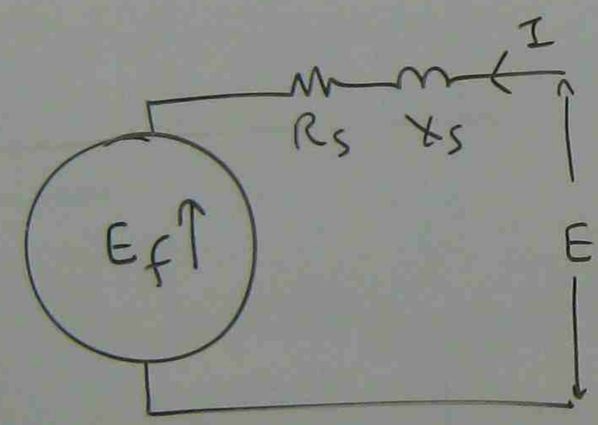
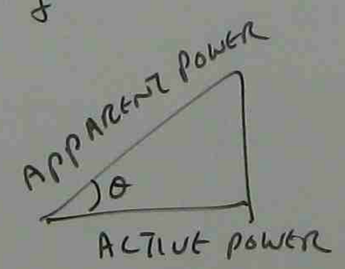
1/ A 400 HP (300 KW), 6600 V, 60 HZ, 200 RPM SYNCHRONOUS MOTOR OPERATES AT FULL LOAD AT LEADING POWER FACTOR of 0.8. IF THE SYNCHRONOUS REACTANCE IS 11Ω. CALCULATE THE FOLLOWINGS.

(a) THE APPARENT POWER OF THE MOTOR PER PHASE (b) THE AC LINE CURRENT

(c) THE VALUE AND PHASE OF Ef (d) TORQUE ANGLE (δ)



$E_f = V - I Z_s$



(a) ACTIVE POWER / PHASE $= \frac{3\phi \text{ POWER}}{3} = \frac{300\text{ KW}}{3} = 100\text{KW}$

APPARENT POWER / PHASE $= \frac{\text{ACTIVE POWER / PHASE}}{\text{POWER FACTOR}} = \frac{100\text{KW}}{0.8} = 125\text{KVA}$

(b) $\sqrt{3}\, E\, I \cos\theta = 3\phi$ ACTIVE POWER

$1.7321 \times 6600 \times I \times 0.8 = 300 \times 10^3$

$I = \frac{300 \times 10^3}{1.7321 \times 6600 \times 0.8} = 32.8\text{ A}$

$\cos\theta = 0.8$

$\theta = \cos^{-1} 0.8 = 36.8$

(c) $E_f = V - I Z_s$

$= \frac{6600}{1.7321} - 32.8 \angle +36.8 \times (0+j11)$

$= 3810 - 32.8 \angle +36.8 \times 11 \angle 90$

$= 3810 - 360.8 \angle 126.8$

$= 3810 - 360.8 (\cos 126.8 + j \sin 126.8)$

$= 3810 - (-216.48 + j288.64)$

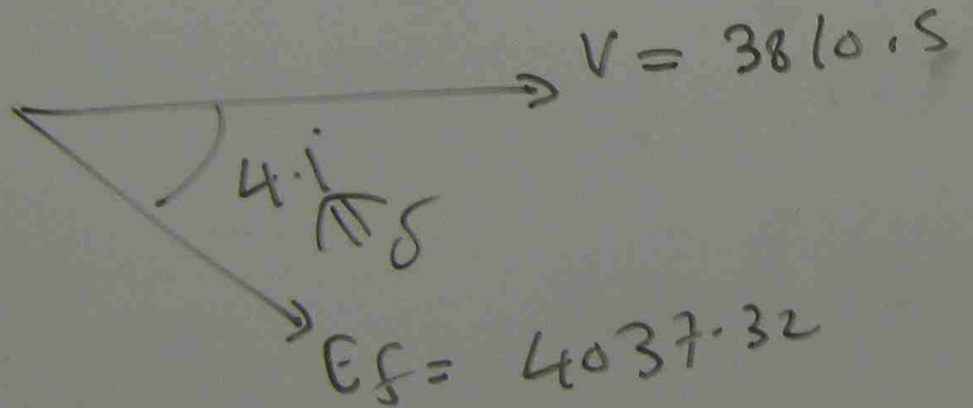
$= 3810 + 216.48 - j288.64$

$= 4026.48 - j288.64$

$$E_f = \sqrt{4026.99^2 + 288.64^2} \angle -\tan^{-1}\frac{288.64}{4026.99}$$

$$= 4037.32 \angle -4.1°$$

δ = TORQUE ANGLE

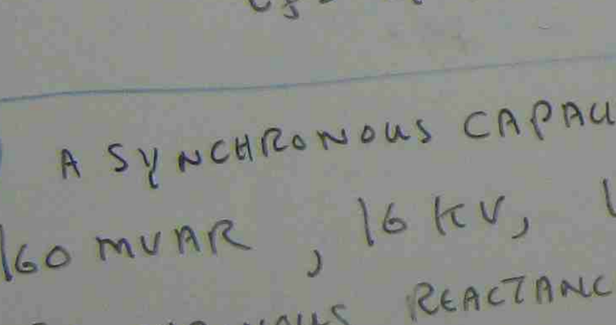


+j11)

$= \sqrt{4026.99^2 + 288.64^2} \angle \tan^{-1}\frac{288.64}{4026.99}$

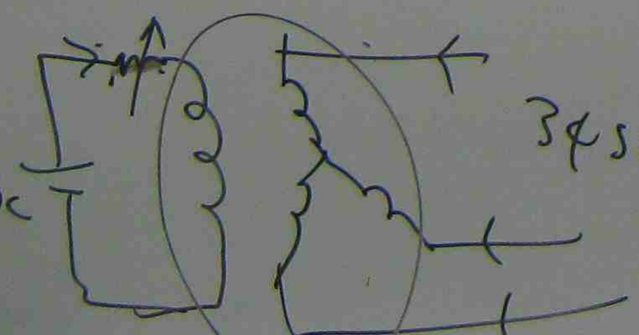
$= 4037.32 \angle 4.1°$

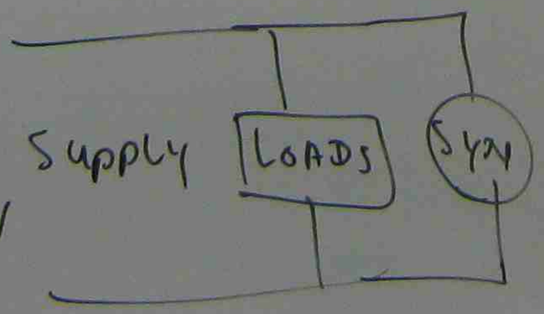
δ = TORQUE ANGLE



A SYNCHRONOUS CAPACITOR IS RATED AT 160 MVAR, 16 KV, 1200 RPM, 60 Hz. IT HAS A SYNCHRONOUS REACTANCE OF 0.8 pu AND IS CONNECTED TO A 16 KV LINE.

CALCULATE THE VALUE OF Ef SO THAT THE MACHINE (a) ABSORBS 160 MVAR (b) DELIVER 120 MVAR





$V = \frac{\text{LINE VOLTAGE}}{\sqrt{3}} = \frac{16\times10^3}{1.7321} = 9237.6\,V$

TO ABSORBS 160 MVAR $\longrightarrow I \angle -90°$

TO DELIVER 120 MVAR $\longrightarrow I \angle +90°$

$I = \frac{\text{3}\phi \text{ REACTIVE POWER}}{\sqrt{3} \times \text{LINE VOLTAGE}} = \frac{160\times10^3}{1.7321\times16\times10^3} = 5773.5\,A$

$E_f = V - I Z_s = 9237.6 - 5773.5 \angle -90 \,(0 + jX)$

$(\Omega) = pu \times \frac{\text{RATED VOLTAGE}^2}{\text{RATED V.A}} = \frac{0.8\times(16\times10^3)^2}{160\times10^6} = 1.28\,\Omega$

$E_f = 9237.6 - 5773.5 \angle -90 \,(0 + j1.28)$

$= 9237.6 - 5773.5 \angle -90 \times 1.28 \angle +90 =$

$= 9237.6 - 7390 = 1847.42\,V$

$E_f = V - I Z_s = 9237.6 - I \angle +90 \times 1.28 \angle 90$

$I = \frac{120\times10^6}{1.7321\times16\times10^3} = 4330.13$

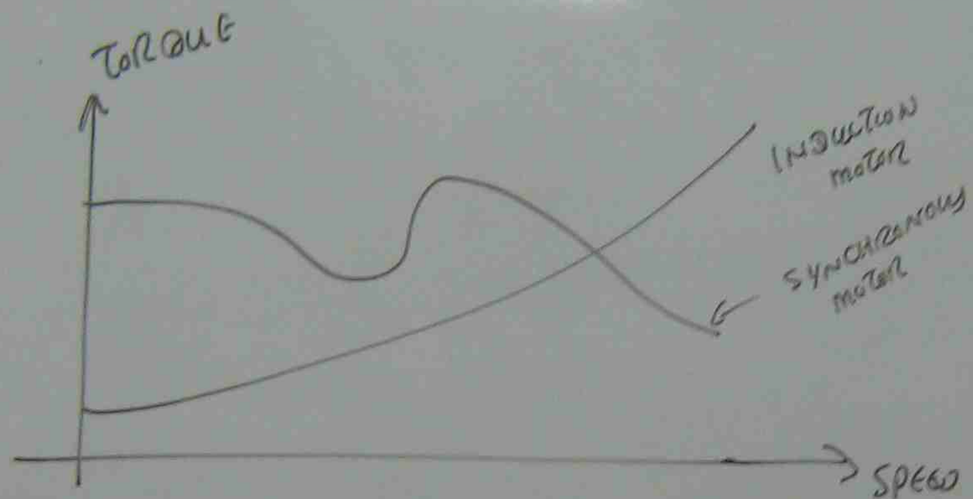
$E_f = 9237.6 - 4330.13 \angle 90 \times 1.28 \angle 90$

$= 9237.6 - 5542.5 \angle 180°$

$= 9237.6 - 5542.5(\cos 180 + j \sin 180)$

$= 9237.6 + 5542.6 = 14780\,V$

Q5



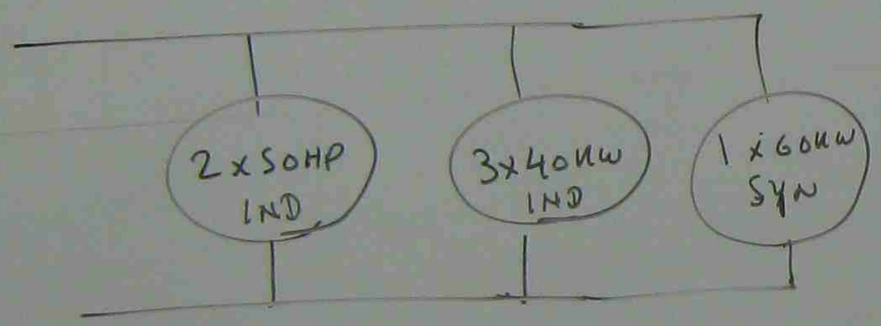
(3) THE FACTORY HAS THE FOLLOWING LOADS

(1) Two 50 HP 3ϕ INDUCTION MOTORS PF 0.707 LAGGING. EFFICIENCY 90%

(2) THREE 40 kW 3ϕ INDUCTION MOTORS POWER FACTOR 0.8 LAGGING EFFICIENCY 95%.

(3) IF 1 60 kW 3 PHASE SYNCHRONOUS MOTOR WITH EFFICIENCY 98% 0.6 P.F LEADING IS CONNECTED IN PARALLEL.

CALCULATE TOTAL ACTIVE AND REACTIVE POWER ABSORBED FROM THE SUPPLY AND TOTAL POWER FACTOR.



2 x 50HP INDUCTION MOTORS

$$kW_1 = \frac{HP \times 0.746 \times \text{NO. OF MOTORS}}{\text{EFFICIENCY}}$$

$$= \frac{50 \times 0.746 \times 2}{0.9}$$

$$= 82.88\ kW$$

$$\phi_1 = \cos^{-1} P.F = \cos^{-1} 0.707 = 45^\circ \text{ LAGGING}$$

$$kVAR_1 = kW_1 \tan\phi_1 = 82.88 \tan 45$$

$$= 82.88\ kVAR$$

$$kW_2 = \frac{\text{OUTPUT POWER} \times \text{NO. OF MOTORS}}{\text{EFFICIENCY}}$$

$$= \frac{40 \times 3}{0.95} = 126.32\ kW$$

$$\phi_2 = \cos^{-1} P.F = \cos^{-1} 0.8 = 36.8$$

$$kVAR_2 = kW_2 \tan\phi_2$$

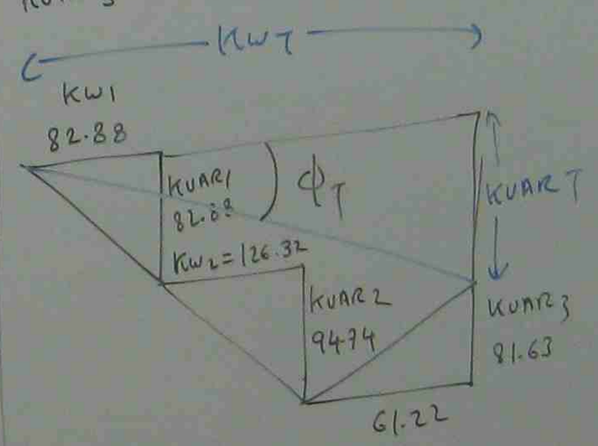
$$= 126.32 \tan 36.8$$

$$= 94.74\ kVAR$$

$$kW_3 = \frac{\text{OUT PUT POWER}}{\text{EFFICIENCY}} = \frac{60}{0.98} = 61.22\ kW$$

$$\phi_3 = \cos^{-1} PF = \cos^{-1} 0.6 = 53.13$$

$$kVAR_3 = kW_3 \tan\phi_3 = 61.22 \tan 53.13 = 81.63\ kVAR$$



$$kW_T = kW_1 + kW_2 + kW_3 = 82.88 + 126.32 + 61.22$$

$$= 270.42\ kW$$

$$kVAR_T = kVAR_1 + kVAR_2 - kVAR_3$$

$$= 82.88 + 94.74 - 81.63$$

$$= 95.99\ kVAR$$

$$\tan\phi_T = \frac{kVAR_T}{kW_T} = \frac{95.99}{270.42} = 0.354$$

$\phi_T =$

P.F =

$$\phi_T = \tan^{-1} 0.354 = 19.54$$

$$P.F = \cos \phi_T = \cos 19.54 = 0.94 \text{ LAGGING}$$

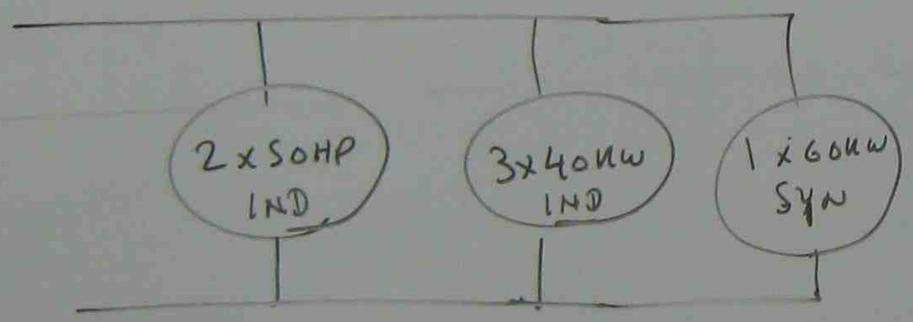
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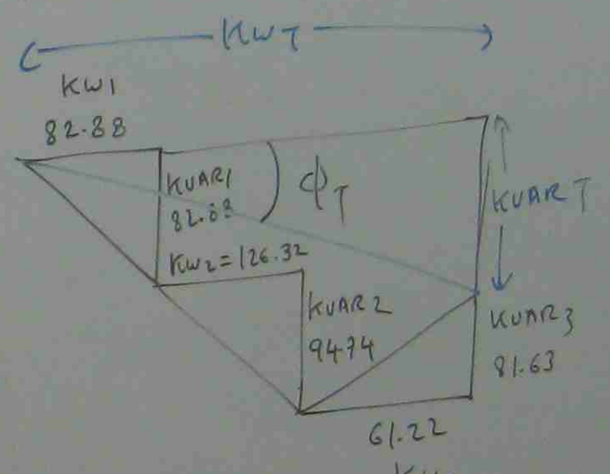
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$$KVAR_3 = KW_3 \tan\phi_3 = 61.22 \tan 53.13 = 81.63\ KVAR$$



$$KW_T = KW_1 + KW_2 + KW_3 = 82.88 + 126.32 + 61.22$$

$$= 270.42\ KW$$

$$KVAR_T = KVAR_1 + KVAR_2 - KVAR_3$$

$$= 82.88 + 94.74 - 81.63$$

$$= 95.99\ KVAR$$

$$\tan\phi_T = \frac{KVAR_T}{KW_T} = \frac{95.99}{270.42} = 0.354$$

61.22 KW

= 81.63 KVAR

-T

23

3

6.32 + 61.22

KW

3

-63

854

$$\phi_T = \tan^{-1} 0.354 = 19.54$$

$$P.F = \cos \phi_T = \cos 19.54 = 0.94 \text{ LAGGING}$$

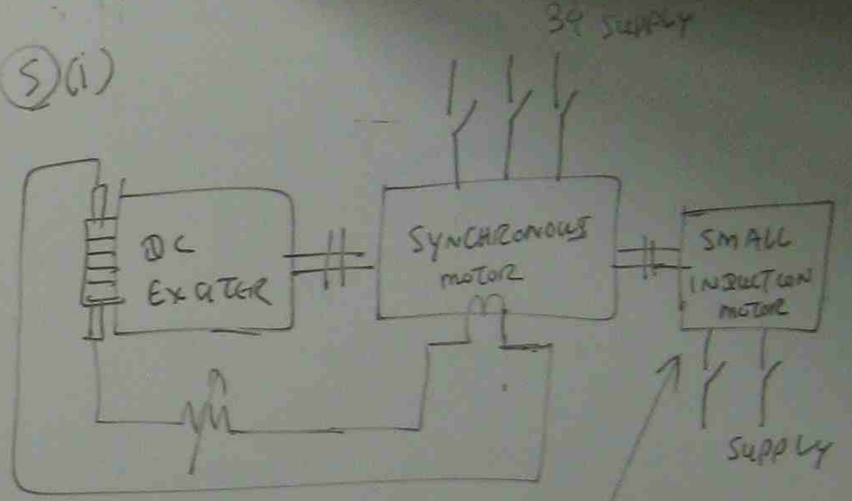
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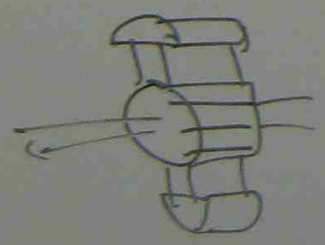
(4) SKETCH THE CONNECTION DIAGRAM OF SYNCHRONOUS INDUCTION MOTOR

(5) DESCRIBE (i) AUXILIARY MOTOR STARTING
(ii) INDUCTION MOTOR STARTING OF A SYNCHRONOUS MOTOR

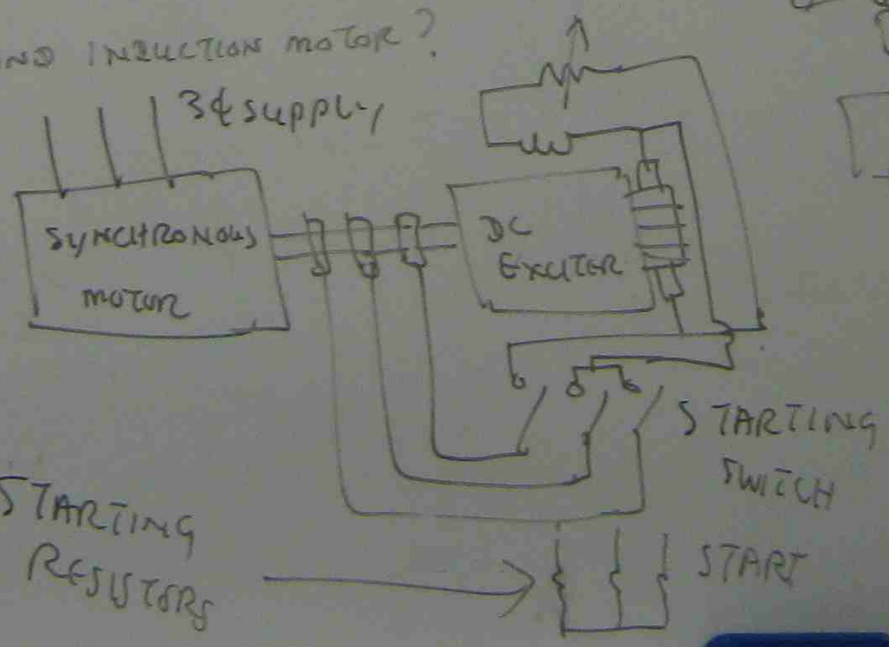
(6) WHAT IS SIGNIFICANT DIFFERENCE BETWEEN SYNCHRONOUS MOTOR AND INDUCTION MOTOR?

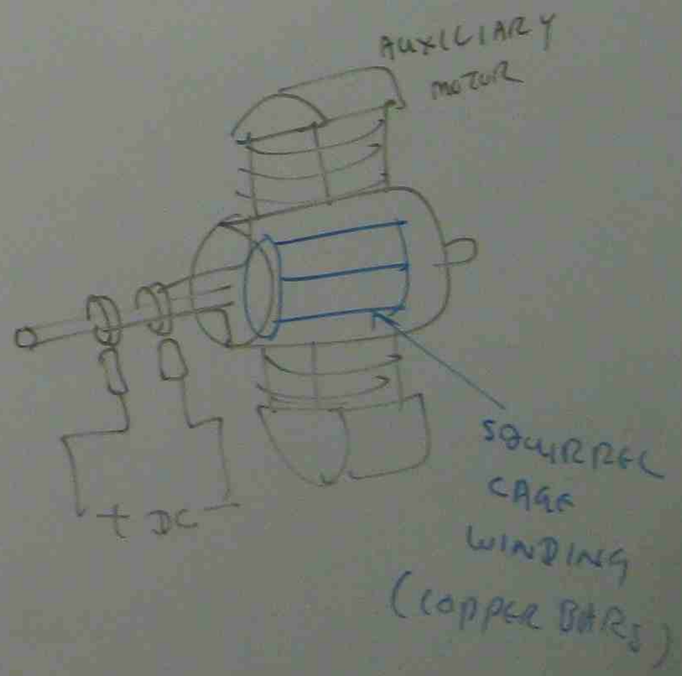
(5)(i)





(4)



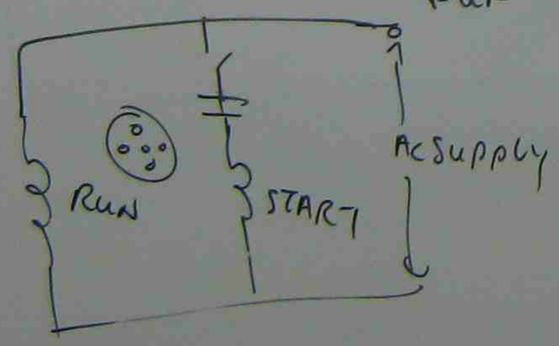


ADVANCED AC MACHINE

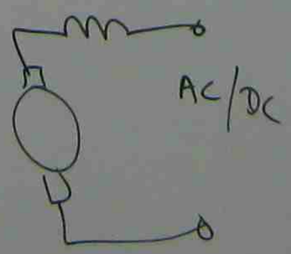
1. EXPLAIN THE OPERATION OF SERIES MOTOR
2. EXPLAIN THE OPERATION PRINCIPLE OF CAPACITOR START MOTOR
3. SKETCH THE VECTOR DIAGRAM OF CAPACITOR RUN MOTOR
4. HOW WILL YOU REVERSE THE DIRECTION OF THE ROTATION OF 1φ MOTOR
5. EXPLAIN THE OPERATION OF SHADED POLE MOTOR

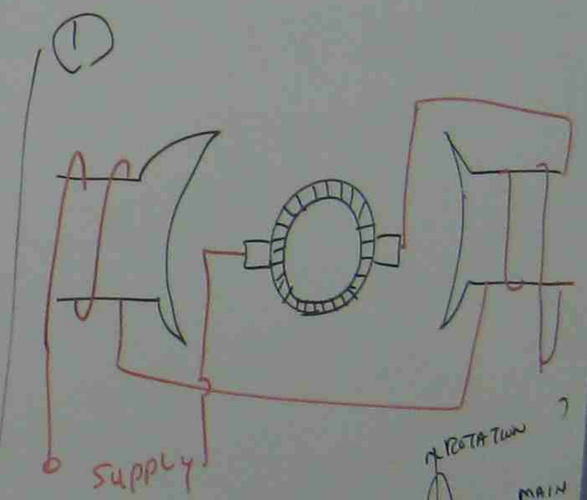
SPLIT PHASE

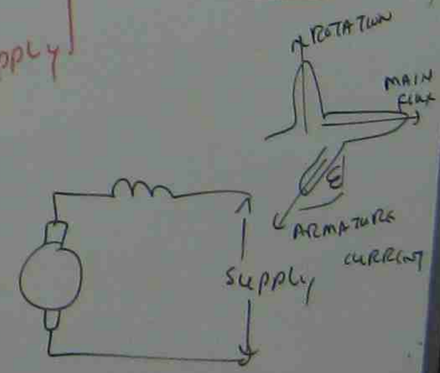
CAPACITOR START | CAPACITOR RUN | SHADED POLE MOTOR | UNIVERSAL MOTOR | RELUCTANCE MOTOR | HYSTERESIS MOTOR







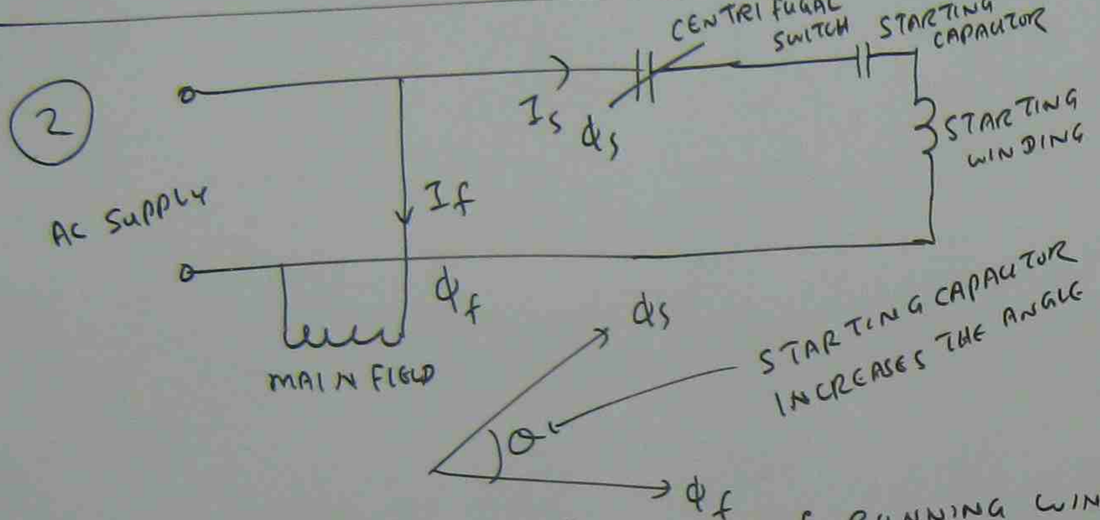




THE SERIES AC MOTOR IS ELECTRICALLY THE SAME AS A DC SERIES MOTOR.
IT FOLLOWS LEFT HAND RULE.
WHEN THE CURRENT FLOWS, THE MAIN FIELD PRODUCES THE FLUX AND ARMATURE CURRENT ALSO PRODUCES FLUX

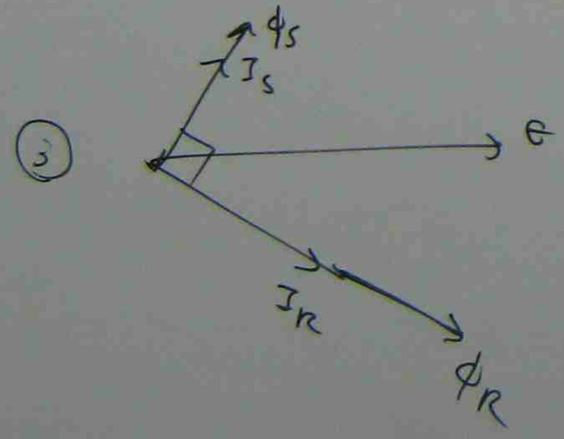
TWO FLUXES INTERACTION ROTATES THE ARMATURE.

(2)

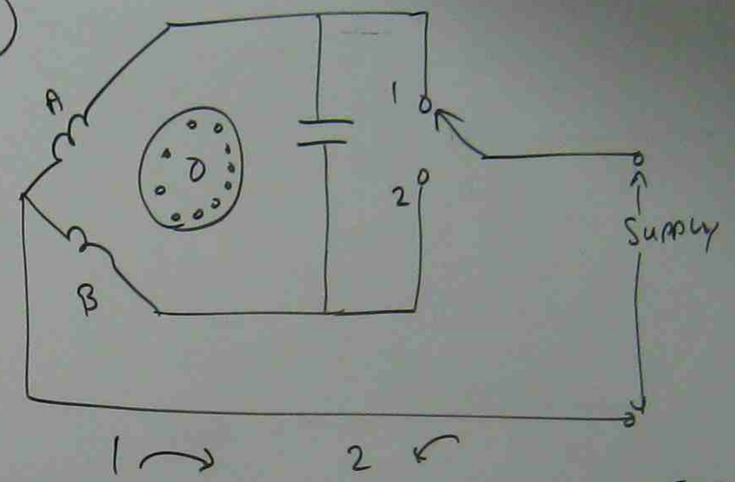


CAPACITOR START MOTOR CONSISTS of RUNNING WINDING AND AUXILIARY (STARTING WINDING). THE PHASE ANGLE BETWEEN TWO WINDINGS ARE INCREASED BY CAPACITOR. WHEN MOTOR SPEEDS UP AND REACHES 75% of FULL LOAD SPEED CENTRIFUGAL SWITCH CUTS OFF THE STARTING WINDING AND IT RUNS WITH MAIN WINDING.

(3)



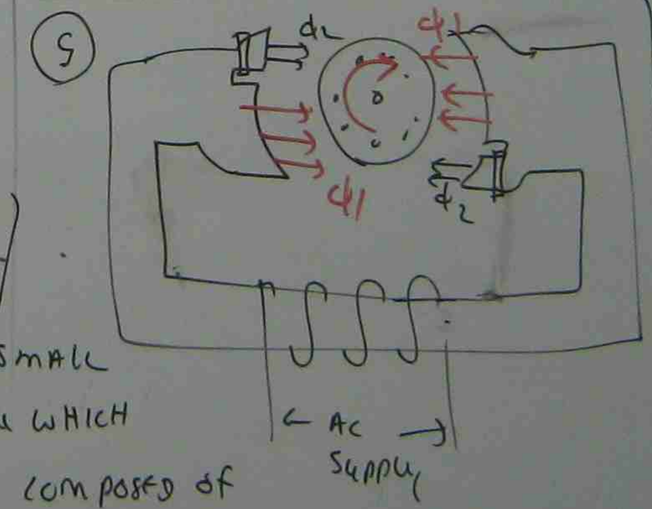
(4)



TO REVERSE THE DIRECTION of THE ROTATION, WE NEEDS TO CHANGE THE LEADS of EITHER AUXILIARY OR MAIN WINDING.

SHADED POLE MOTOR IS A SMALL SQUIRREL CAGE MOTOR IN WHICH THE AUXILIARY WINDING IS COMPOSED of A COPPER RING SURROUNDING THE PORTION of EACH POLE.
THE SHADING RING DIVIDES FLUX INTO ϕ_1 AND ϕ_2

(5)



ϕ_1 IS GREATER THAN ϕ_2 MOTOR RUNS FROM ϕ_1 TO ϕ_2 DIRECTION.

(6) A SMALL 60 HZ HYSTERESIS CLOCK MOTOR POSSESSES 32 POLES. IN MAKING ONE COMPLETE TURN WITH RESPECT TO THE REVOLVING FIELD, THE HYSTERESIS LOSSES IN THE ROTOR IS 0.8 J.

(i) CALCULATE (a) THE PULL IN AND PULL OUT TORQUES
(b) MAXIMUM POWER OUT PUT BEFORE THE MOTOR STALLS
(c) THE ROTOR LOSSES WHEN THE MOTOR IS STALLED.
(d) THE ROTOR LOSSES WHEN THE MOTOR RUNS AT SYNCHRONOUS SPEED.

(7) STATE (i) LOCKED ROTOR TORQUE (ii) BREAK DOWN TORQUE.

(8) COMPARE THE ADVANTAGES AND DISADVANTAGES of 1ϕ AND 3ϕ MOTORS.

(9) WHAT ARE THE ABNORMAL OPERATING CONDITIONS FOR AC INDUCTION MOTORS

(10) A LARGE REEL OF PAPER INSTALLED AT THE END OF PAPER MACHINE HAS A DIAMETER OF 1.8 m, LENGTH of 5.6 m AND MOMENT OF INERTIA 4500 Kg-m^2. IT IS DRIVEN BY DC MOTOR RUNNING AT 120 RPM. THE PAPER IS KEPT UNDER CONSTANT TENSION 6000 N.

(a) CALCULATE THE POWER of MOTOR WHEN THE REEL TURNS AT 120RPM
(b) IF THE SPEED IS RAISED FROM 120 TO 160 RPM IN 5 second, CALCULATE THE TORQUE THAT MOTOR DEVELOPS DURING THIS INTERVAL
(c) CALCULATE THE POWER of MOTOR AT 160RPM

(6) $T = \frac{E}{6.28}$ E = ENERGY IN ROTOR

(a) $= \frac{0.8}{6.28} = 0.127$ N-m

(b) $P = \frac{nT}{9.55}$ P = POWER, n = SPEED, T = TORQUE

$P = \frac{225 \times 0.127}{9.55}$ $n = \frac{120f}{P} = \frac{120 \times 60}{32}$

$= 3$ W $= 225$ rpm

(c) ROTOR LOSS WHEN THE MOTOR IS STALLED = Rpm x HYSTERESIS LOSS
$= 225 \times 0.8$
$= 180$ J

(d) 5 POWER = 8W

(7) LOCKED ROTOR TORQUE

THE TORQUE REQUIRED TO HOLD THE MOTOR SHAFT TO PREVENT FROM RUNNING.

BREAK DOWN TORQUE IS THE MAXIMUM TORQUE THAT STOPS THE MOTOR SHAFT WHICH IS RUNNING AT FULL SPEED

(8)

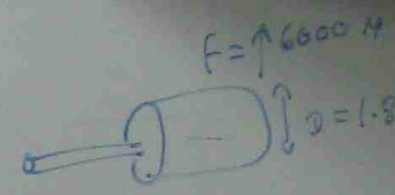
	3φ MOTOR	1φ MOTOR
ADVANTAGE	HIGHER EFFICIENCY SMALLER SUITABLE FOR POWER FREQUENCY	NEEDS ONLY 2 WINDINGS
DISADVANTAGE	NEED 3 IDENTICAL WINDINGS	LARGER SIZE HIGHER CURRENT

(9) ABNORMAL OPERATION

UNEQUAL PHASE VOLTAGE, INCORRECT VOLTAGE, INCORRECT POLARITY

FREQUENCY VARIATION CAUSING SPEED CHANGE

(11)



(a) $P = \frac{nT}{9.55}$ $T = f \times r$

$= 6000N \times \frac{1.8}{2}$

$= 5400\ N-m$

$P = \frac{120 \times 5400}{9.55} = 67850W = 67.85kW$

(b) $\Delta n = \frac{9.55(T_2 - T_1)\Delta t}{J}$

$(160-120) = \frac{9.55(T_2 - 5400)}{4500} \times 5$

$40 = \frac{9.55(T_2 - 5400)}{4500} \times 5$

$\frac{40}{5} \times \frac{4500}{9.55} + 5400 = T_2 = 9170\ N-m$

(c) $P = \frac{nT}{9.55} = \frac{160 \times 9170}{9.55}$

$= 153660\ W$

$= 153.66\ kW$

WEEK 4

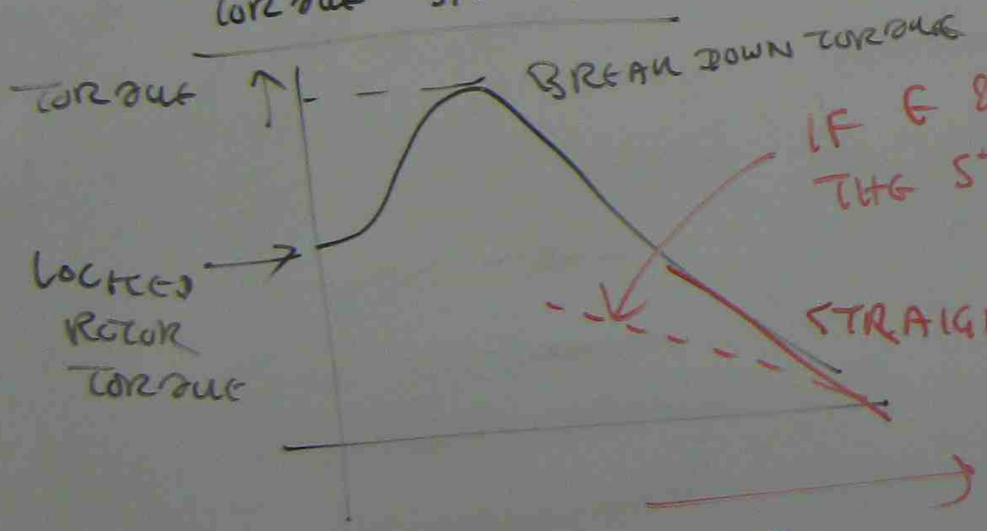
INDUCTION MOTOR CHARACTERISTICS DURING VARIOUS LOADING

SLIP (S) TORQUE (T), LINE VOLTAGE (E), MOTOR RESISTANCE (R)

$$\text{SLIP } (S) = \frac{K\,T\,R}{E^2} \longrightarrow K = \frac{S\,E^2}{TR}$$

$$\frac{S_1 E_1^2}{T_1 R_1} = \frac{S_2 E_2^2}{T_2 R_2} = \frac{S_3 E_3^2}{T_3 R_3} = \cdots$$

TORQUE - SPEED CURVE



EXAMPLE (33)

A 3PHASE 208V INDUCTION MOTOR HAVING A SYNCHRONOUS SPEED of 1200RPM RUNS AT 1140RPM WHEN CONNECTED TO A 215V LINE AND DRIVING A CONSTANT TORQUE LOAD. CALCULATE THE SPEED IF THE MOTOR VOLTAGE INCREASES TO 240V.

$$S_1 = \frac{n_s - n}{n} = \frac{1200 - 1140}{1200} = 0.05$$

$E_1 = 215V$

$S_2 = ?$ $E_2 = 240V$

ASSUME CONSTANT TORQUE/RESISTANCE

$T_1 = T_2$

$$\frac{S_1 E_1^2}{T_1 R_1} = \frac{S_2 E_2^2}{T_2 R_2} \Rightarrow \frac{0.05 \times 215^2}{T_1 R_1} = \frac{S_2 \times 240^2}{T_2 R_2} \quad T_1 = R_2$$

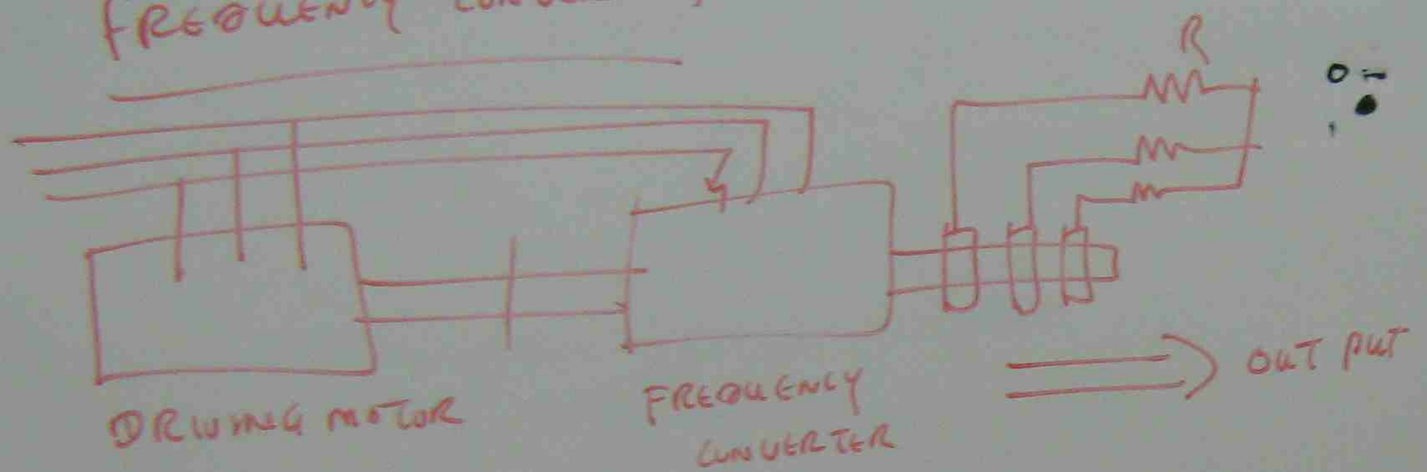
$$S_2 = \frac{0.05 \times 215^2}{240^2} = 0.04$$

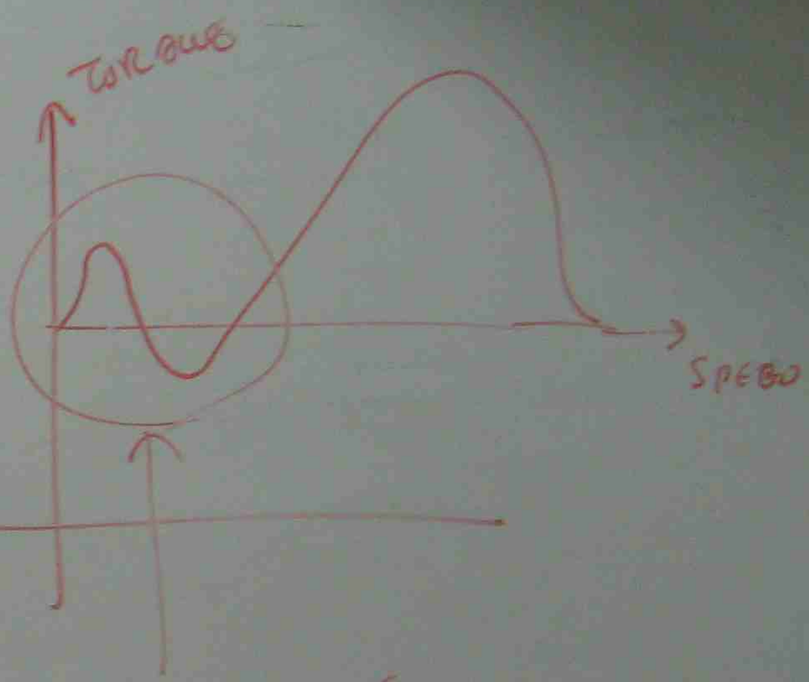
$n = (1-S) \times n_s$

$= (1-0.04) \times 1200$

$= 1152$ RPM

FREQUENCY CONVERTER





IT HAPPENS WHEN THE FULL LOAD IS APPLIED BEFORE MOTOR REACHES FULL SPEED

POWER TRANSFERRED FROM STATOR TO ROTOR OF WOUND ROTOR MOTOR = $\frac{\text{POWER GENERATED}}{\text{SLIP}}$

SLIP-TORQUE CHARACTERISTICS OF INDUCTION MACHINE

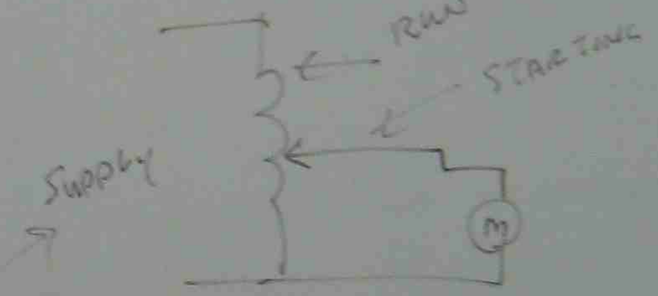
WEEK 5

STARTING OF SQUIRREL CAGE MOTOR



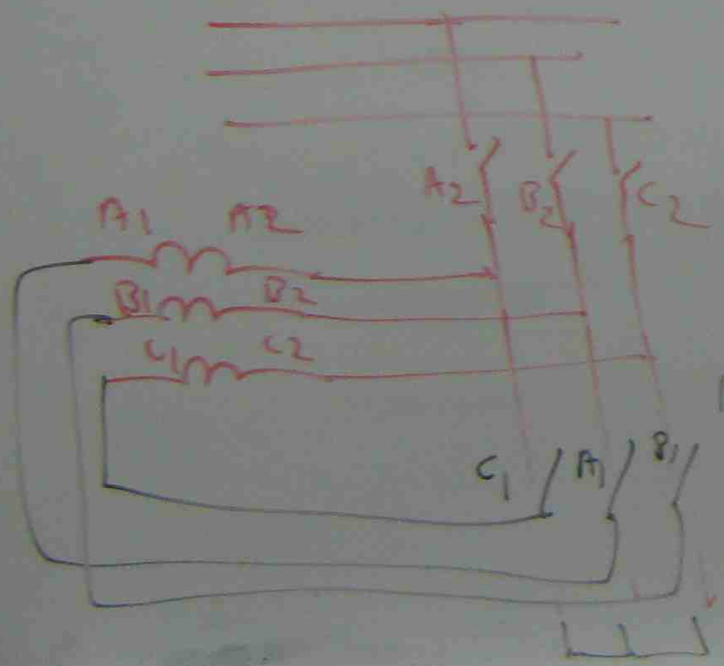
HIGH CURRENT

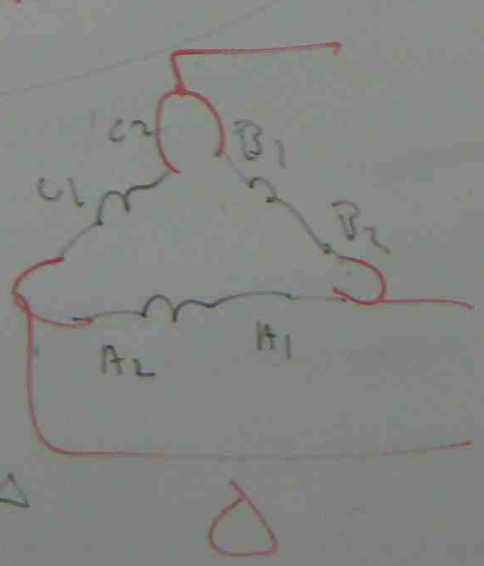
DIRECT ON LINE STARTING → 2KW OR LESS

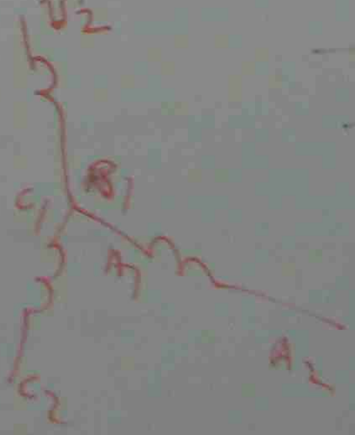


REDUCED VOLTAGE STARTER

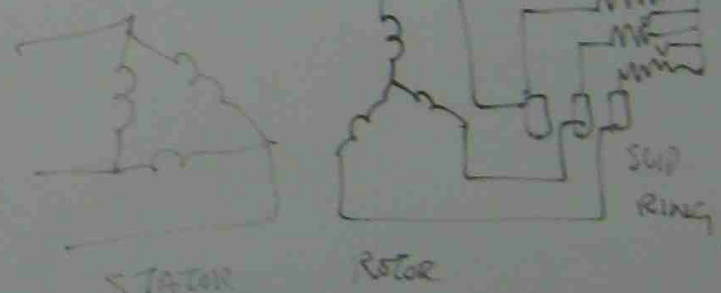
- λ Δ STARTER
- AUTO TRANSFORMER STARTER
- PRIMARY RESISTANCE STARTER
- WOUND ROTOR MOTOR







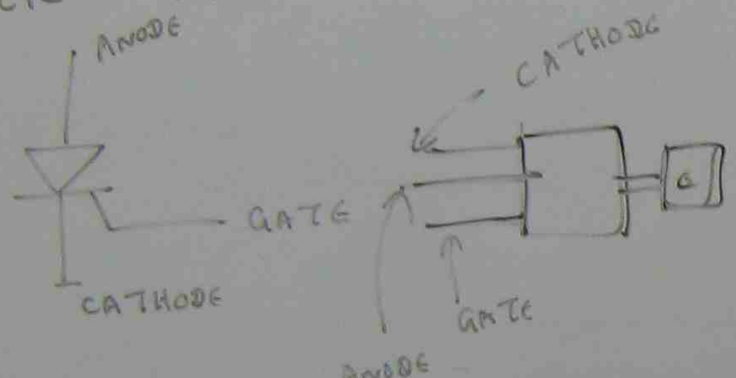
WOUND ROTOR MOTOR

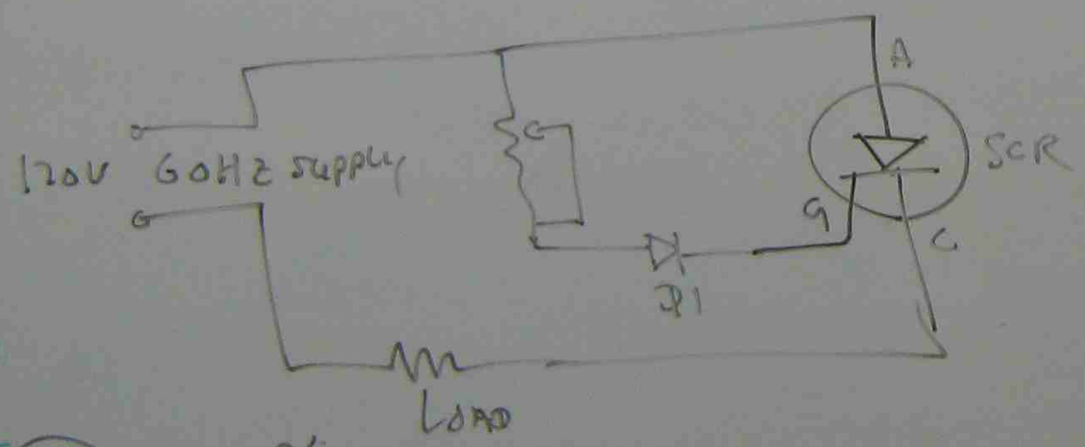


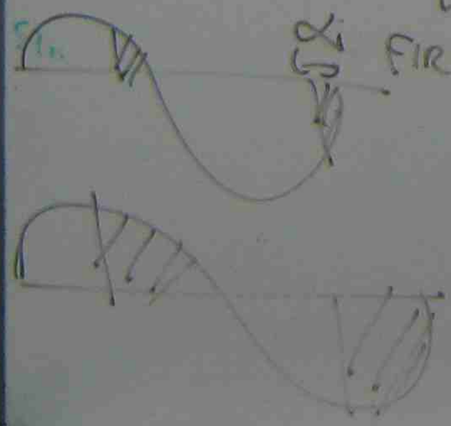
WEEK 6

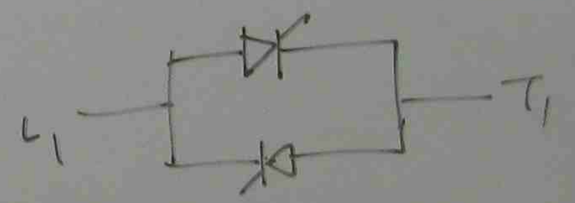
SOLID STATE REDUCED VOLTAGE STARTERS

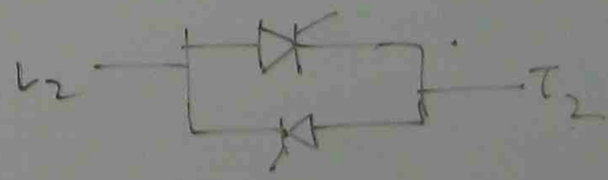
SCR – SILICON CONTROLLED RECTIFIER (THYRISTOR









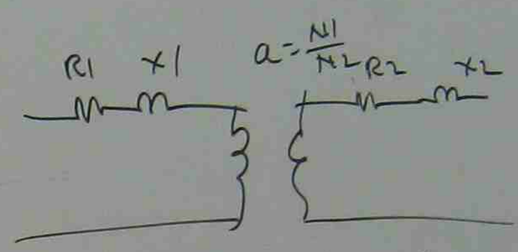




3φ SCR

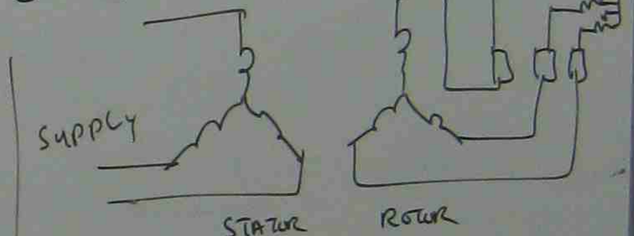
WEEK 5

Q. 40 A 3 PHASE SQUIRREL CAGE INDUCTION MOTOR HAS A STATOR RESISTANCE PER PHASE OF 0.5 Ω AND A ROTOR RESISTANCE PER PHASE REFERRED TO THE STATOR OF 0.5 Ω. THE TOTAL STAND STILL REACTANCE PER PHASE REFERRED TO THE STATOR IS 4.92 Ω. IF THE RATIO OF MAXIMUM TORQUE TO FULL LOAD TORQUE IS 2:1, FIND THE RATIO OF ACTUAL STARTING TO FULL LOAD TORQUE FOR (a) DIRECT STARTING (b) STAR – DELTA STARTING AND (c) AUTO TRANSFORMER STARTING WITH A TAPPING OF 75%.



$R_e = R_1 + a^2 R_2$

$X_e = X_1 + a^2 X_2$



$I = \frac{E}{\sqrt{(R_s + R_r)^2 + (X_s + X_r)^2}}$

$$\text{MAXIMUM TORQUE} = \frac{3 V_s^2}{4\pi n_0} \left(\frac{1}{\sqrt{R_s^2 + (X_s + X_r)^2} \mp R_1} \right) \begin{matrix} - \text{ FOR GENERATOR} \\ + \text{ FOR MOTOR} \end{matrix}$$

MOTOR ACTION

LET $K = \frac{3}{4\pi n_0}$

$$= K V_s^2 \left[\frac{1}{\sqrt{0.5^2 + (4.92)^2} + 0.5} \right] = \frac{K V_s^2}{4.94}$$

Full load torque $T_{FL} = \frac{1}{2} T_{MAX} = \frac{1}{2} \times \frac{K V_s^2}{4.94} = \frac{K V_s^2}{9.89}$

STARTING TORQUE

$$T_{st} = \frac{3V_s^2}{2\pi n_o} \cdot \frac{\frac{1}{s}R_r'}{(R_s + R_r')^2 + s^2(X_s + X_r')^2}$$

DIRECT STARTING $s = 1$

$$= \frac{3V_s^2}{2\pi n_o} \times \frac{1 \times 0.5}{(1 \times 0.5 + 0.5)^2 + 1^2(4.92)^2}$$

$$= k \times \frac{0.5}{(1)^2 + 4.92^2}$$

$$T_{st} = \frac{k V_s^2}{25.2}$$

DIRECT STARTING

(a) $$\frac{T_{st}}{T_{fL}} = \frac{\frac{k}{25.2} V_s^2}{\frac{k V_s^2}{9.84}} = 0.4$$

(b) $$T_{k\Delta} = \left(\frac{1}{\sqrt{3}}\right)^2 T_{st \text{ to } T_{fL}(\text{DIRECT})}$$

K/D STARTING

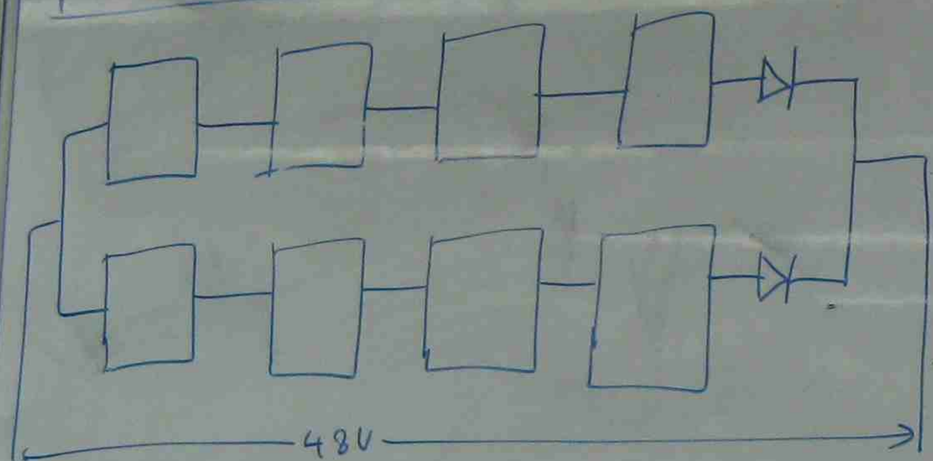
$$= \frac{1}{3} \times 0.4 = 0.131 \%$$

(c) $$T_{\text{AUTO TR STARTING}} = \left(\%\text{ TAPPING}\right)^2 \times T_{st \text{ to } T_{FL}(\text{DIRECT})}$$

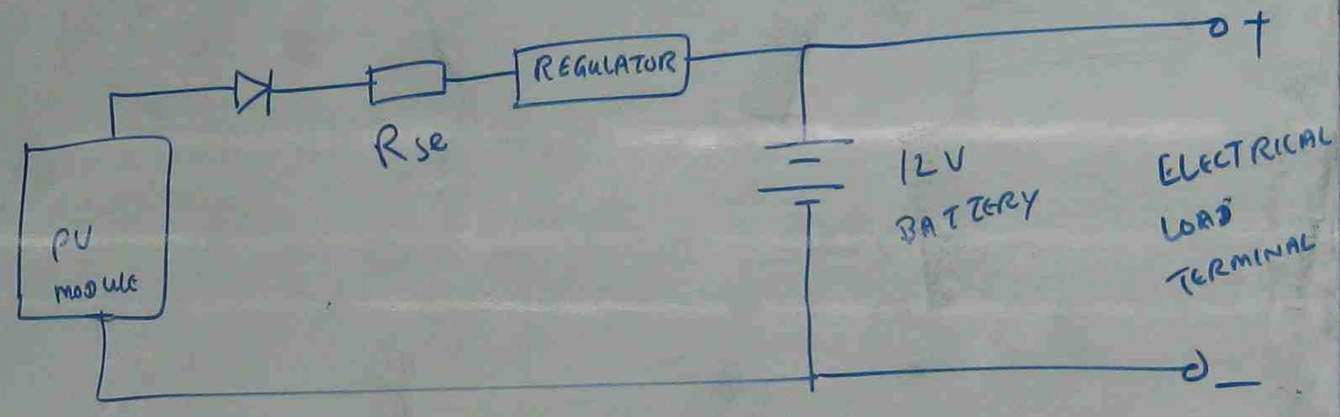
$$= (0.75)^2 \times 0.392$$

$$= 0.231$$

PARALLEL CONNECTION



P.V MODULE AND REGULATOR



P.V MODULES ARE CONNECTED IN SERIES WITH SERIES RESISTOR, (FOR OVER VOLTAGE PROTECTION), DIODE (BACK POWER FLOW PROTECTION), REGULATOR (VOLTAGE REGULATION).

WHEN THE MODULE IS SHADED, THE REVERSE CURRENT FLOW AND OVER VOLTAGE NEEDS TO BE PROTECTED BY DIODE AND RESISTOR.

DIODE IS

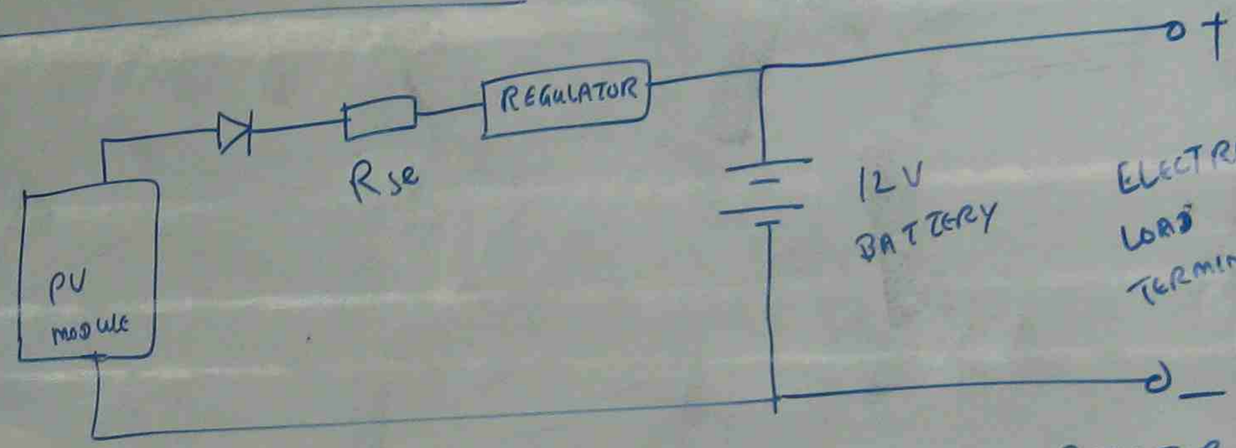
SOLAR MODULE

PARALLEL CONNECTION



P.V MODULE VOLTAGE = BATTERY VOLTAGE + REGULATOR VOLTAGE DROP + CABLE VOLTAGE DROP + DIODE VOLTAGE DROP

P.V MODULE AND REGULATOR



P.V MODULES ARE CONNECTED IN SERIES WITH SERIES RESISTOR, (FOR OVER VOLTAGE PROTECTION), DIODE (BACK POWER FLOW PROTECTION), REGULATOR (VOLTAGE REGULATION).

WHEN THE MODULE IS SHADED, THE REVERSE CURRENT FLOW AND OVER VOLTAGE NEEDS TO BE PROTECTED BY DIODE AND RESISTOR.

= 18 chairs
18 desks

ENERGY OUT PUT EQUATION FOR SOLAR MODULE

$$E_{MODULE} = P_{STC} \times P_{SH} \times f_{DERATE}$$

E_{MODULE} = DAILY ENERGY OUT PUT OF THE MODULE (W.h)

P_{STC} = MODULE POWER OUTPUT RATING UNDER STANDARD TEST CONDITION (STC)

P_{SH} = PEAK SUN HOURS (DAILY IRRADIATION INCIDENT ON THE MODULE)

f_{DERATE} = DERATING FACTOR

Pb

A CRYSTALLINE MODULE. PEAK OUT PUT P_{STC} = 80W

IRRADIATION = 22 mJ/m² ←

DERATING FACTOR = 0.75

CALCULATE MODULE ENERGY OUT PUT.

$$P_{SH} = \frac{\text{IRRADIATION}}{3.8} \quad \text{KWH/m}^2$$

SOLAR TABLE

$$= \frac{22}{3.8}$$

$$E_{MODULE} = P_{STC} \times P_{SH} \times f_{DERATE}$$

$$= 80 \times \frac{22}{3.8} \times 0.75$$

$$= 367 \text{ WH}$$

BASED ON MODULE ENERGY OUT PUT, BATTERY SIZE AND APPROPRIATE EQUIPMENT CAN BE SELECTED.

ACCURATE METHOD FOR BATTERY CHARGING OPERATION

$$E_{module} = V_{MODULE} \times I_{TV} \times f_{man} \times f_{dirt} \times H_{DAILY}$$

E_{module} = DAILY ENERGY OUT PUT OF MODULE (Wh)

V_{module} = TYPICAL OPERATING VOLTAGE OF MODULE (V)

I_{TV} = OUT PUT CURRENT OF MODULE (A)

f_{man} = DERATING FACTOR FOR MANUFACTURING TOLERANCE

f_{dirt} = DERATING FACTOR FOR DIRT

H_{DAILY} = DAILY IRRADIATION (KWh/m^2 ON PEAK SUN HOUR)

ACCURATE METHOD FOR MAXIMUM POWER POINT OPERATION

$$E_{MODULE} = P_{STC}\left[1 - r(T_{cell} - T_{ref}) f_{man} \times f_{dirt} \times H_{DAILY}\right]$$

Pb CALCULATE THE DAILY ENERGY OUT PUT OF P.V MODULE

LEAD ACID BATTERY CHARGING, AMBIENT TEMPERATURE 25c, $f_{derate} = 1$, $V_{MODULE} = 14V$

IRRADIATION = $4\ KWh/m^2$, MAXIMUM MODULE POWER RATING = 72 W

NOCT = 49c, $H_{DAILY} = 4$

REFERENCE TABLE

CELL TEMPERATURE Tcell	OUT PUT CURRENT I_{TV}
40c	4
42c	4.8
49c	5

ACCURATE METHOD FOR BATTERY CHARGING OPERATION

$$E_{module} = V_{module} \times I_{TV} \times f_{man} \times f_{dirt} \times H_{DAILY}$$

E_{module} = DAILY ENERGY OUT PUT OF MODULE (Wh)

V_{module} = TYPICAL OPERATING VOLTAGE OF MODULE (V)

I_{TV} = OUT PUT CURRENT OF MODULE (A)

f_{man} = DERATING FACTOR FOR MANUFACTURING TOLERANCE

f_{dirt} = DERATING FACTOR FOR DIRT

H_{DAILY} = DAILY IRRADIATION (KWh/m^2 ON PEAK SUN HOUR)

ACCURATE METHOD FOR MAXIMUM POWER POINT OPERATION

$$E_{MODULE} = P_{STC} \left[1 - r(T_{cell} - T_{ref}) f_{man} \times f_{dirt} \times H \right]$$

Pb/ CALCULATE THE DAILY ENERGY OUT PUT OF P.V MODULE

LEAD ACID BATTERY CHARGING, AMBIENT TEMPERATURE 25c, $f_{derate} = 1$, $V_{module} = 14V$

IRRADIATION = 4 KWh/m^2, MAXIMUM MODULE POWER RATING = 72 W

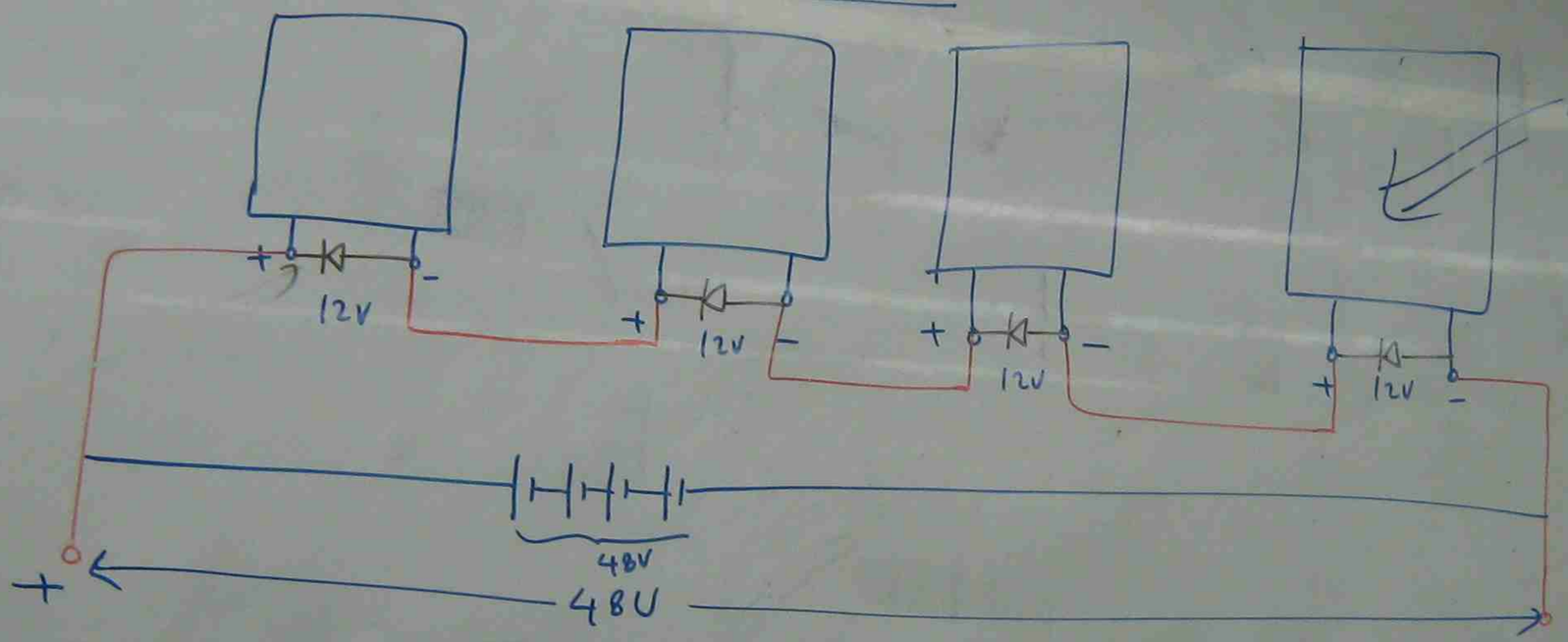
NOCT = 49c, $H_{DAILY} = 4$, ENERGY OUT PUT =

REFERENCE TABLE

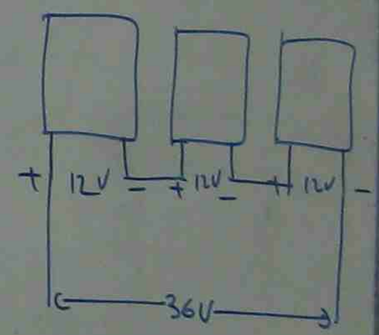
CELL TEMPERATURE Tcell	OUT PUT CURRENT I_{TV}
40c	4
42c	4.8
49c	5

Cap = 18 chairs
18 desks

CONNECTION OF SOLAR MODULES



PROTECTION DIODE IS INCLUDED IN SOLAR MODULE



WHEN ONE MODULE IS SHADED, THE OTHER MODULES WILL BE OVER LOADED.

THE PROTECTION DIODE IS CONNECTED TO PROTECT THE OVER LOAD.

IT BYPASSES THE ELECTRICAL CURRENT.

8 chairs
8 desks

$$f_{mism} = \frac{\text{MODULE POWER}}{\text{ENERGY OUTPUT}} = \frac{72}{77} = 0.94$$

$$T_{cell} = T_A + K(80 \times H_{DAILY} + 150)$$

$T_A = 25$ $\quad K = \frac{NOCT - 20}{800}$

$= \frac{49 - 20}{800} = 0.036$

$T_{cell} = 25 + 0.036(80 \times 4 + 150)$

$= 42^{\circ}C$

FROM TABLE $I_{TV} = 4.8\,A$

$E_{MODULE} = V_{MODULE} \times I_{TV} \times f_{mism} \times f_{derate} \times H_{DAILY}$

$= 14 \times 4.8 \times 0.94 \times 1 \times 4$

$= 253\ Wh$

WIND ENERGY

WIND TURBINE ⟶ ELECTRICITY FROM WIND ENERGY

50 KW ⟶ 3 MW

ENERGY AVAILABLE FROM WIND

THERE ARE THREE PRINCIPLES GOVERNING THE AMOUNT OF ENERGY AVAILABLE FROM THE WIND.

1. THE POWER GENERATED BY THE TURBINE IS PROPORTIONAL TO THE WIND SPEED.

2. THE POWER AVAILABLE IS DIRECTLY PROPORTIONAL TO THE SWEPT AREA OF THE BLADES

3. MAXIMUM THEORETICAL EFFICIENCY OF GENERATOR IS 59%.

CUT IN / CUT OUT SPEED

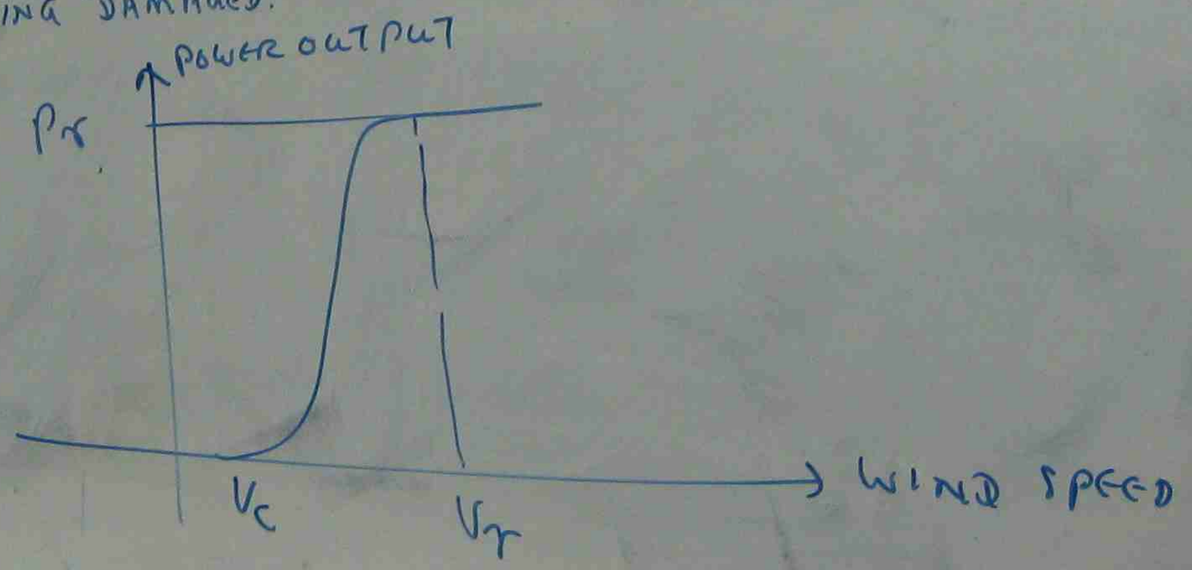
CUT-IN SPEED (V_C)

MINIMUM SPEED OF WIND REQUIRED TO ROTATE THE TURBINE

4 ⟶ 5 m/s

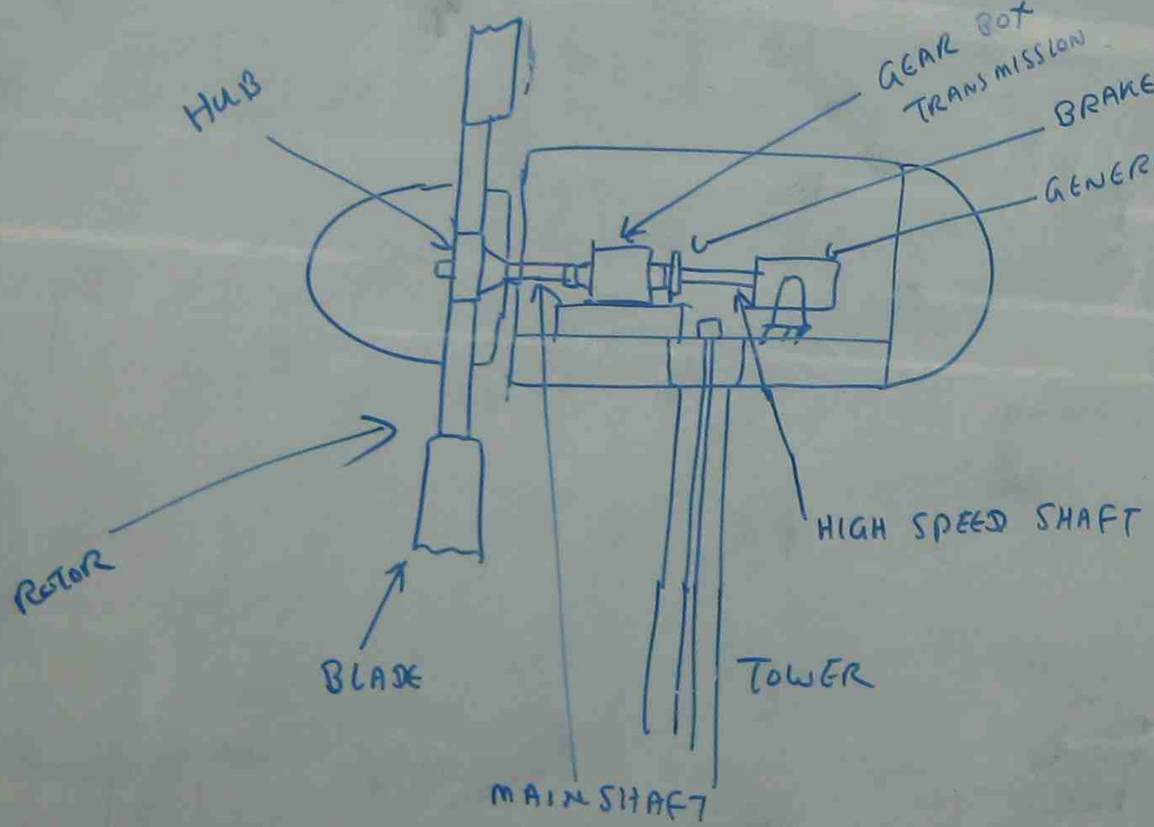
CUT OUT SPEED (V_N)

THE HIGHEST SPEED THE MACHINE CAN SAFELY STAND WITHOUT BEING DAMAGED.



ap = 18 chairs
18 desks

COMPONENTS of WIND TURBINE



ROTOR

THE BLADES of THE ROTOR ARE DESIGNED TO SPIN THE WIND DRIVING THE TURBINE GENGRATOR.

SOME TIME, GEARING IS USED TO OBTAIN THE RIGHT FREQUENCY FOR ELECTRICITY

GENERATOR GENGRATES THE ELECTRICITY WHEN THERE IS SUFFICIENT WIND TO ROTATE THE BLADES.

DIRECTIONAL SYSTEM

HORIZONTAL AXIS MACHINES REQUIRE A MECHANISM TO SWING THEM IN TO LINE WITH THE WIND

PROTECTION SYSTEM MODERN WIND TURBINES ARE USUALLY EQUIPPED WITH MECHANISMS TO PREVENT DAMAGE IN EXCESSIVE HIGH WIND.

WIND ENERGY

WIND TURBINE ⟶ ELECTRICITY FROM WIND ENERGY

50 KW ⟶ 3 MW

ENERGY AVAILABLE FROM WIND

THERE ARE THREE PRINCIPLES GOVERNING THE AMOUNT OF ENERGY AVAILABLE FROM THE WIND.

1. THE POWER GENERATED BY THE TURBINE IS PROPORTIONAL TO THE WIND SPEED.

2. THE POWER AVAILABLE IS DIRECTLY PROPORTIONAL TO THE SWEPT AREA OF THE BLADES

3. MAXIMUM THEORETICAL EFFICIENCY of GENERATOR IS 59%.

CUT IN / CUT OUT SPEED

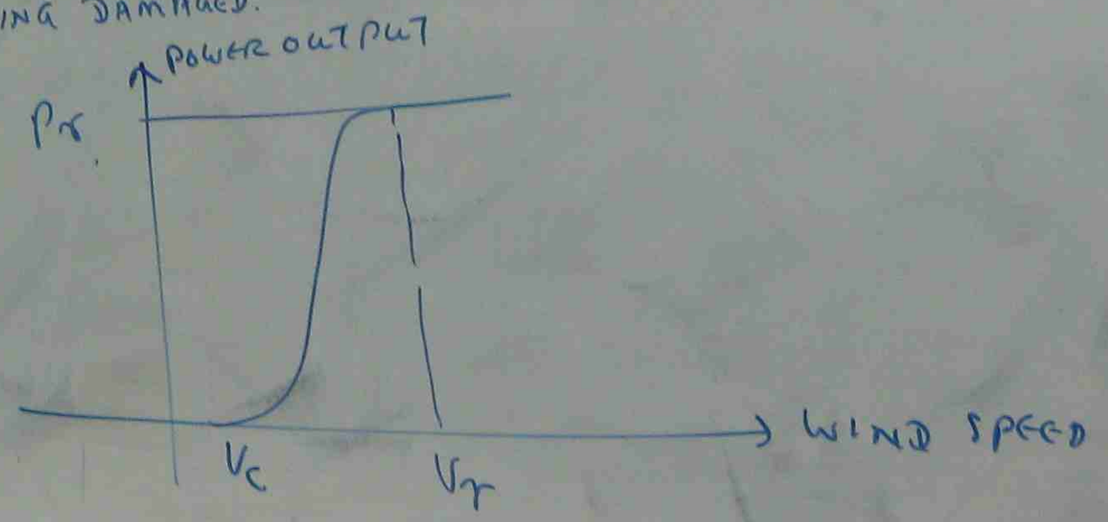
CUT-IN SPEED (V_C)

MINIMUM SPEED OF WIND REQUIRED TO ROTATE THE TURBINE

4 ⟶ 5 m/s

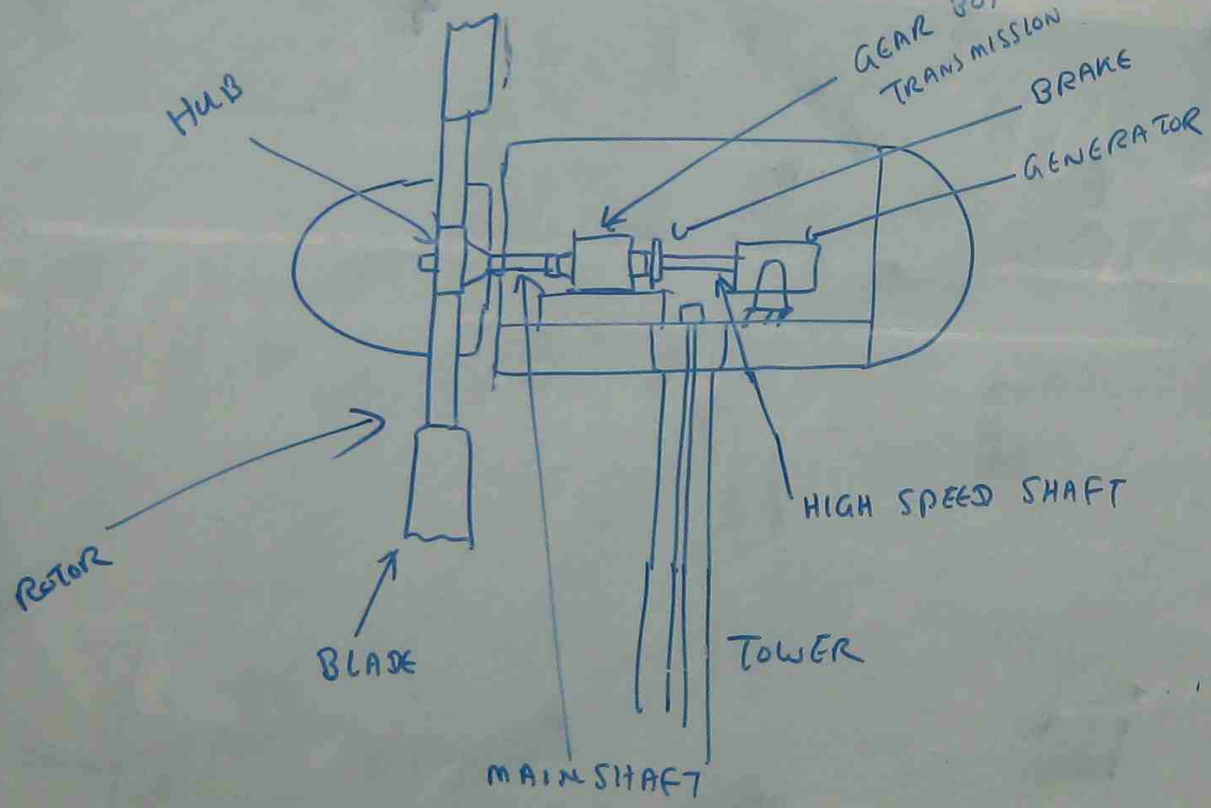
CUT OUT SPEED (V_N)

THE HIGHEST SPEED THE MACHINE CAN SAFELY STAND WITHOUT BEING DAMAGED.



18 chairs
18 desks

COMPONENTS OF WIND TURBINE



ROTOR

THE BLADES OF THE ROTOR ARE DESIGNED TO SPIN THE WIND DRIVING THE TURBINE GENGRATOR. SOME TIME, GEARING IS USED TO OBTAIN THE RIGHT FREQUENCY FOR ELECTRICITY

GENERATOR GENGRATES THE ELECTRICITY WHEN THERE IS SUFFICIENT WIND TO ROTATE THE BLADES.

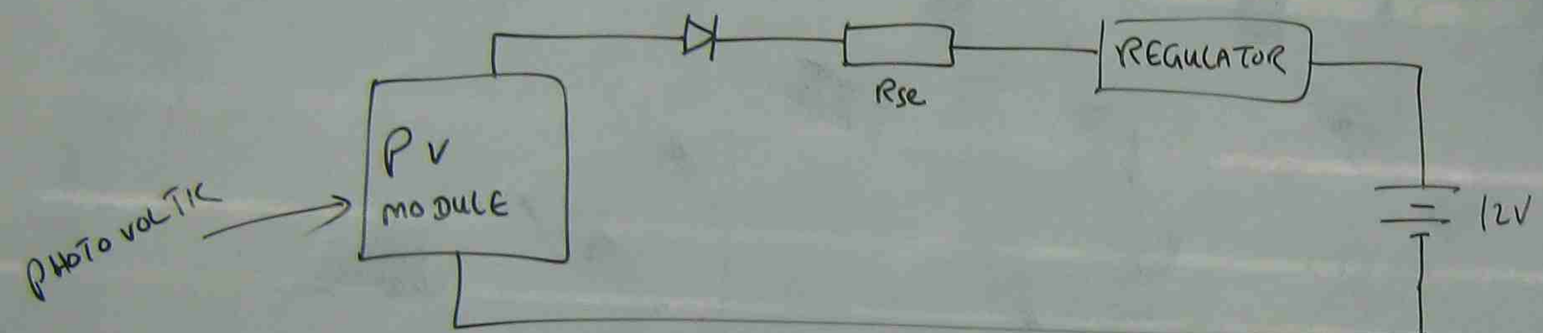
DIRECTIONAL SYSTEM

HORIZONTAL AXIS MACHINES REQUIRE A MECHANISM TO SWING THEM IN TO LINE WITH THE WIND

PROTECTION SYSTEM MODERN WIND TURBINES ARE USUALLY EQUIPPED WITH MECHANISMS TO PREVENT DAMAGE IN EXCESSIVE HIGH WIND.

Cap = 18 chairs
18 desks

P.V REGULATOR



DIODE - REVERSE POWER FLOW PROTECTION

Rse - VOLTAGE PROTECTION / OVER VOLTAGE PROTECTION

REGULATOR - REGULATE THE BATTERY CHARGING VOLTAGE

P. V MODULE VOLTAGE = BATTERY VOLTAGE + REGULATOR VOLTAGE DROP + CABLE VOLTAGE DROP + DIODE VOLTAGE DROP

ENERGY OUT PUT BY P.V MODULE

$$E_{MODULE} = P_{STC} \times P_{SH} \times f_{derate}$$

E_{module} = DAILY ENERGY OUT PUT OF THE MODULE (W.h)

P_{STC} = MODULE POWER OUT PUT RATING UNDER STANDARD TEST (W)

$P_{S.H}$ = PEAK SUN HOURS

f_{derate} = DERATING FACTOR DUE TO TEMPERATURE AND OPERATING POINT.

Ex

Ex CRYSTALLINE MODULE, PEAK OUT PUT $P_{STC} = 80W$

IRRADIATION = 22 mJ/m^2. CALCULATE DAILY ENERGY OUT PUT. $f_{derate} = 0.75$

$$E_{MODULE} = P_{STC} \times P_{SH} \times f_{derate}$$

$$P_{SH} = \frac{\text{IRRADIATION}}{3.8} = \frac{22}{3.8}$$

$$E_{MODULE} = 80 \times \frac{22}{3.8} \times 0.75 = 367 \text{ Whr}$$

ACCURATE METHOD FOR BATTERY CHARGING OPERATION

$$E_{MODULE} = V_{MODULE} \times I_{TV} \times f_{man} \times f_{dirt} \times H_{daily}$$

E_{MODULE} = DAILY ENERGY OUT PUT OF THE MODULE

I_{TV} = OUT PUT CURRENT OF MODULE AT CELL OPERATING TEMPERATURE

f_{man} = DERATING FACTOR FOR MANUFACTURING TOLERANCE.

f_{dirt} = DERATING FACTOR FOR DIRT.

H_{daily} = DAILY IRRADIATION (KWh/m^2)

Cap = 18 chains
18 desics

Pb CALCULATE DAILY ENERGY OUT PUT OF 77 W MODULE.

LEAD ACID CHARGING ; AMBIENT TEMPERATURE = 25°C. ← T_A

$f_{dint} = 1$ $V_{module} = 14V.$

IRRADIATION = 4 Kwh/m^2, MAXIMUM MODULE POWER RATING = 72W

NOCT = 49°C , $H_{daily} = 4$

TABLE

CELL TEMPERATURE T_{cell}	OUT PUT CURRENT OF MODULE
40°C	4 A
42°C	4.8 A
44°C	5 A

V_{module} = MODULE OPERATING VOLTAGE

$E_{module} = V_{module} \times I_{TV} \times f_{mman} \times f_{dint} \times H_{daily}$

$T_{cell} = T_A + k(80\ H_{daily} + 150)$

$T_{cell} = 25 + k(80 \times 4 + 150)$

$k = \frac{NOCT - 20}{800} = \frac{49 - 20}{800} = 0.036$

$T_{cell} = 25 + 0.036\ (80 \times 4 + 150)$

$= 42°C$

$42°C \longrightarrow I_{TV} = 4.8$ Amp

$f_{dint} = 1$, $f_{mman} = \frac{\text{MODULE POWER OUTPUT}}{\text{ENERGY OUTPUT}} = \frac{72}{77}$

$= 0.94$

$E_{module} = 14 \times 4.8 \times 0.94 \times 1 \times 4$

$= 253$ Whr

ap = 18 chairs
18 desks

Pb CALCULATE DAILY ENERGY OUT PUT OF 77 W MODULE.

LEAD ACID CHARGING, AMBIENT TEMPERATURE = 25°C ← T_A

$f_{dirt} = 1$ $V_{module} = 14V$.

IRRADIATION = 4 kwh/m², MAXIMUM MODULE POWER RATING = 72W

NOCT = 49°C, $H_{daily} = 4$

TABLE

CELL TEMPERATURE T_{cell}	OUT PUT CURRENT of MODULE
40°C	4 A
42°C	4.8 A
44°C	5 A

V_{module} = MODULE OPERATING VOLTAGE

$$E_{module} = V_{module} \times I_{TV} \times f_{man} \times f_{dirt} \times H_{daily}$$

$$T_{cell} = T_A + k(80\, H_{daily} + 150)$$

$$T_{cell} = 25 + k(80 \times 4 + 150)$$

$$k = \frac{NOCT - 20}{800} = \frac{49 - 20}{800} = 0.036$$

$$T_{cell} = 25 + 0.036\,(80 \times 4 + 150)$$

$$= 42°C$$

$42°C \longrightarrow I_{TV} = 4.8$ Amp

$f_{dirt} = 1$, $f_{man} = \frac{\text{MODULE POWER (OUT PUT)}}{\text{ENERGY OUT PUT}} = \frac{72}{77}$

$= 0.94$

$E_{module} = 14 \times 4.8 \times 0.94 \times 1 \times 4$

$= 253$ W hr

PD - $f_{dirt} = 1$ $f_{dirt} = 95\%$ $H_{daily} = 5.5$, $T_{ref} = 35c$

NOCT = 49 $P_{STC} = 95W$, γ = power out put coefficient = 0.05

CALCULATE DAILY ENERGY OUT PUT BY USING ACCURATE METHOD FOR MAXIMUM POWER POINT OPERATION.

AMBIENT TEMPERATURE 25c

$$E_{module} = P_{STC}\left[1 - \gamma(T_{cell} - T_{ref})\right] f_{man} \times f_{dirt} \times H_{daily}$$

P_{STC} = module power out put rating under standard test

γ = power out put coefficient

T_{cell} = cell operating temperature (c)

T_{ref} = cell temperature at STC (c)

f_{man} = manufacturing tolerance derating factor

f_{dirt} = derating factor due to dirt

H_{daily} = daily irradiation

$$T_{cell} = T_A + k(80\, H_{daily} + 150)$$

$$= 25 + k(80 \times 5.5 + 150)$$

$$k = \frac{NOCT - 20}{800} = \frac{49 - 20}{800} = 0.036$$

$$T_{cell} = 25 + 0.036(80 \times 5.5 + 150)$$

$$= 43^{\circ}c$$

$$E_{module} = 95\left[1 - \frac{0.05}{100}(43 - 35)\right] \times 1 \times 0.95 \times 5.5$$

$$= 435\ w\text{-}hr$$

μ = 18 chairs
18 desks

WIND ENERGY

WIND → WIND TURBINE ‖ ALTERNATOR → ELECTRICITY

WIND ENERGY CONVERSION SYSTEM (WIND TURBINES) ARE DESIGNED TO CONVERT THE ENERGY OF WIND MOVEMENT (KINETIC ENERGY) IN TO MECHANICAL ENERGY (MOVEMENT OF A MACHINE). IN WIND TURBINE GENERATORS, THIS MECHANICAL ENERGY IS CONVERTED IN TO ELECTRICITY AND IN WIND MILLS THIS ENERGY IS USED TO DO WORK SUCH AS PUMPING WATER MILLING GRAINS OR DRIVING MACHINERY. THE ELECTRICITY GENERATED CAN BE EITHER STORED IN BATTERIES OR USED DIRECTLY.

CUT IN SPEED (V_c)

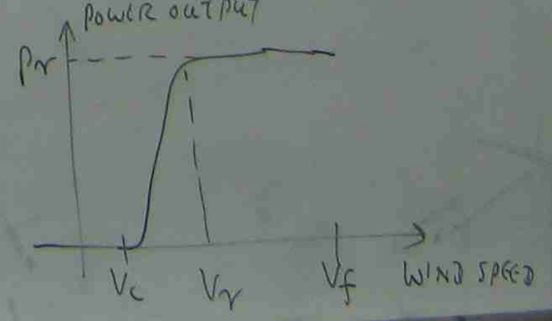
MINIMUM WIND SPEED TO DRIVE WIND TURBINE $4 \rightarrow 5$ m/s

CUT OUT SPEED (V_f)

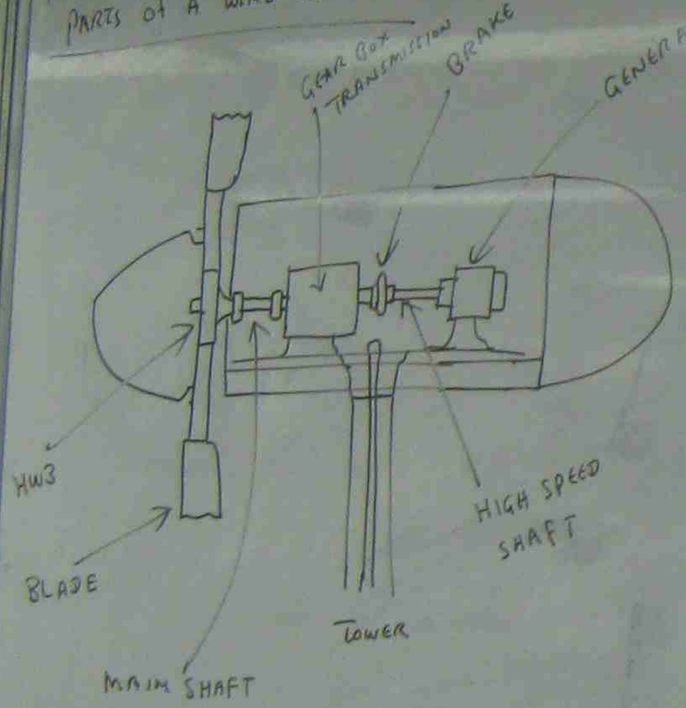
THE HIGHEST THE MACHINE CAN SAFELY STAND WITHOUT BEING DAMAGED.

RATED SPEED (V_R)

THE WIND SPEED AT WHICH THE PARTICULAR MACHINE ACHIEVES IT'S MAXIMUM OUTPUT



PARTS OF A WIND TURBINE



ROTOR THE BLADES OF THE ROTOR ARE DESIGNED TO SPIN IN WIND, DRIVING THE TURBINE GENERATOR. SOMETIMES GEARING IS USED TO OBTAIN THE RIGHT FREQUENCY FOR ELECTRICITY GENERATION.

GENERATOR THIS GENERATES THE ELECTRICITY WHEN THERE IS SUFFICIENT WIND TO ROTATE THE BLADES

DIRECTIONAL SYSTEM HORIZONTAL AXIS MACHINES REQUIRE A MECHANISM TO SWING THEM IN TO LINE WITH THE WIND

PROTECTION SYSTEM MODERN WIND TURBINES ARE USUALLY EQUIPPED WITH MECHANISMS TO PREVENT DAMAGE IN EXCESSIVELY HIGH WIND.

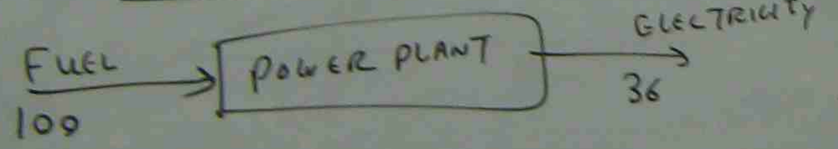
TOWER THE TOWER HOLDS THE TURBINE'S ASSEMBLY ABOVE THE GROUND.

CO-GENGRATION

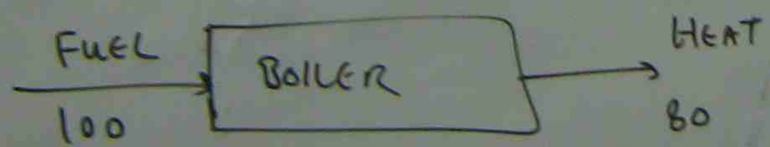
CO-GENERATION IS THE THERMODYNAMICALLY SEQUENTIAL PRODUCTION OF TWO OR MORE USEFUL FORMS OF ENERGY FROM A SINGLE PRIMARY ENGRGY SOURCE.

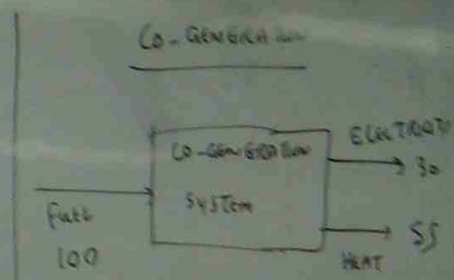
CO-GENERATION IS THE COMBINED PRODUCTION of ELECTRICAL (OR MECHANICAL) AND USEFUL THERMAL ENERGY FROM THE SAME PRIMARY ENERGY SOURCE.

SEPERATE PRODUCTION



TOTAL EFFICIENCY $= \frac{36 + 80}{100 + 100} = 0.58$

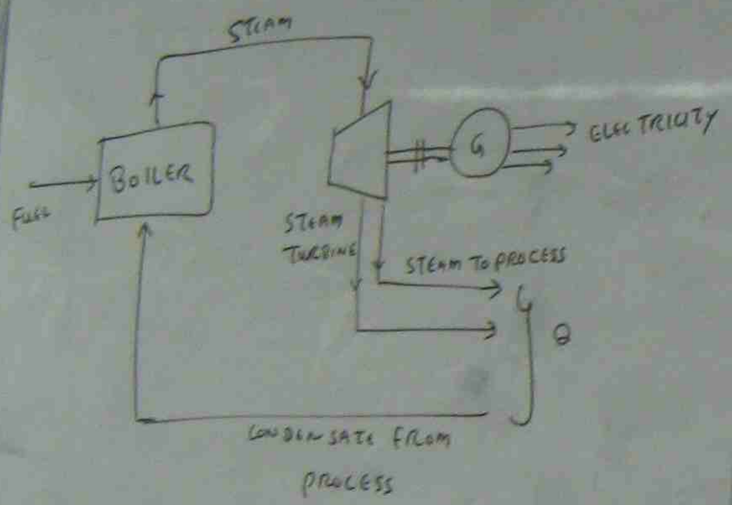




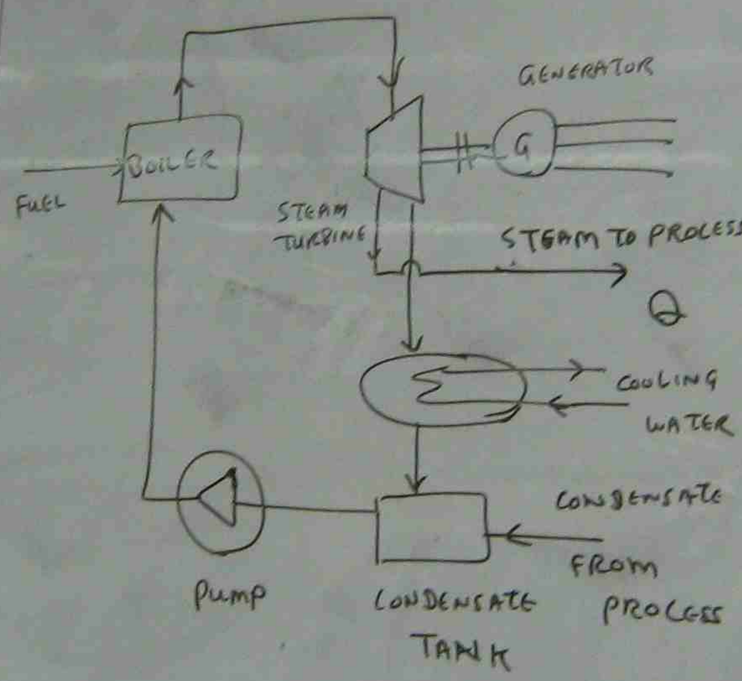
TOTAL EFFICIENCY $= \frac{30 + 55}{100}$

$= 0.85$

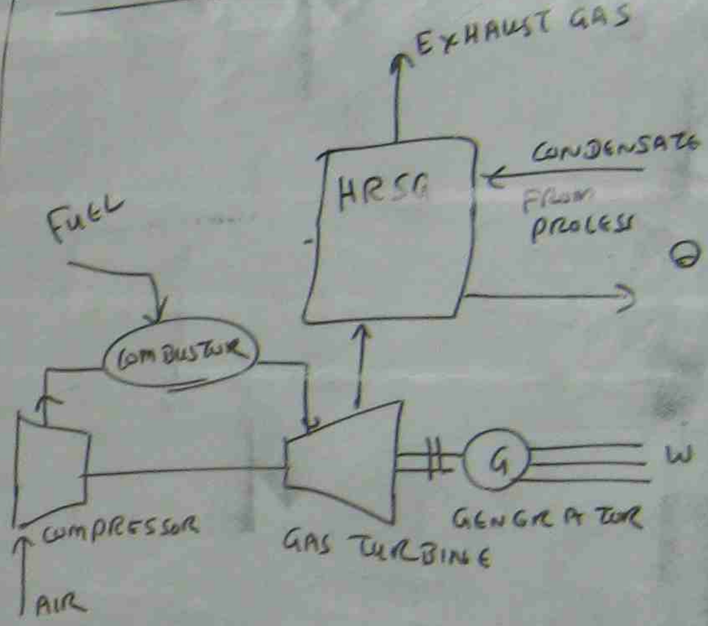
CO-GENERATION SYSTEM WITH BACK PRESSURE STEAM TURBINE



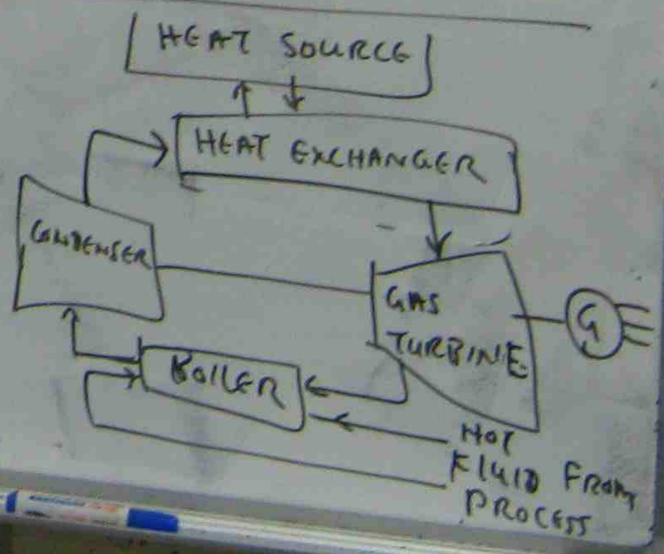
CO-GENERATION SYSTEM WITH CONDENSING STEAM TURBINE



OPEN GAS TURBINE CO-GENERATION SYSTEM



CLOSED CYCLE GAS TURBINE CO-GENERATION SYSTEM



= 18 chairs
18 desks

GAS TURBINE

ELECTRIC EFFICIENCY = 25 ⟶ 35%

POWER TO HEAT RATIO 0.5 ⟶ 0.8

EXHAUST GAS TEMPERATURE - 1200 ⟶ 1400c

RATING

SMALL UNIT GAS ENGINE (15 ⟶ 1000 KW)
DIESEL ENGINE (75 ⟶ 1000 KW)

MEDIUM 1 ⟶ 6 MW GAS / DIESEL ENGINE

HIGH HIGHER THAN 6MW DIESEL ENGINE

FUEL HYDROGEN, METHANE, ETHYLENE
ETHANE, PROPANE, BUTANE
NATURAL GAS, SEWAGE GAS
LAND FILL GAS

APPLICATION OF CO-GENERATION

- UTILITY
- INDUSTRIAL
  - DRYING
  - PULP/PAPER
  - CHEMICAL
  - CEMENT/METAL
- BUILDING
  - HOME
  - HOTEL
  - SCHOOL
  - OFFICE
  - RESTAURANT
  - SWIMING POOL
- RURAL

DOMESTIC HOT WATER SERVICE
SPACE HEATING / COOLING
LAUNDRY FACILITIES
DRYER
SWIMMING POOL WATER HEATING

FUEL