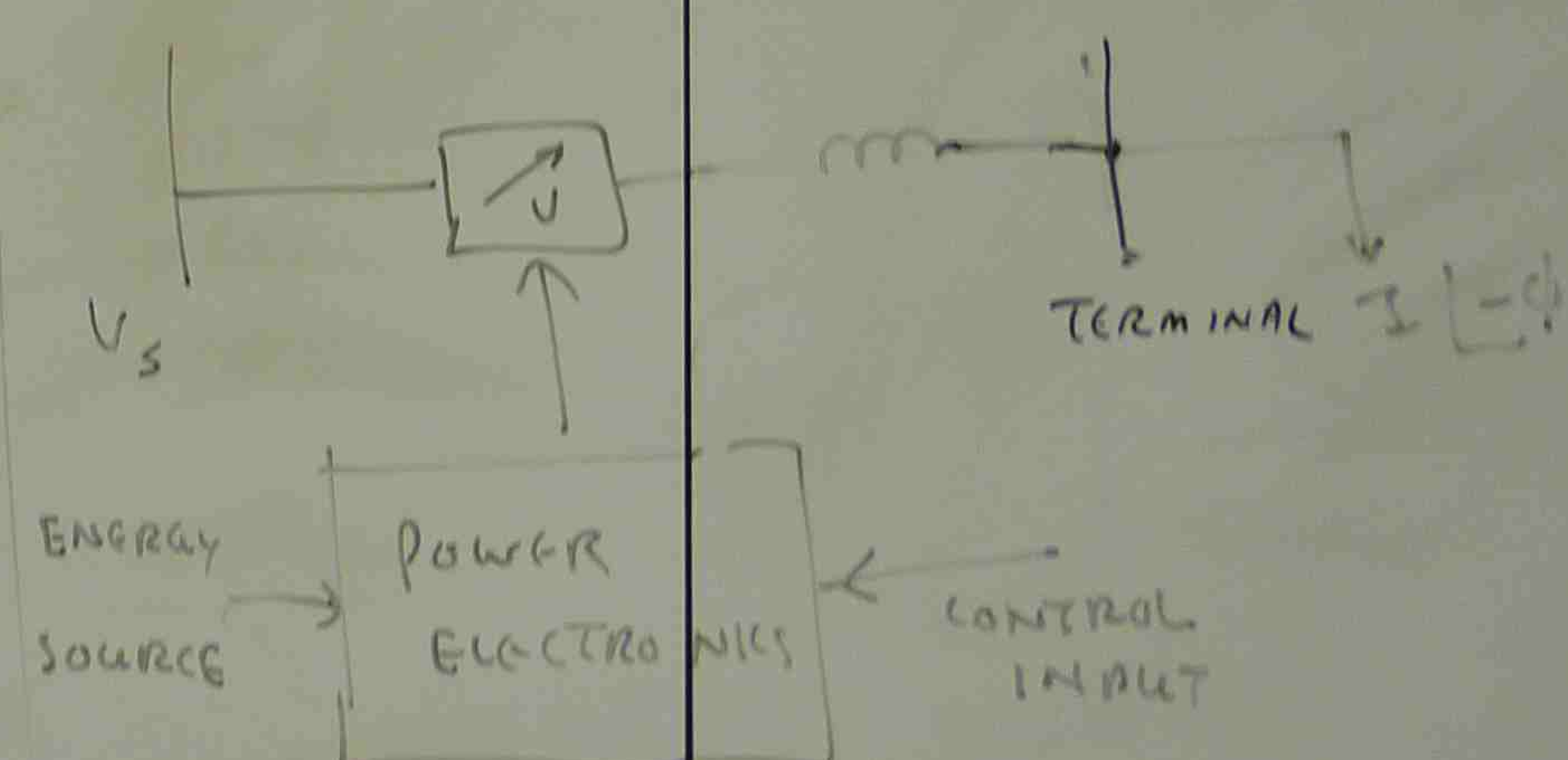


SERIES INJECTION OF REACTIVE POWER

AVR - AUTOMATIC VOLTAGE REGULATOR

TAP CHANGING TRANSFORMER





LO

V1

INCOMING VOLTAGE

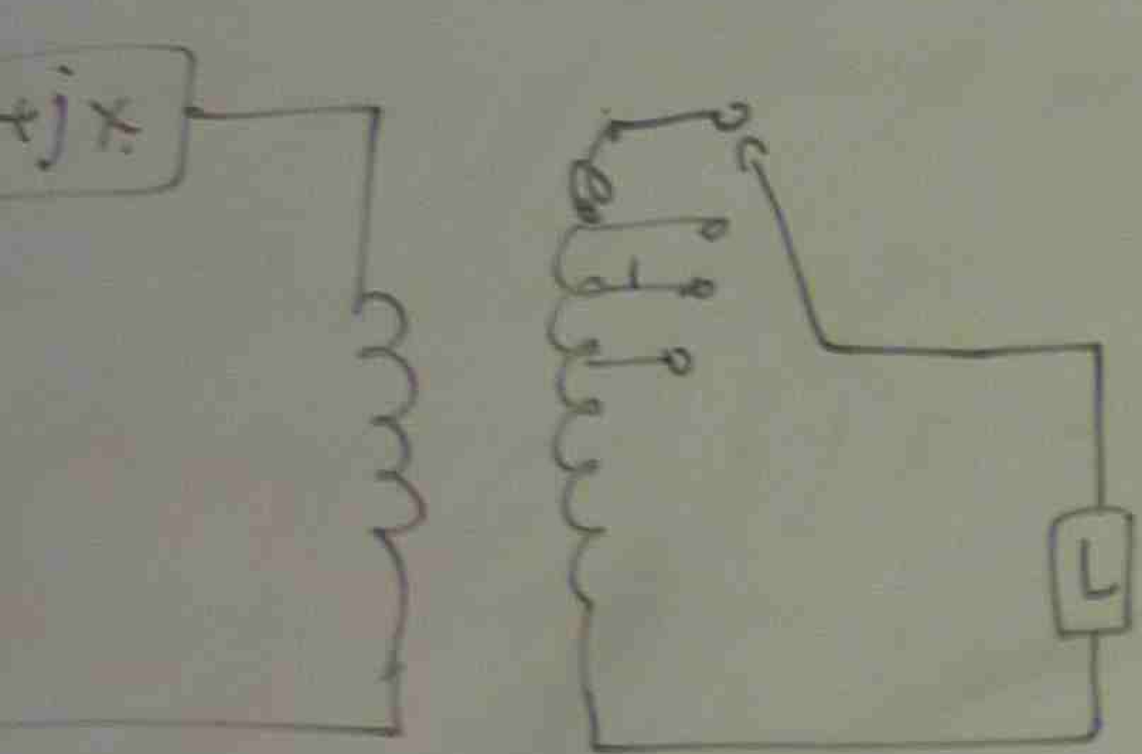
BOOST

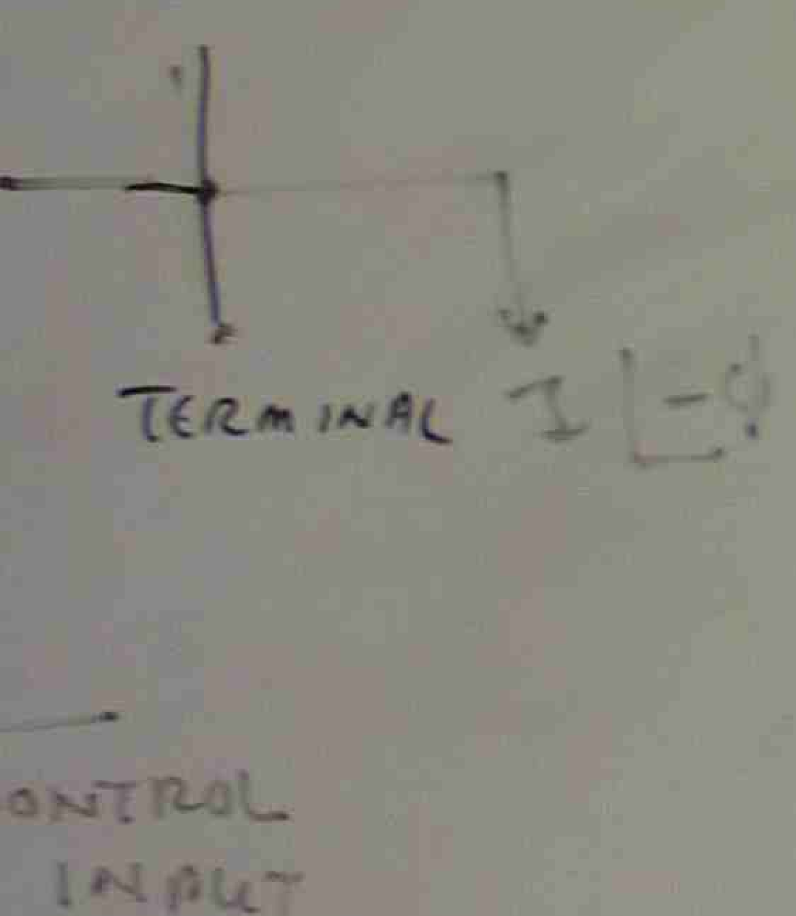
LINE

BOOST T

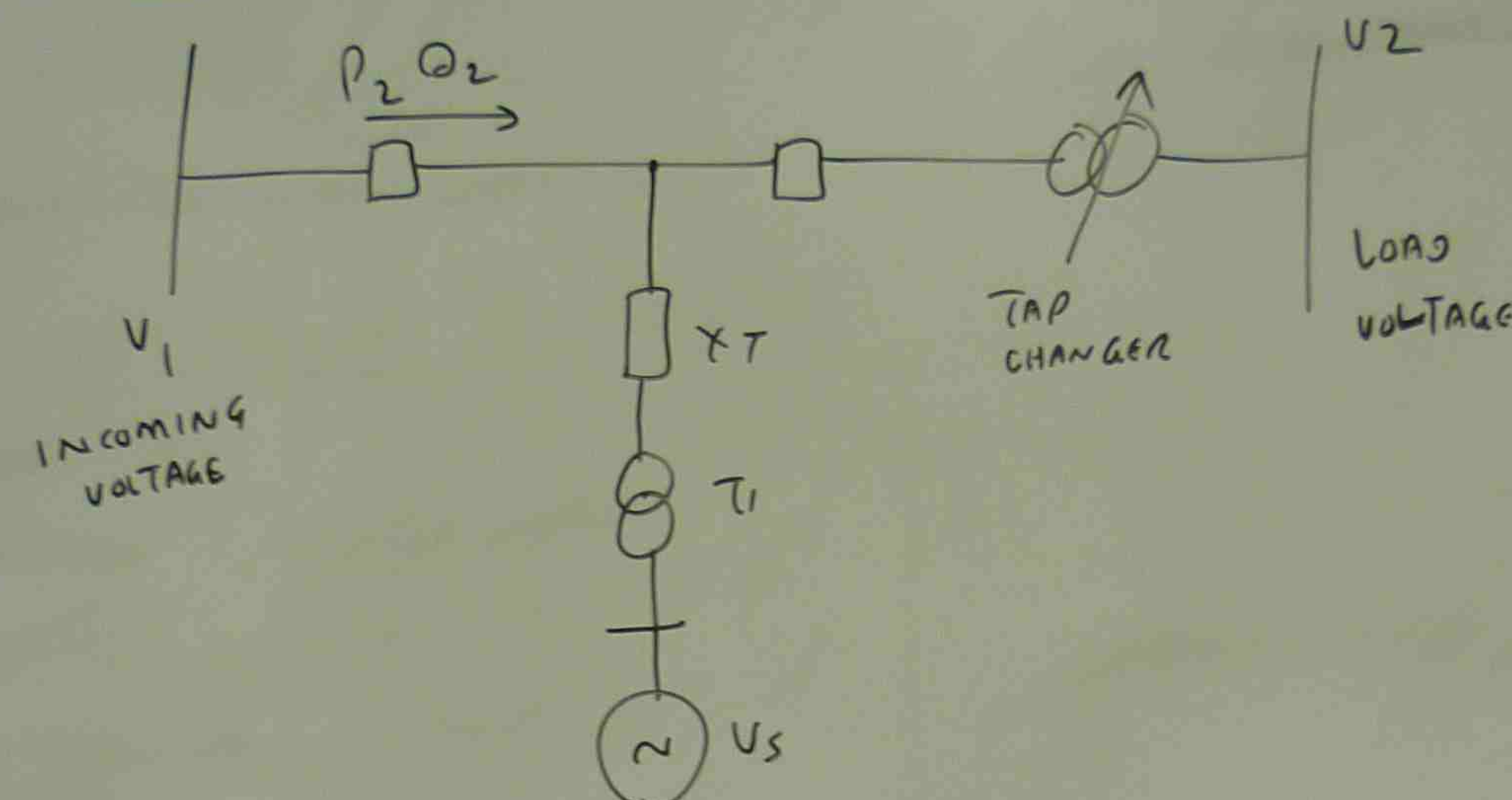
TRANS

MER

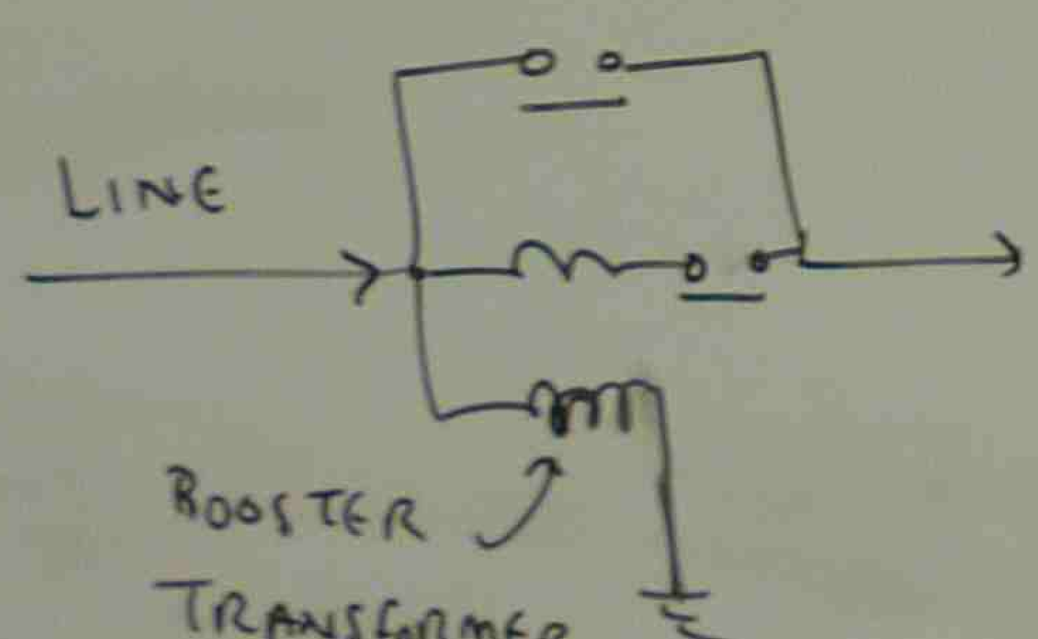




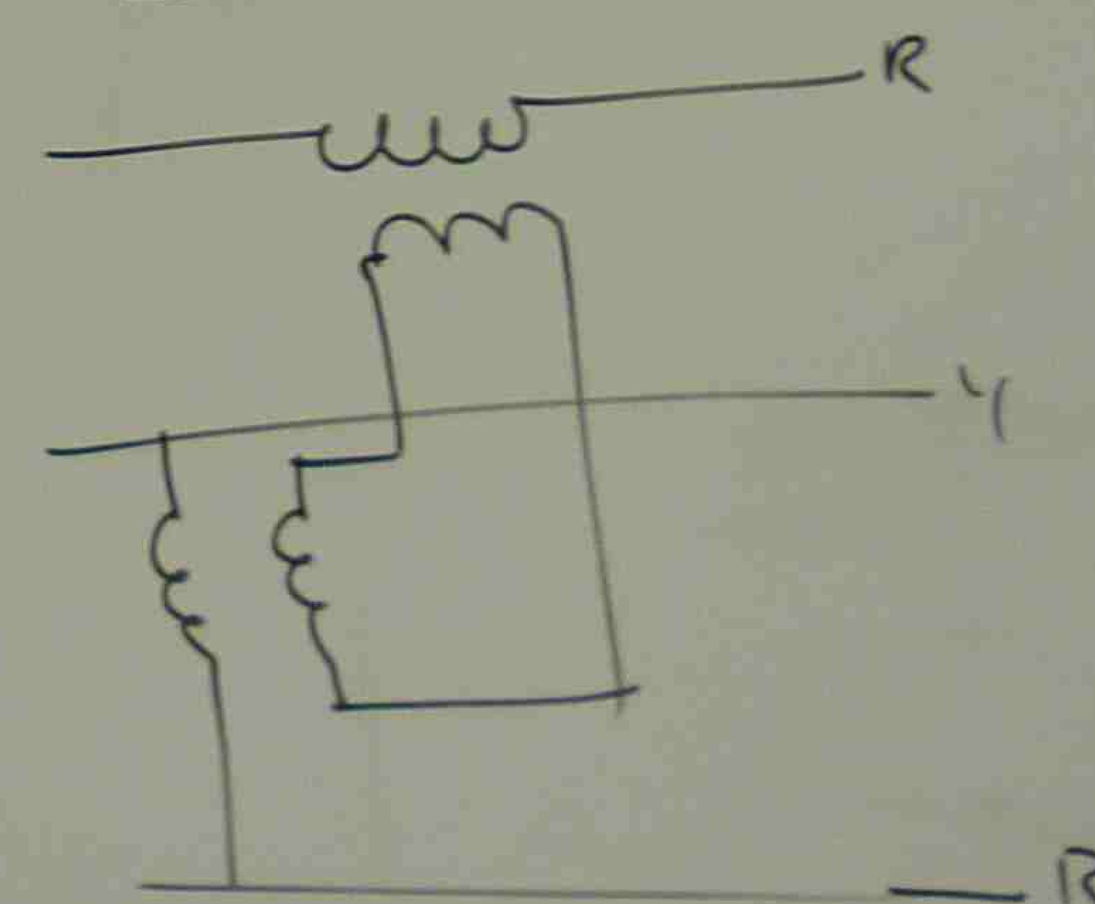
LOCATION OF TAP CHANGER IN POWER SYSTEM



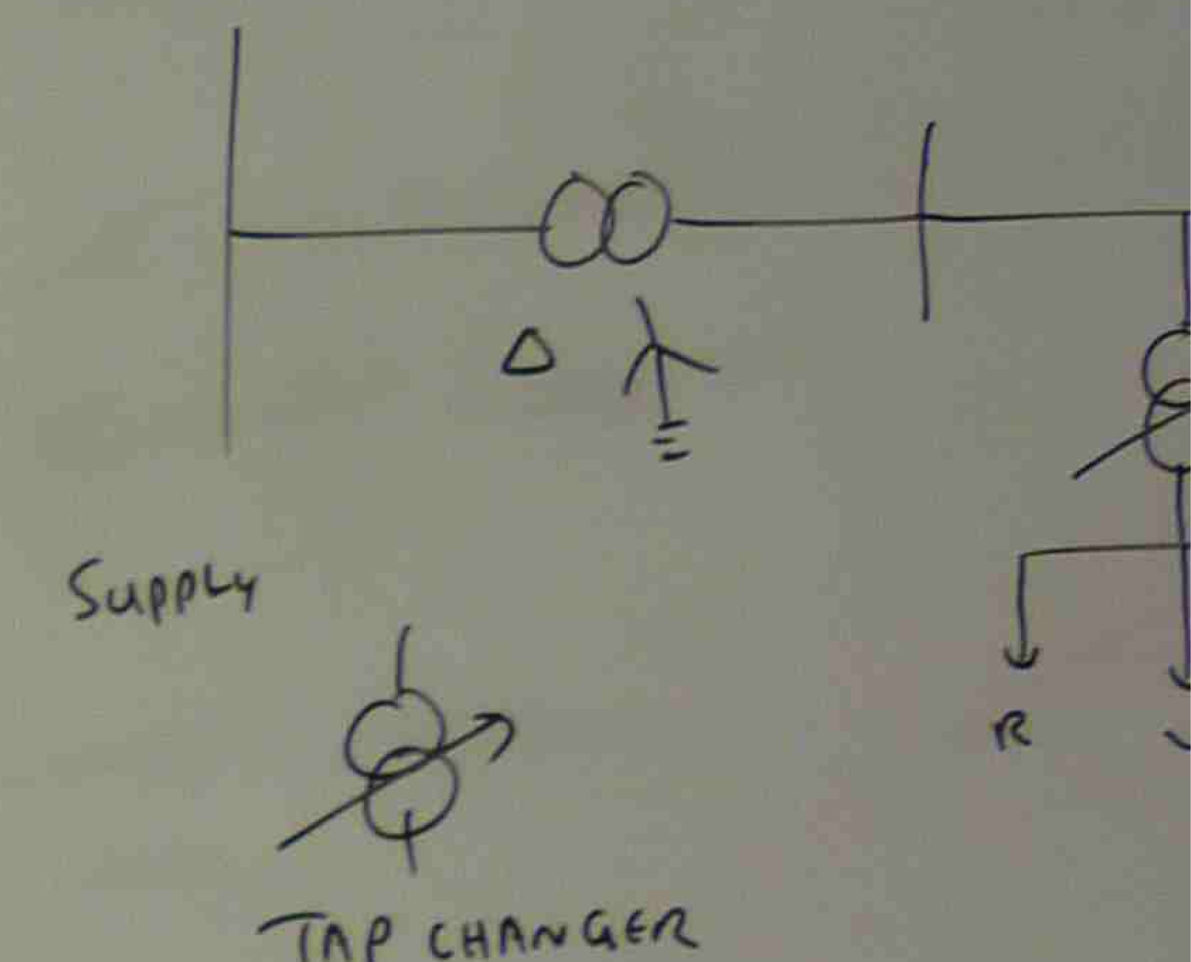
BOOSTER TRANSFORMER



PHASE SHIFT TRANSFORMER



VOLTAGE CONTROL IN DISTR



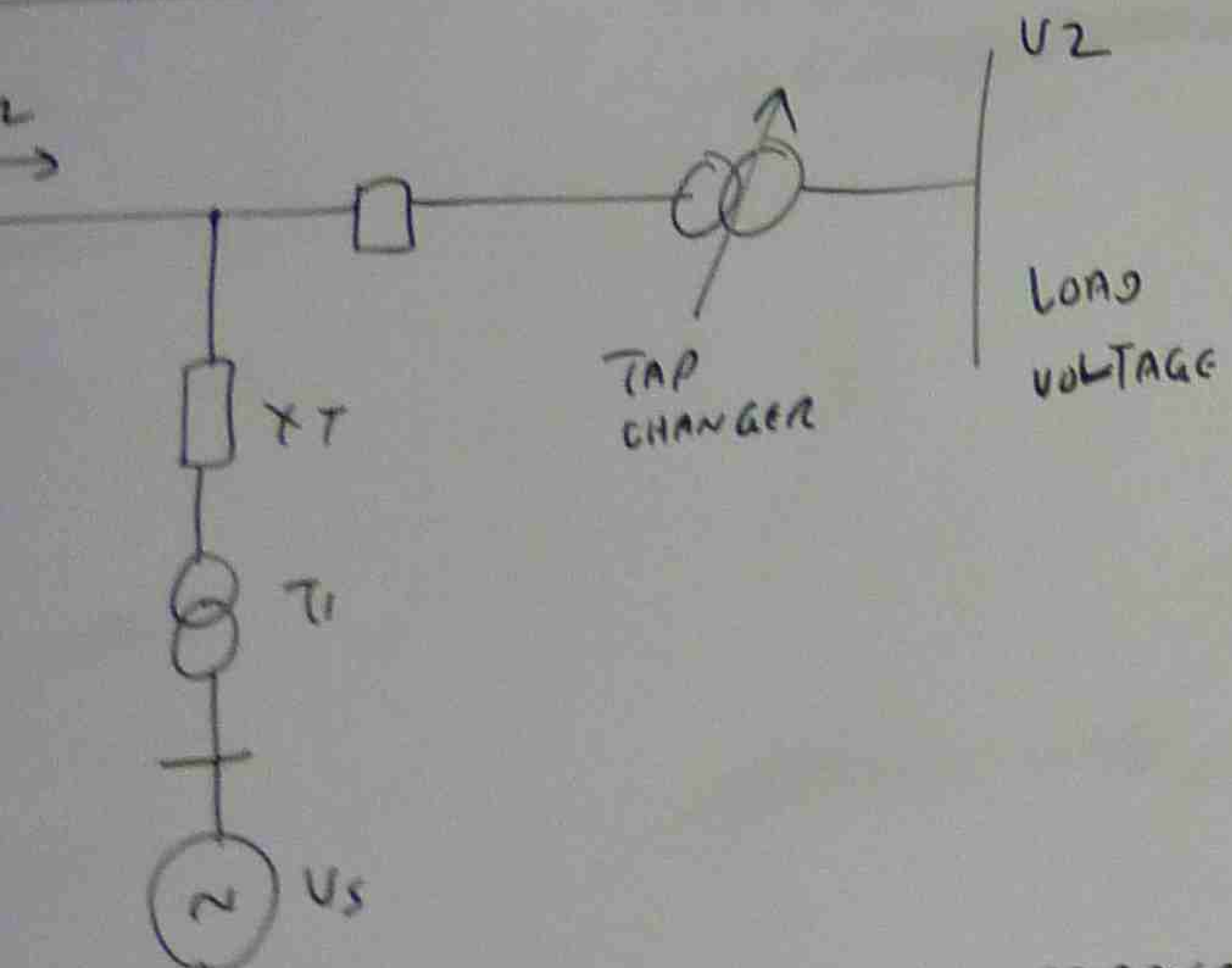
SYNCHRONIZING

THE PROCESS OF SYN

(a) THE FREQUENCY OF T
INCOMING MACHINE
OF LIVE BUSBAR.

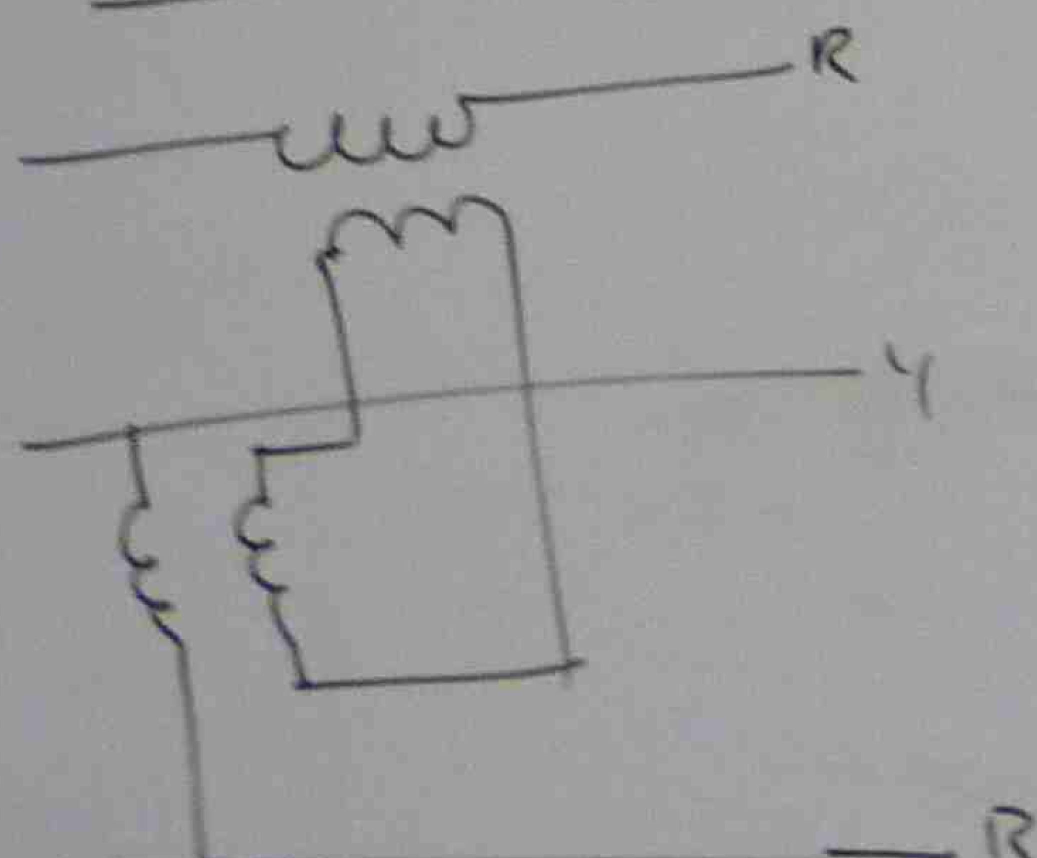
(b) THE INDUCED VOLTAG
~~BE~~ EQUAL TO THE L
AND PHASE.

...f TAP CHANGER IN POWER SYSTEM

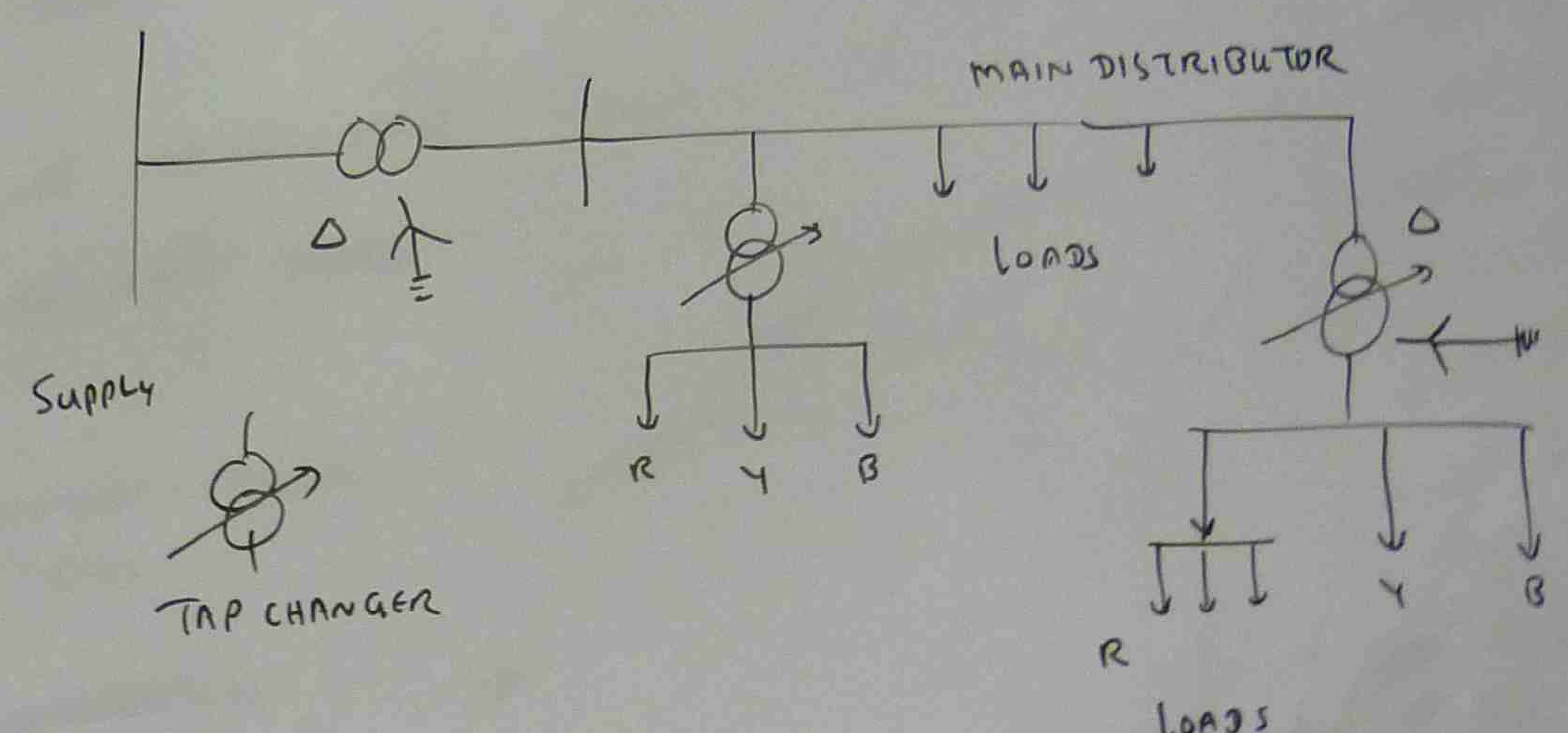


...SFORMER

PHASE SHIFT TRANSFORMER



VOLTAGE CONTROL IN DISTRIBUTION NETWORK



SYNCHRONIZING

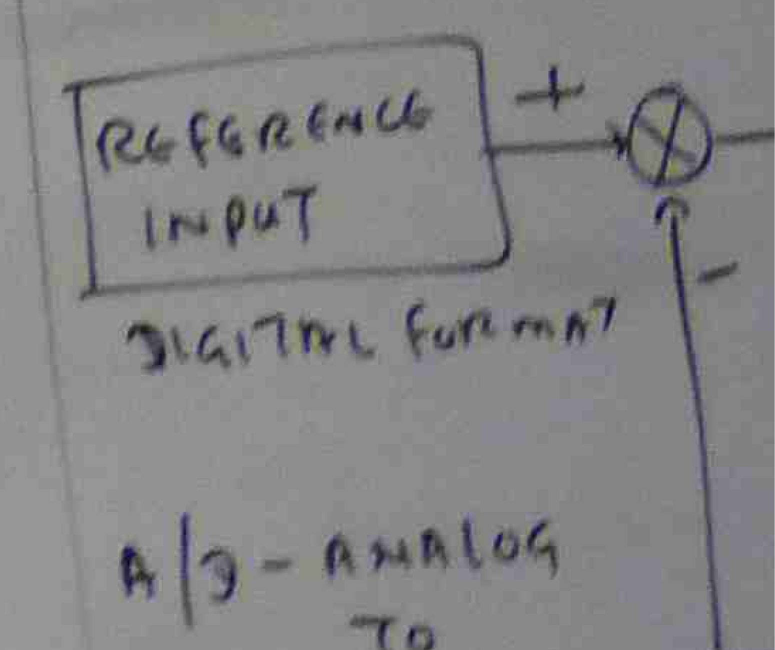
THE PROCESS OF SYNCHRONIZING IS

(a) THE FREQUENCY OF THE INDUCED VOLTAGES IN THE INCOMING MACHINE MUST BE EQUAL TO THE FREQUENCY OF LIVE BUSBAR.

(b) THE INDUCED VOLTAGE IN THE INCOMING MACHINE MUST BE EQUAL TO THE LIVE BUSBAR VOLTAGES IN MAGNITUDE AND PHASE.

(c) PHASE SEQUENC...
MACHINE VOLT...

DIGITAL EXCIT...



DIGITAL FORMAT

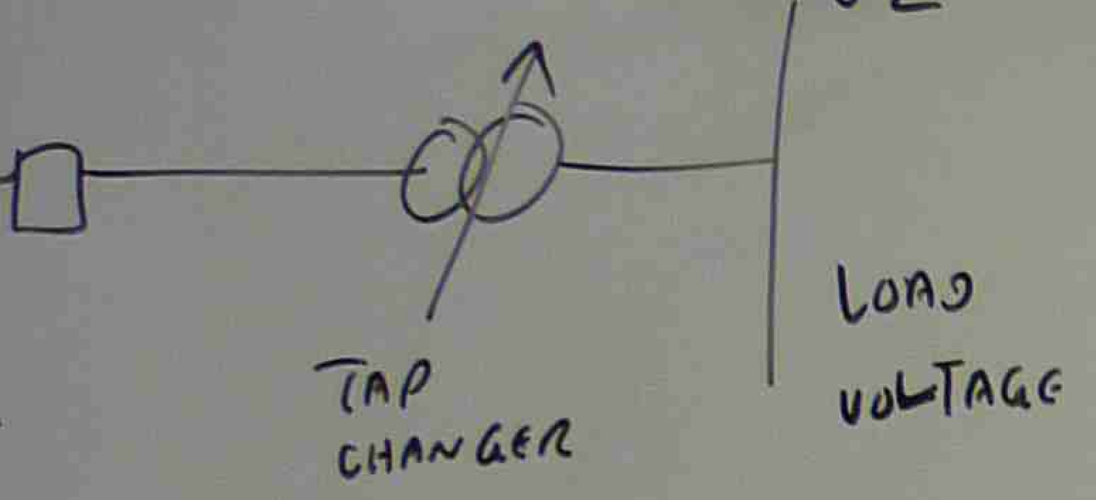
A/D - ANALOG TO DIGITAL CONVERTER

D/A - DIGITAL TO AN... CONVERTER

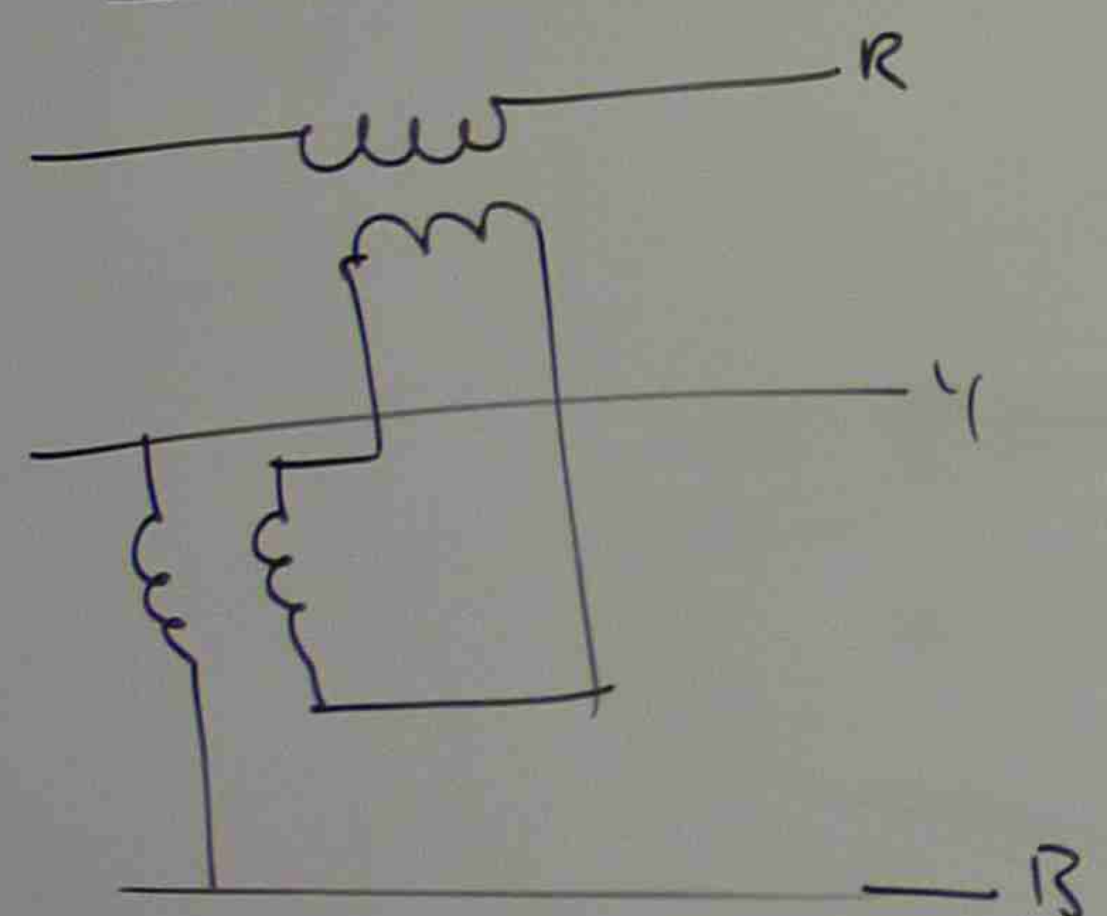
THE OUT PUT ...
BEFORE GEN...

THE OUT P...
CONVERTE...

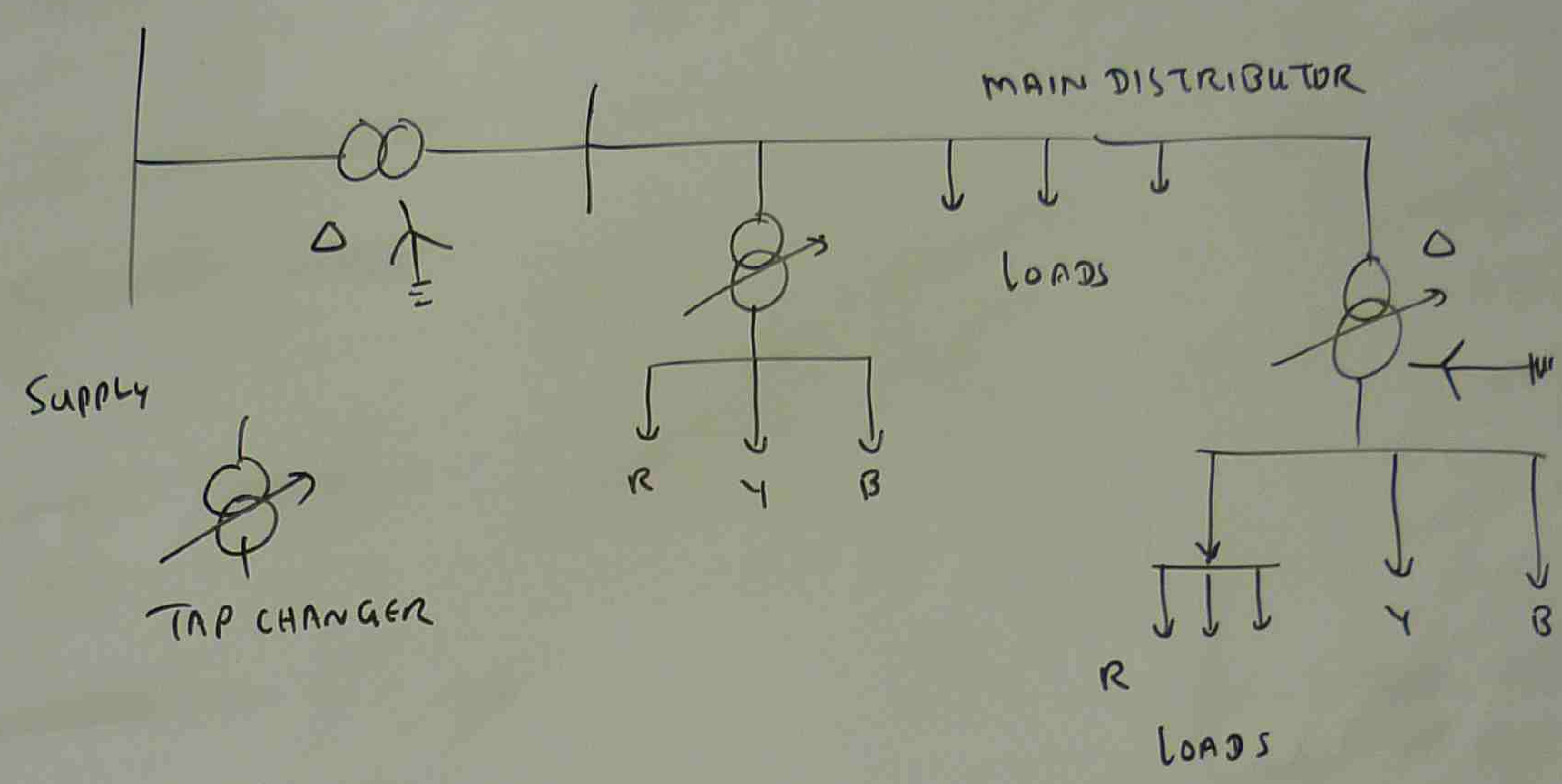
...GER IN POWER SYSTEM



PHASE SHIFT TRANSFORMER



VOLTAGE CONTROL IN DISTRIBUTION NETWORK



SYNCHRONIZING

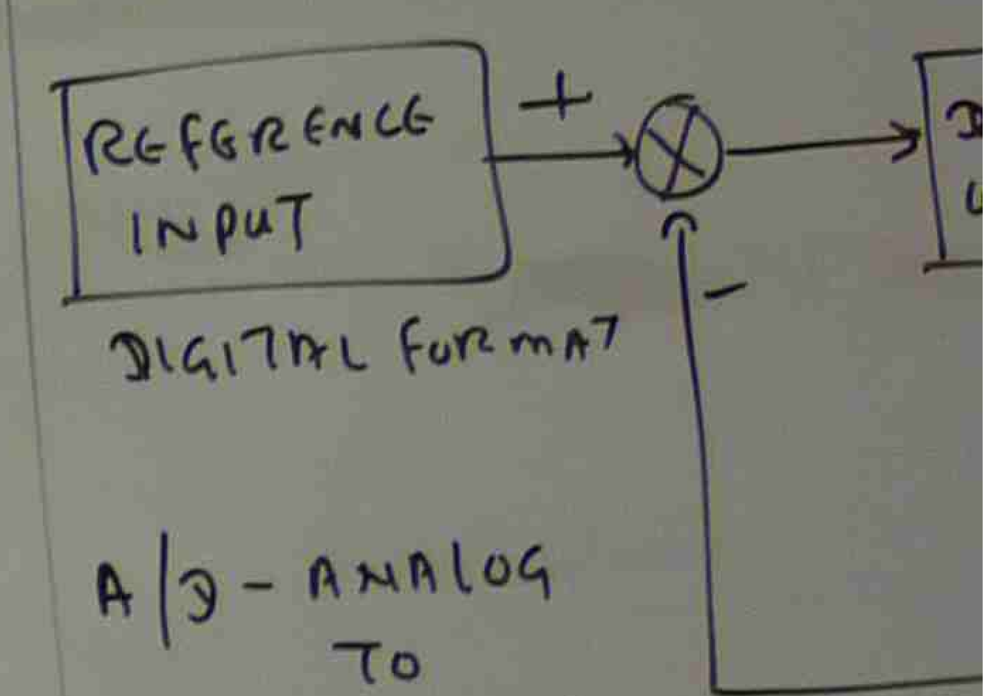
THE PROCESS OF SYNCHRONIZING IS

(a) THE FREQUENCY OF THE INDUCED VOLTAGES IN THE INCOMING MACHINE MUST BE EQUAL TO THE FREQUENCY OF LIVE BUSBAR.

(b) THE INDUCED VOLTAGE IN THE INCOMING MACHINE MUST BE EQUAL TO THE LIVE BUSBAR VOLTAGES IN MAGNITUDE AND PHASE.

(c) PHASE SEQUENCE OF MACHINE VOLTAGE

DIGITAL EXCITATION



DIGITAL FORMAT

A/D - ANALOG TO DIGITAL CONVERTER

D/A - DIGITAL TO ANALOG CONVERTER.

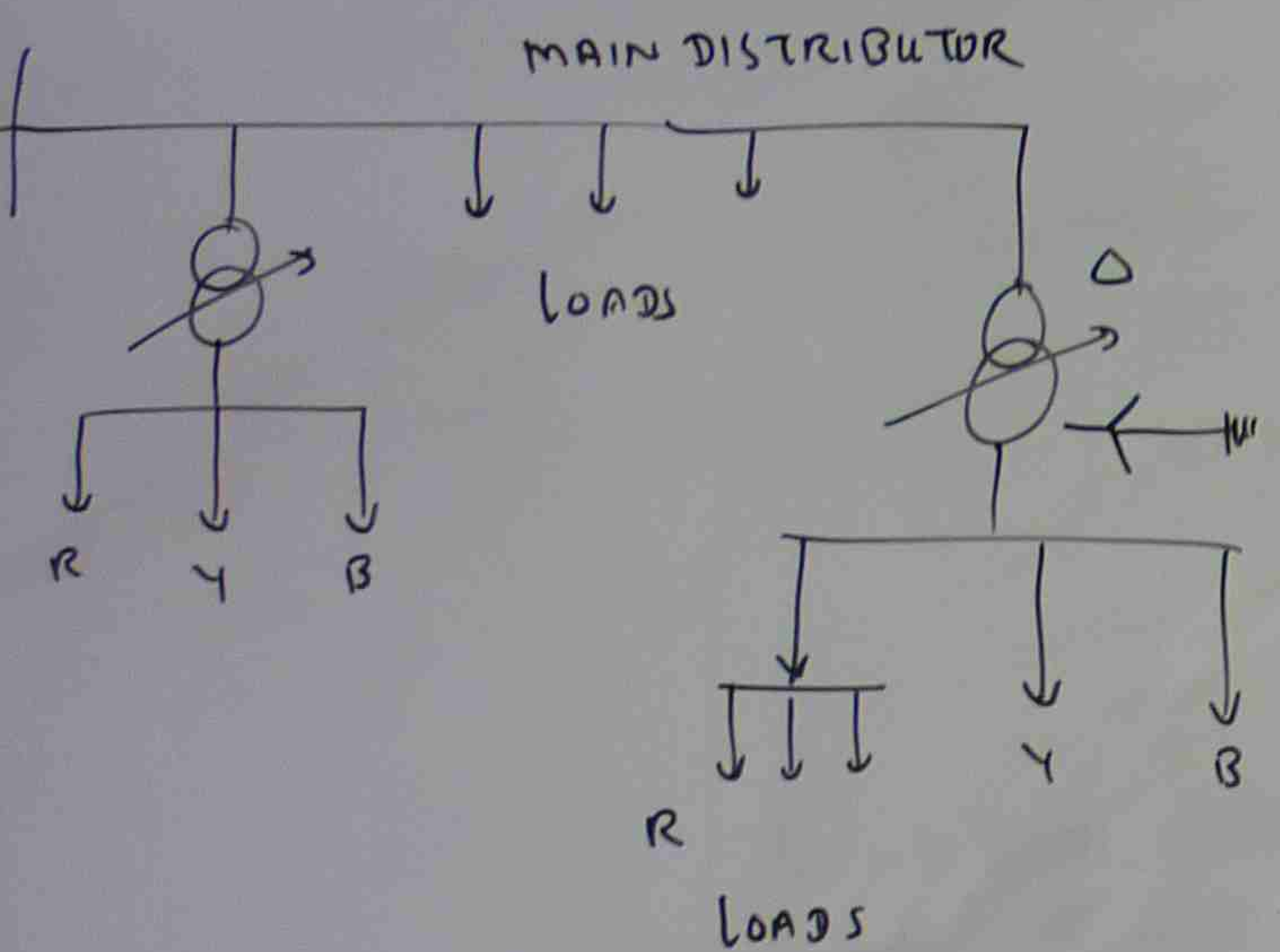
THE OUT PUT FIRST ...

BEFORE GENERATIN...

THE OUT PUT SIG...

CONVERTER.

IN DISTRIBUTION NETWORK



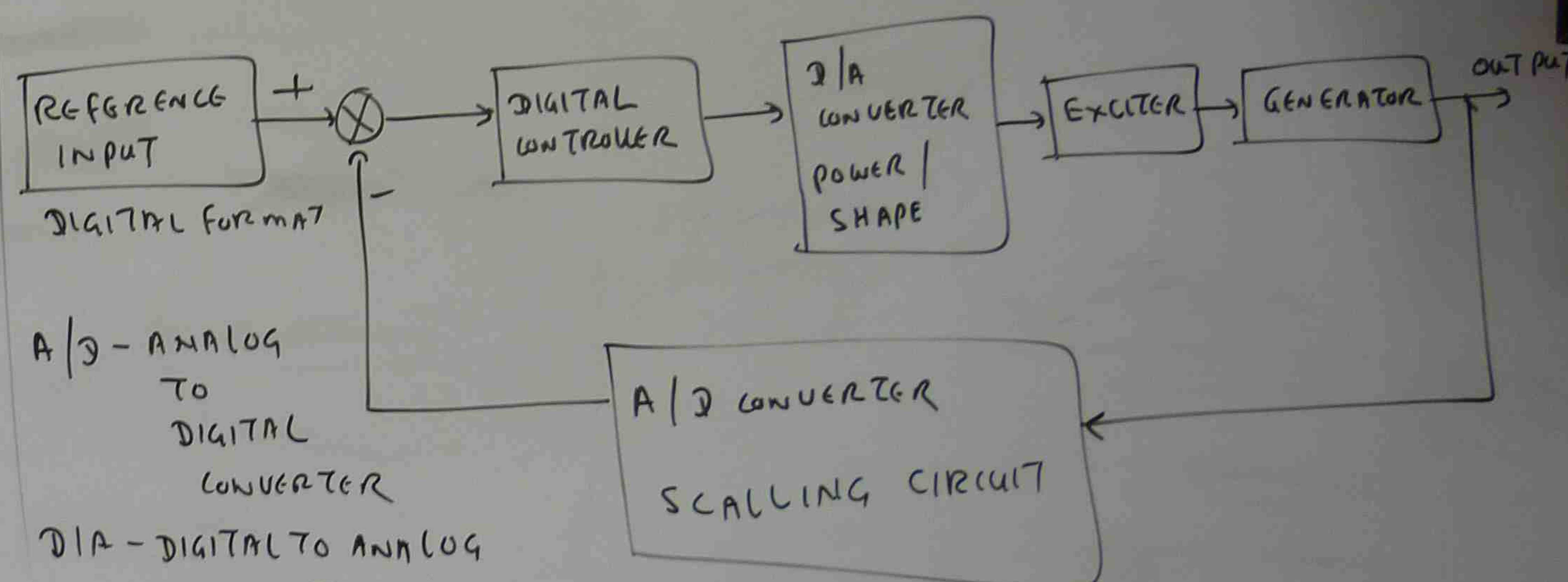
SYNCHRONIZING IS

OF THE INDUCED VOLTAGES IN THE
INE MUST BE EQUAL TO THE FREQUENCY
.

LTAGE IN THE INCOMING MACHINE MUST
HE LIVE BUSBAR VOLTAGES IN MAGNITUDE

(c) PHASE SEQUENCE OF BUSBAR VOLTAGE AND INCOMING MACHINE VOLTAGE MUST BE SAME.

DIGITAL EXCITATION SYSTEM



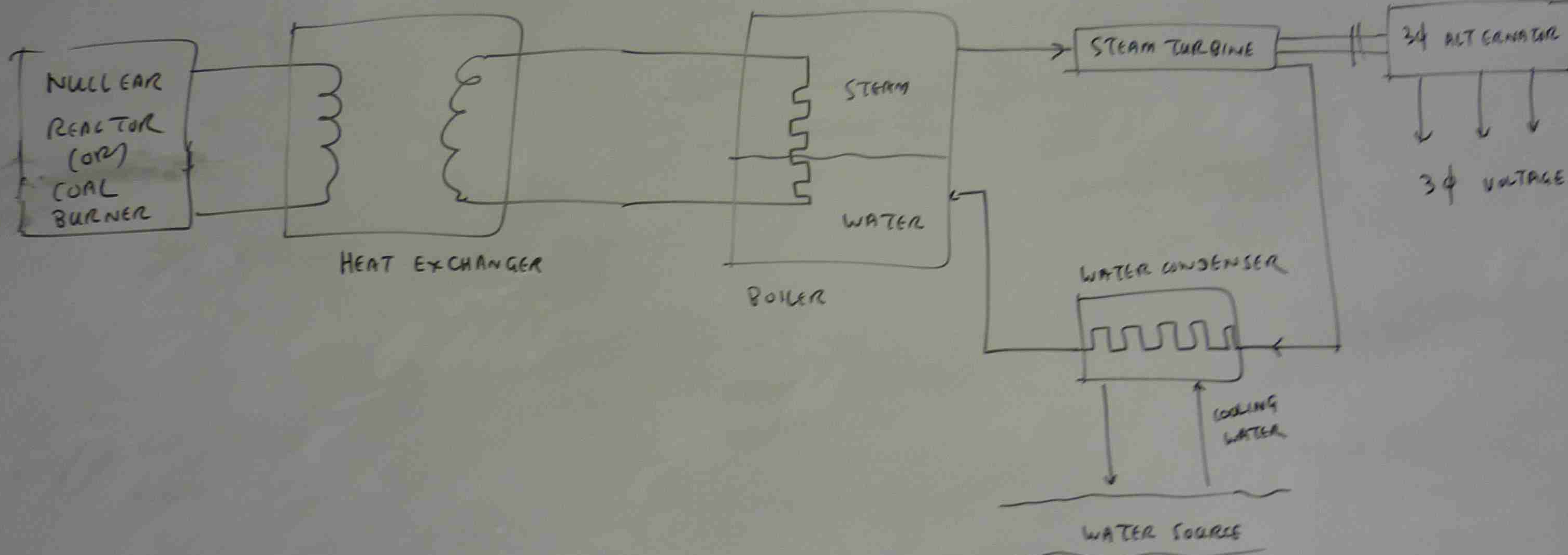
A/D - ANALOG TO DIGITAL CONVERTER

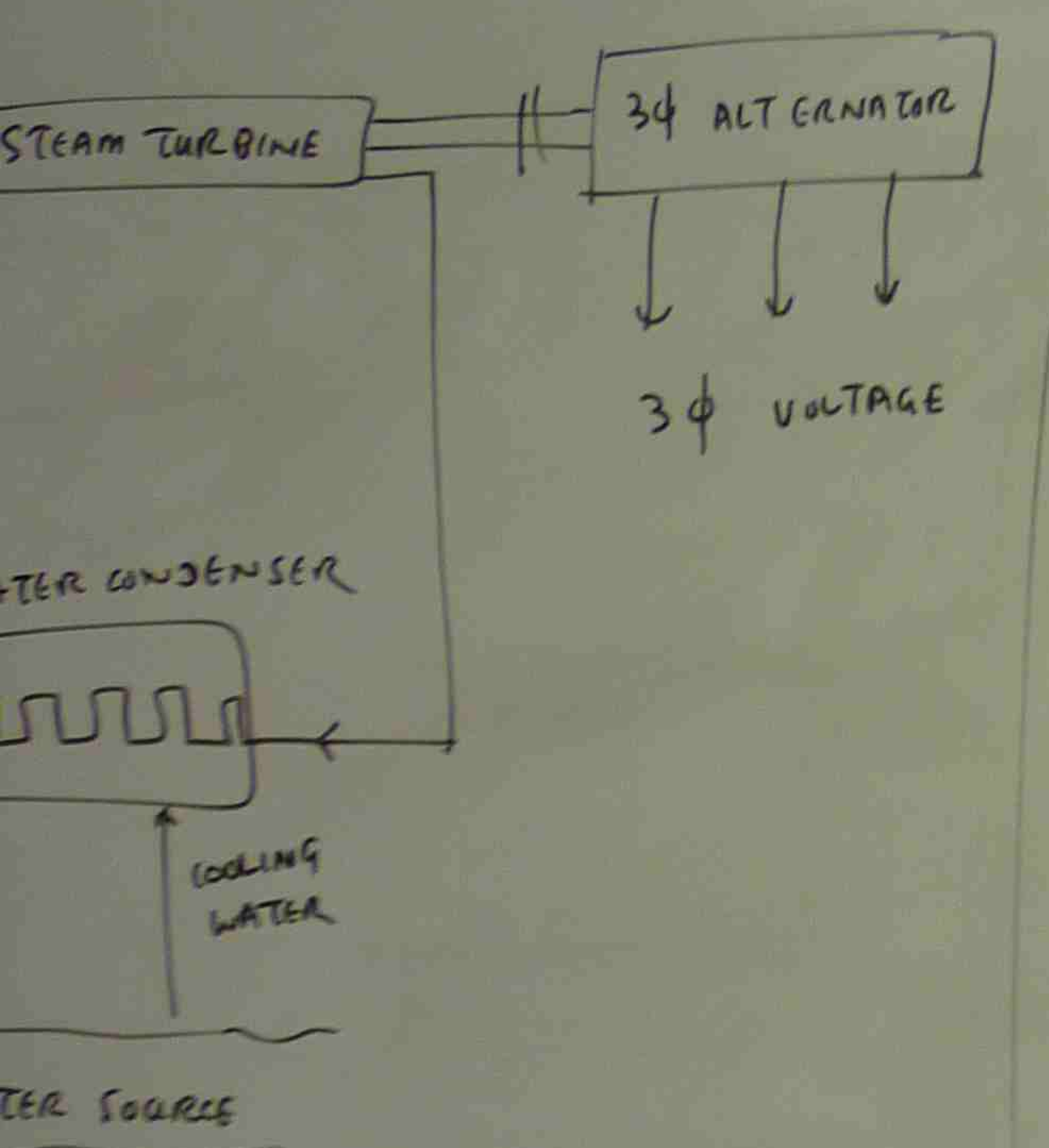
D/A - DIGITAL TO ANALOG CONVERTER.

THE OUTPUT FIRST GOES TO D/A CONVERTER THROUGH POWER SHAPE BEFORE GENERATING THE OUTPUT CONTROL SIGNAL.

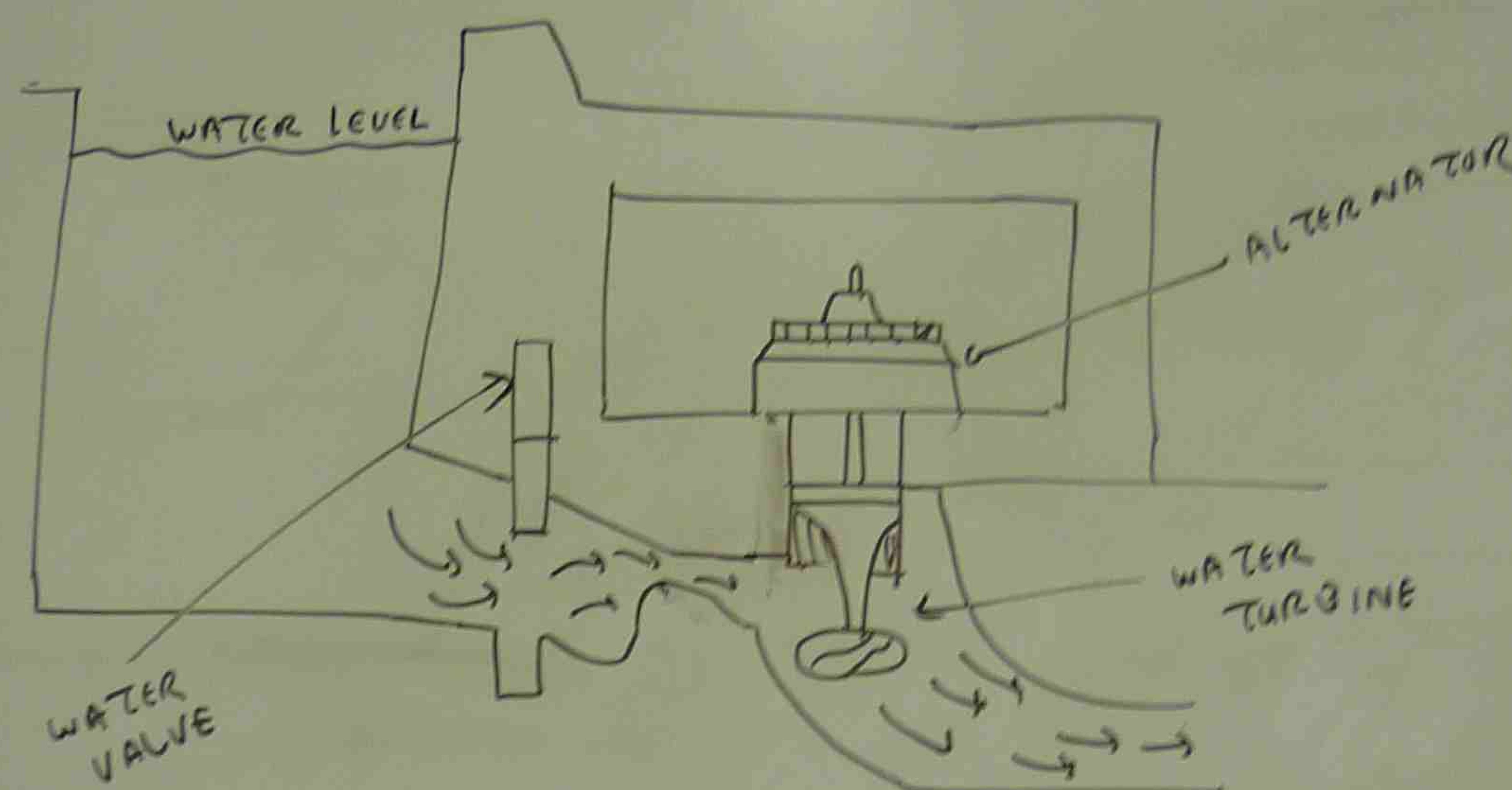
THE OUTPUT SIGNAL IS APPLIED TO INPUT THROUGH A/D CONVERTER.

OVER VIEW OF STEAM TURBINE SYSTEM (NUCLEAR/BOILER/

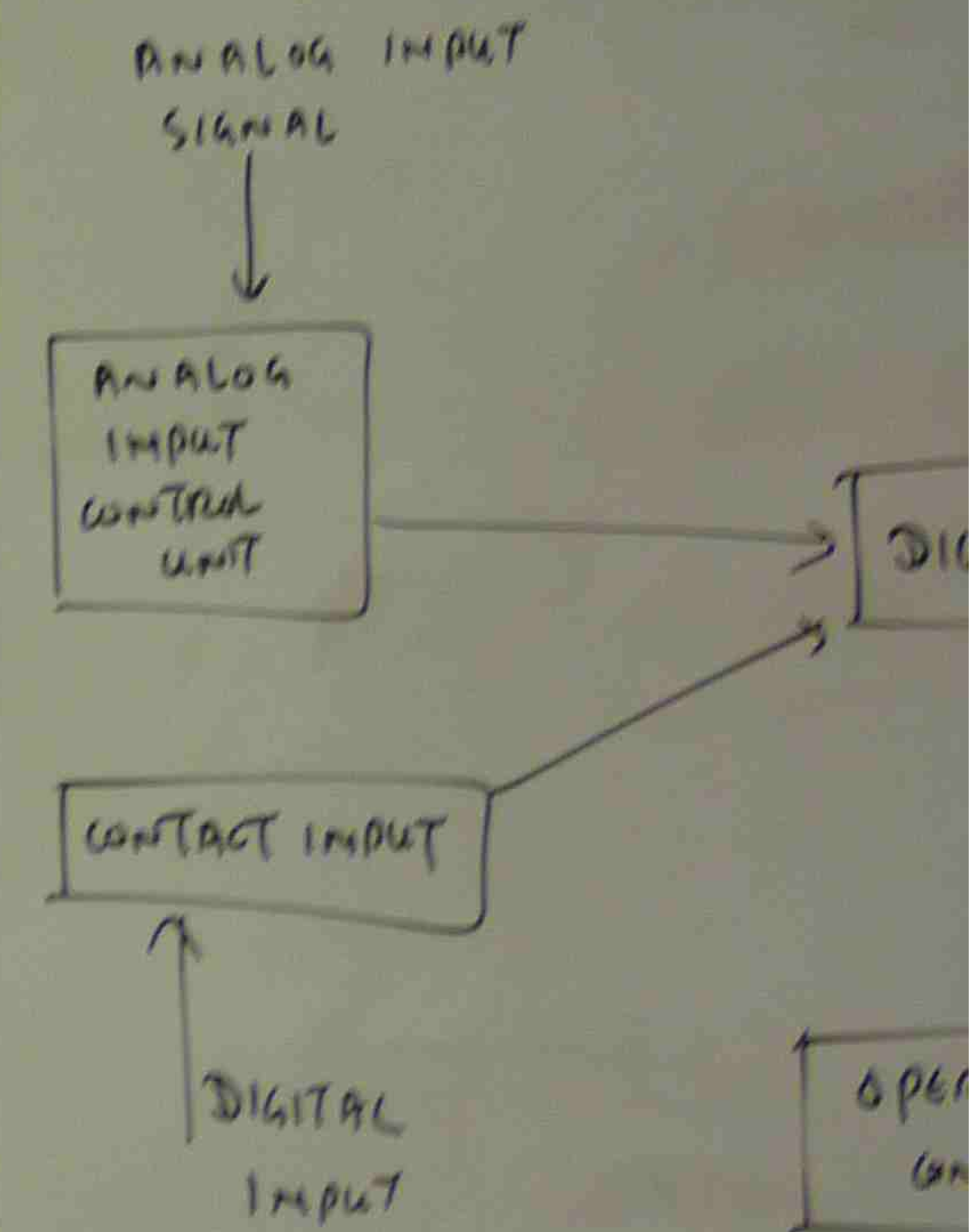




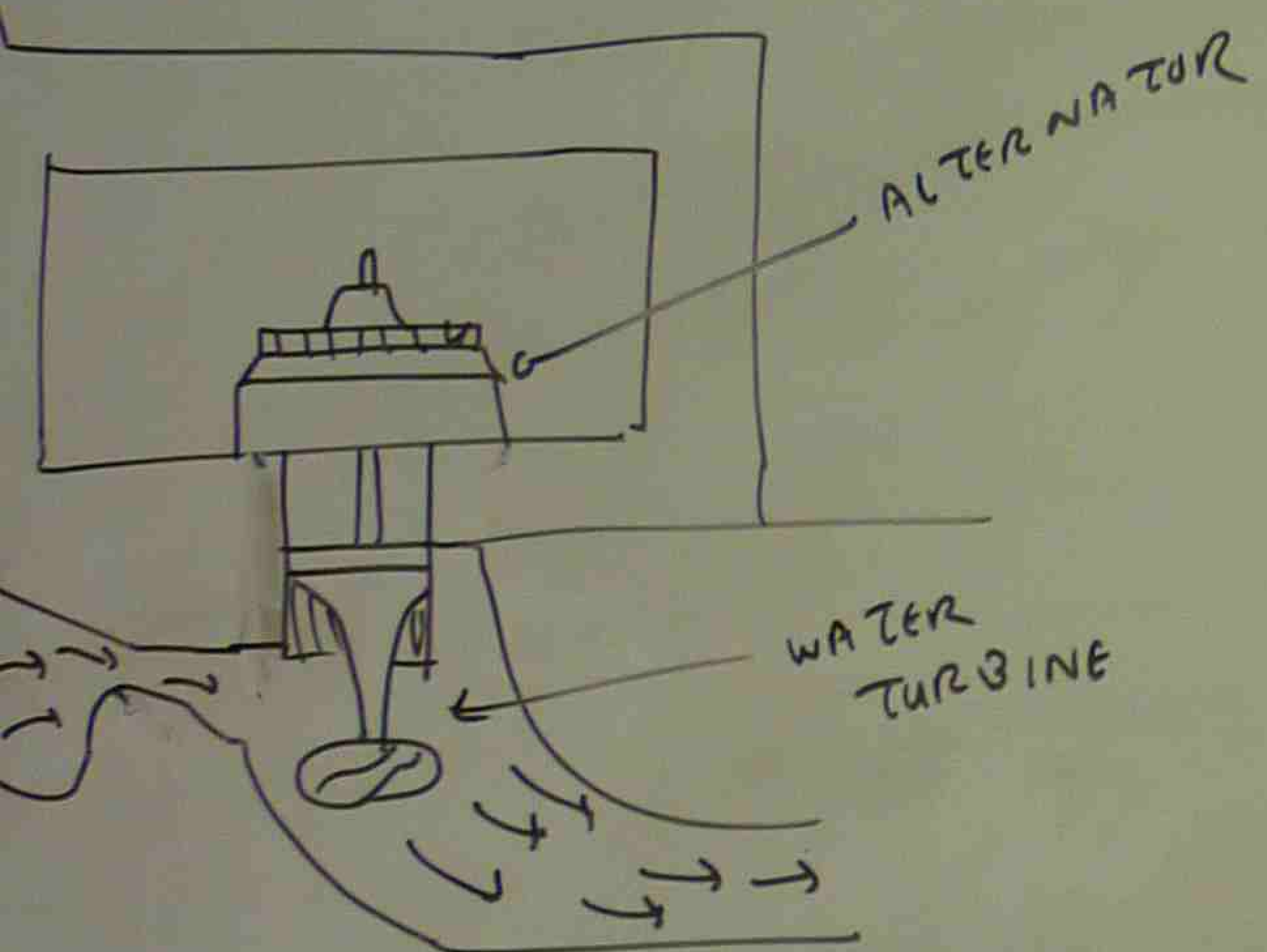
BASIC HYDRO-ELECTRIC POWER SYSTEM



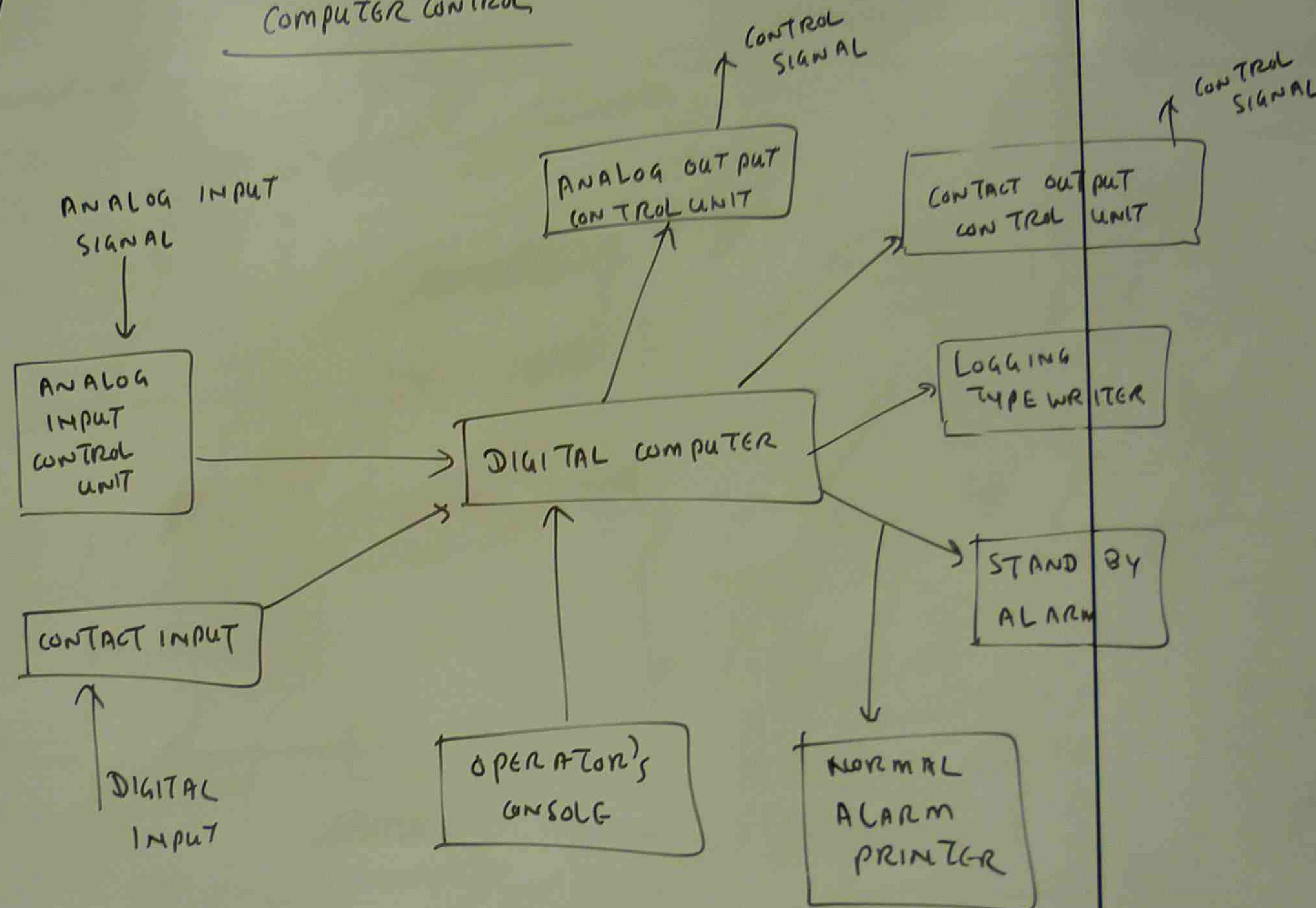
COMPUTER CONTRO



TRIC POWER SYSTEM



COMPUTER CONTROL

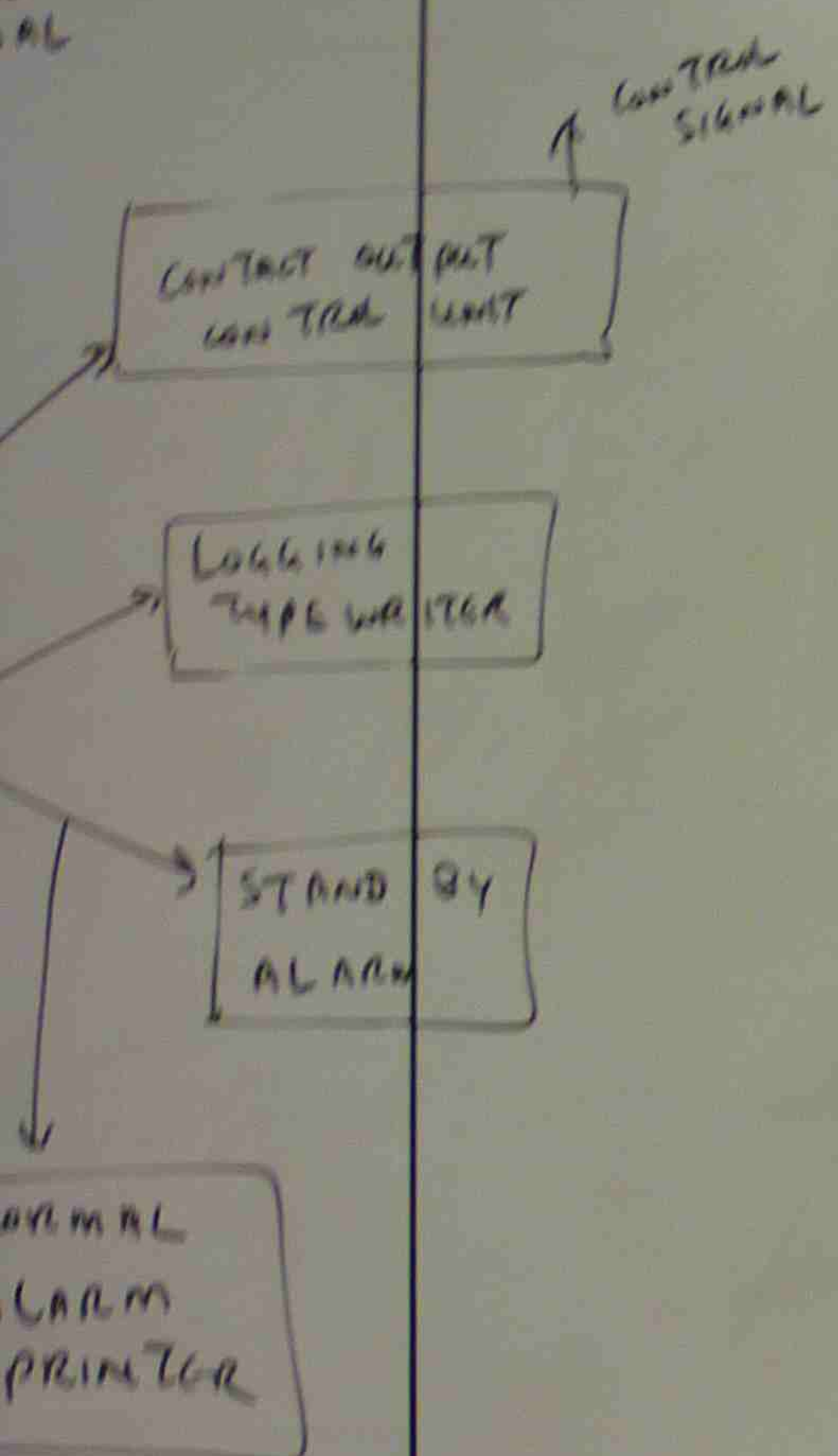


THE DIGITAL

- CONFIRM TH
  ARE IN A
- PERFORM
- ESTABLISH
- LIGHTS AN
- ACCELERAT
  SYSTEM

THE FOLLOW

- ARITHME
- MEMOR
- INTERRU
- CONTACT
- ANALOG
- OUT PU
- DIREC



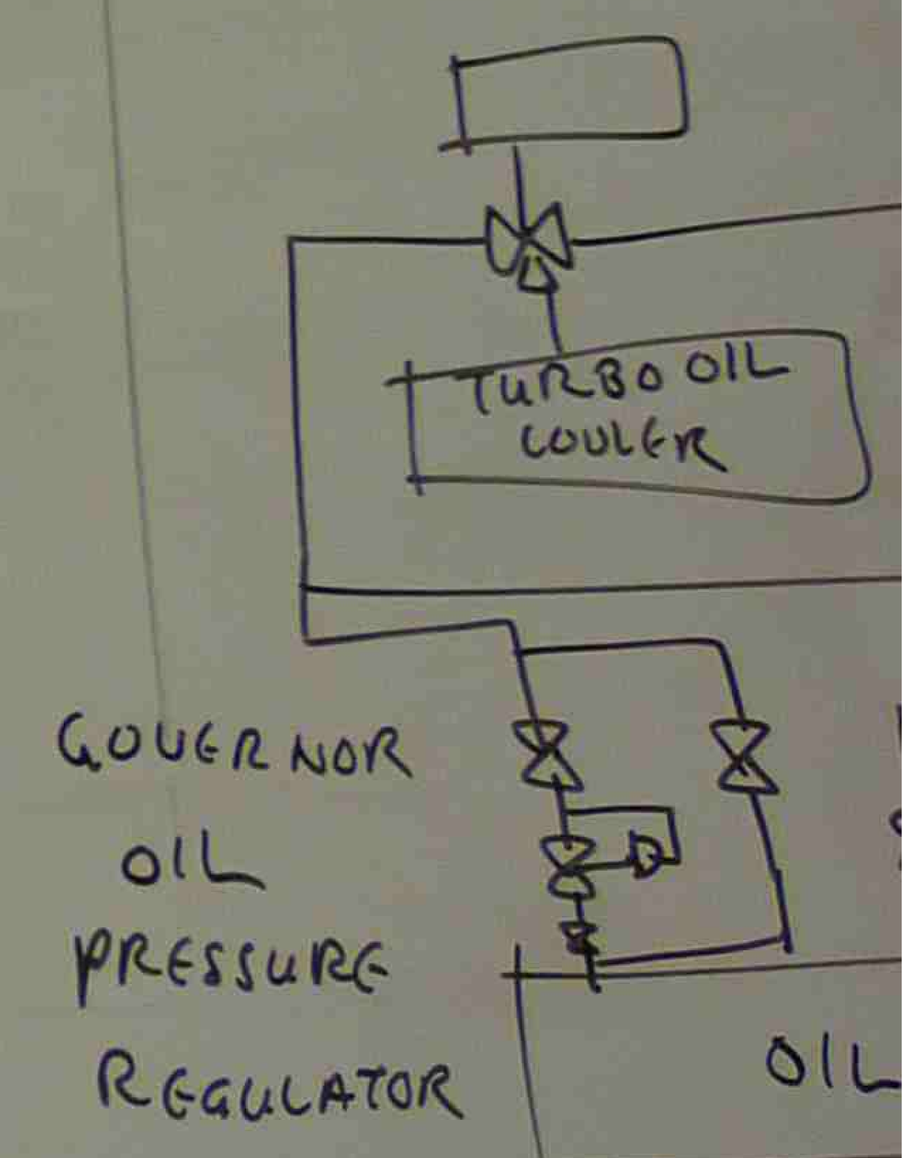
THE DIGITAL COMPUTER CONTROL SYSTEM PERFORMS THE FOLLOWING

- CONFIRM THAT PRESENT CONDITIONS (TEMPERATURE, LEVEL, VALVE SETTINGS) ARE IN ACCORDANCE WITH PROPER SETTING
- PERFORM TURBINE TRIP TEST
- ESTABLISH THE WATER CIRCULATION AND AIR FLOW THROUGH FURNACE
- LIGHTS AND BURNERS
- ACCELERATION THE TURBINE UP TO 3600 RPM, SYNCHRONIZES TO SYSTEM FREQUENCY AND LOADING THE GENERATOR

THE FOLLOWING SYSTEMS ARE INCLUDED

- ARITHMETIC | CONTROL UNIT
- MEMORY UNIT
- INTERRUPT CONTROL UNIT
- CONTACT INPUT CONTROL UNIT
- ANALOG | DIGITAL CONVERTER
- OUT PUT CONTROL UNITS
- DIRECT DIGITAL CONTROL (DDC)

- SEQUENCE CONTROL
- SEQUENCE MONITOR
  TO KNOW THE SY
- PERFORMANCE CA
  - BOILER EFFIC
  - TURBINE E
  - FEED WATER
  - CONDENSER
  - OVER ALL C



FOLLOWING

E, LEVEL, VALUE SETTINGS)

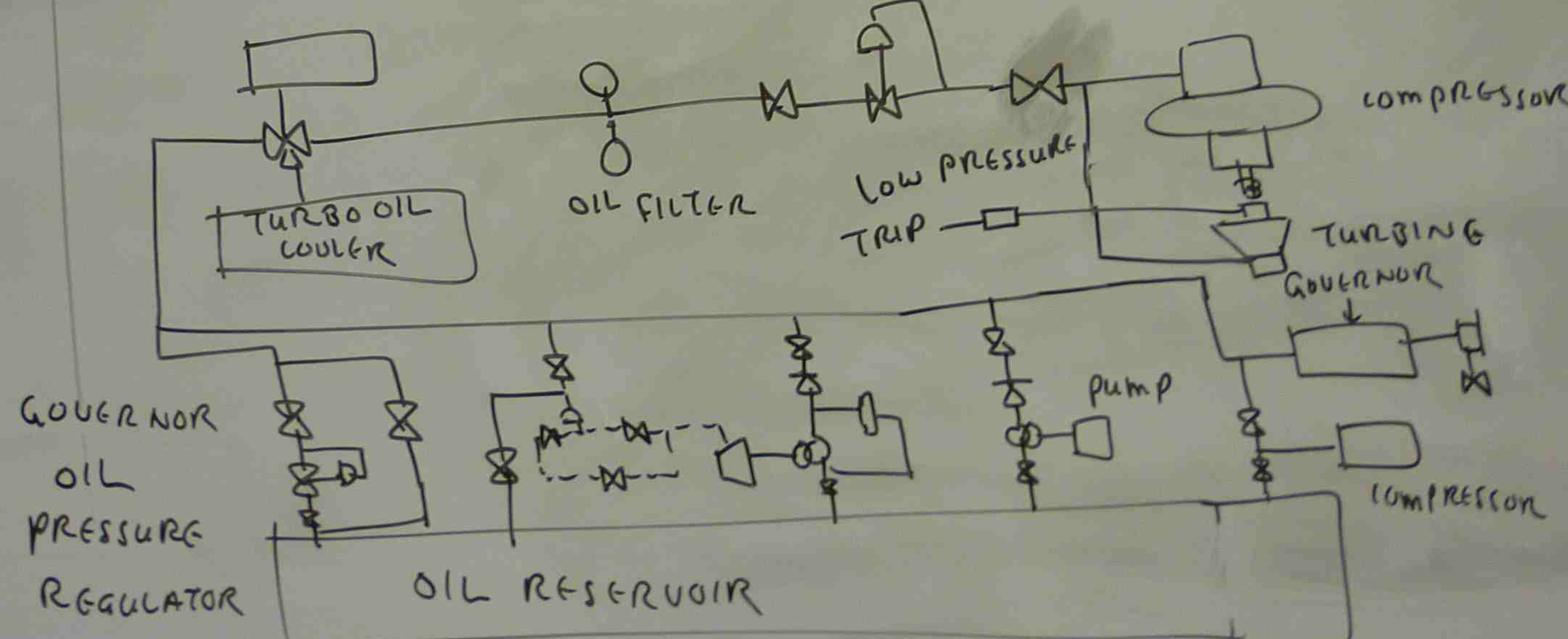
R FLOW THROUGH FURNACE

PM , SYNCHRONIZES TO

RATOR.

- SEQUENCE CONTROL IS IMPORTANT DURING START UP AND SHUT DOWN.
- SEQUENCE MONITORING IS IMPORTANT FOR STARTUP AND SHUT DOWN TO KNOW THE SYSTEM CONDITION.
- PERFORMANCE CALCULATION
  - BOILER EFFICIENCY
  - TURBINE EFFICIENCY
  - FEED WATER HEATER PERFORMANCE
  - CONDENSER PERFORMANCE
  - OVER ALL CYCLE HEAT RATE.

LUBRICATING / COOLING



PERFORMANCE

COMPUTER PERFOR

(a) RELIABILITY

- ON LINE COMPUTE
  UNLESS DEFIN

- RELIABILITY OF
  EXPERIENCE

TURBINE COM

CASING, BU
GOVERNOR

TURBINE IN

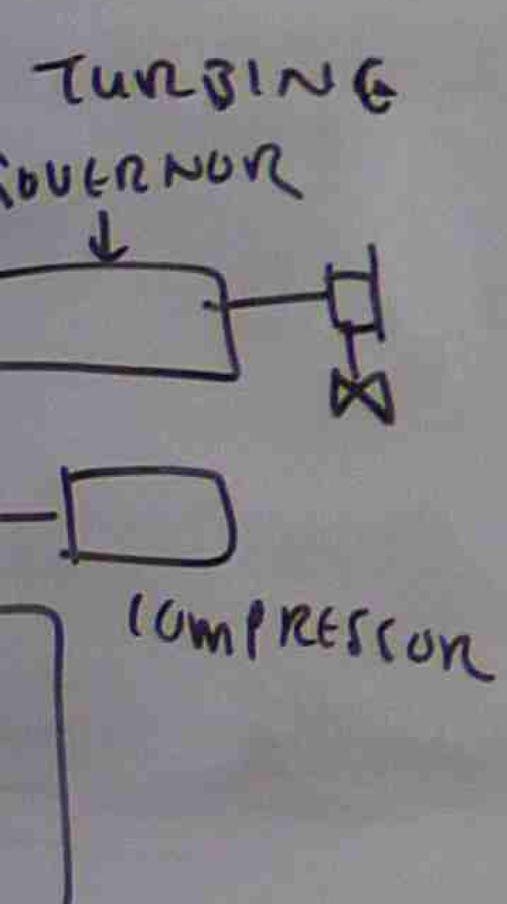
SPINDLE ACC
SHAFT VIBR
SPINDLE
CYLINDER

D SHUT DOWN.

AND SHUT DOWN

ATING | COOLING

COMPRESSOR



PERFORMANCE OF COMPUTER

COMPUTER PERFORMANCE SHOULD BE RATED ACCORDING TO
(a) RELIABILITY (b) SPEED (c) MEMORY STORAGE

- ONLINE COMPUTERS CAN NOT DEAL WITH A REAL TIME PROBLEM UNLESS DEFINED ACTIONS ARE STORED AND ARE AVAILABLE WHEN NEEDED.
- RELIABILITY OF COMPUTERS SHOULD BE EVALUATED IN ACTUAL FIELD EXPERIENCE

TURBINE COMPONENTS

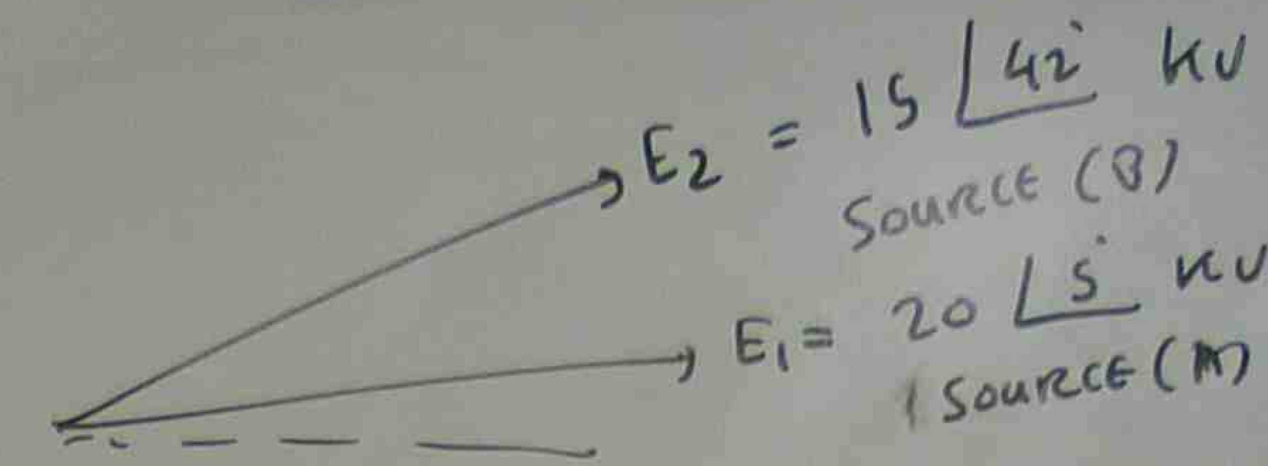
CASING, BUCKET, SEAL, GLAND, BEARINGS, BOLT, PIPING
GOVERNOR VALUE.

TURBINE INSTRUMENTATION

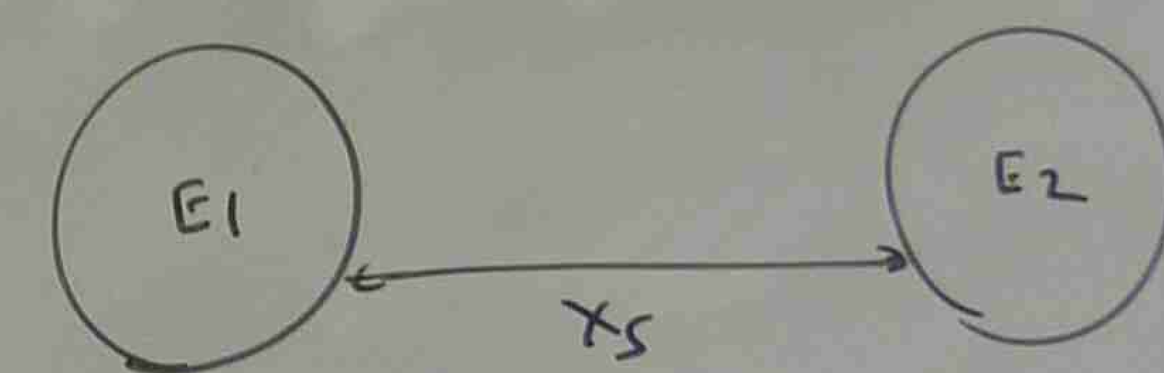
SPINDLE ACCELERATION METER
SHAFT VIBRATION METER
SPINDLE POSITION METER
CYLINDER EXPANSION METER

- SPEED AND GOVERNOR VALUE POSITION METER
- BEARING CONDITION
- STEAM CONDITION
- GLAND SPEED CONDITION.

Pb



CALCULATE ACTIVE POWER FLOW OVER THE LINE AND THE CONNECTING LINE HAS INDUCTIVE REACTANCE 14 Ω.



$$P = \frac{E_1 E_2}{X_S} \sin\delta$$

$$= \frac{20 \times 15}{14} \sin(42-5)$$

$$= \frac{300}{14} \sin 37 = 12.9 \text{ mW}$$

MAIN FEEDER

MAIN FEEDER I

THE FEEDER CA

FACILITY CABLE

SECTIONALIZATION

SEPARATION

RE-CLOSER

AUTOMATIC, H

THE TROUBLE

LOAD BALANC

BALANCING

VOLTAGE REG

ELECTRIC

BOOSTER

TO COM

MAIN FEEDER

MAIN FEEDER IS THE FIRST FACILITY CABLE COMING FROM THE DISTRIBUTION SUBSTATION
THE FEEDER CABLE RUNS TO CROSS CONNECT POINTS IN THE NETWORK WHERE THE SECOND
FACILITY CABLE FEEDS ARE CONNECTED.

SECTIONALIZATION

SEPARATION BY THE CREATION OF BOUNDARY THAT DIVIDES (OR) KEEPS APART

RE-CLOSER

AUTOMATIC, HIGH VOLTAGE ELECTRIC SWITCH. IT AUTOMATICALLY RECLOSES WHEN
THE TROUBLE IN LINE HAS BEEN REMOVED.

LOAD BALANCING

BALANCING THE LOADS DRAWN FROM THE FEEDER

VOLTAGE REGULATOR

ELECTRIC REGULATOR DESIGNED TO AUTOMATICALLY MAINTAIN A CONSTANT VOLTAGE LEVEL

BOOSTER

TO COMPENSATE THE VOLGE DROP IN LINE. MOTOR GENERATOR SET FOR VOLTAGE REGULATION.