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ESE – 2019 MAINS
OFFLINE TEST SERIES

ELECTRICAL ENGINEERING

TEST – 4
SOLUTIONS

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1(a)

Sol: (i) Full-load armature current per phase,

$$I_a = \frac{500}{\sqrt{3}\times 11} = 26.244\,A$$

Short-circuit load loss at half-full load,

$$= 3\left(\frac{I_a}{2}\right)^2 \times r_a + \text{stray-load loss, which is zero here}$$

$$= 3\left(\frac{26.244}{2}\right)^2 \times 4 = 2066.24\text{ W}$$

Total loss at half-full load

= 1500 + 2500 + 2066.24 + 1000

= 7066.24 W

$$\text{Efficiency at half-full load} = \left[1 - \frac{7066.24}{500{,}000\times\frac{1}{2}\times 0.8 + 7066.24}\right]\times 100$$

= **96.587%**

(ii) For maximum efficiency, Variable losses are,

$3I_{am}^2 r_a$ = rotational loss + field-circuit loss

$$3I_{am}^2.4 = 1500 + 2500 + 1000 = 5000\text{ W}$$

The current I_{am} at which maximum efficiency occurs is given by

$$I_{am} = \sqrt{\frac{5000}{12}} = 20.412\,A$$

Output at maximum efficiency = 3 V_t I_{am} cosθ

$$= 3\times\frac{11000}{\sqrt{3}}\times 20.412\times 0.8$$

= 311,120.66 W

Total losses at maximum efficiency = 2 × 5000 = 10,000 W

$$\therefore \text{ Maximum efficiency} = \left[1 - \frac{10,000}{311,120.66 + 10,000}\right] \times 100$$

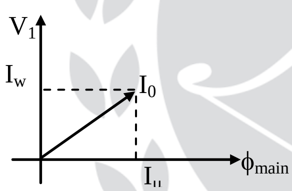
$$= \mathbf{96.886\%}$$

1(b)

Sol: In any elector magnetic device, flux is given by the ratio of magnetizing mmf to reluctance of the flux path.

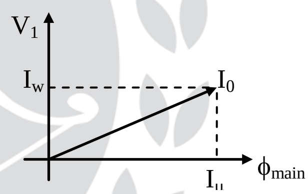
In a transformer, the flux path has no air gap, its reluctance is small, and so the magnetizing mmf required to produce the necessary flux is small. Corresponding magnetizing current is small and the ratio of magnetizing current (or no load current) to rated (or full load) current is small.

In an induction motor, an airgap is essential to enable the rotor to rotate with reference to the stator. But, this increases the reluctance significantly, leading to a much larger no load current and hence the ratio is higher.



No load P.F
0.2 – 0.4 lag

Transformer



No load P.F
0.1 – 0.2 lag

Induction Motor

Numerical:

Power input to stator $= \sqrt{3}\ V_L\ I_L \cos\phi$

$= \sqrt{3} \times 460 \times 25 \times 0.85 = 16.9308$ kW

Stator copper loss + stator core loss

$= 1000 + 800 = 1800$W

Power transferred across the airgap to rotor

= air gap power (P_g) = 16930.8 – 1800 = 15130.8 W

Also, rotor copper losses $= sP_g$

$$\Rightarrow \quad s = \frac{\text{rotor copper losses}}{\text{airgap power}}$$

$$= \frac{500}{15130.8} = 0.033 \quad \Rightarrow s = 0.033$$

Mechanical power developed = shaft power + friction loss + stray load loss = (1–s) P_g

$\Rightarrow$ shaft power + 450 = 15130.8 (1– 0.033) = 14631.5 W

$\therefore$ Shaft output = 14181.5W

$$\%\text{ Efficiency } (\%\eta) = \frac{\text{shaft output}}{\text{power input}} \times 100$$

$$= \frac{14181.5}{16930.8} = 83.76\%$$

1(c)

Sol: (i) Given counter is a mod-16 synchronous up-counter. The total delay that must be allowed between input clock pulses is equal to FF t_{pd} + AND gate t_{pd}. Thus $T_{clock} \geq 50 + 20 = 70$nsec. So the parallel counter has

$$f_{max} = \frac{1}{70\text{ns}} = 14.3\text{MHz} \quad \text{(Synchronous counter)}$$

A mod-16 ripple counter uses four FF's with t_{pd} = 50nsec

Thus f_{max} for the ripple counter is

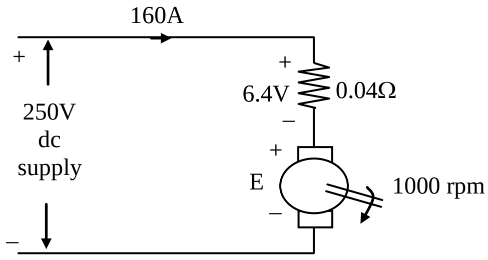
$$f_{max} = \frac{1}{4 \times 50\text{nsec}} = 5\text{MHz} \text{ (ripple counter)}$$

(ii) A fifth FF must be added because $2^5 = 32$. The clock input of this FF is also tied to the input pulses. It's J and K inputs are fed by the output of a four-input AND gate whose inputs are A,B,C and D.

f_{max} for the MOD-32 parallel counter also 14.3MHz,

$$\text{Because } f_{max} = \frac{1}{T_{clock}} = \frac{1}{(50+20)\text{n sec}} = 14.3\text{MHz}$$

1(d)



Sol: Operation at rated conditions:

KVL: 250 = 6.4 + E; so E = 243.6 V.

$E = KI_f\omega_m$

$$\omega_m = \frac{2\pi(1000)}{60} = \frac{100\times\pi}{3}\text{ r/s}$$

$$KI_f\left(\frac{100\pi}{3}\right) = 243.6\text{ V.}$$

which gives $KI_f = 2.3262$

The developed torque = $K\, I_f\, I_a = 2.3262 \times 160$

= 372.2 N-m/r.

Load torque is given to be constant, irrespective of speed variations.

If torque for friction and core losses is also assumed constant, the developed torque will remain constant, irrespective of speed variations.

(i) When field flux is reduced to 70% of its original value but we still want T_d to be unchanged, then I_a = (160/0.7) = 228.6 A.

Corresponding emf = 240.86 V.

(ii) $2.3262\times0.7\times\omega_m = 240.86$

From which ω_m = 147.9 r/sec or 1412.5 rpm.

1(e)

Sol:

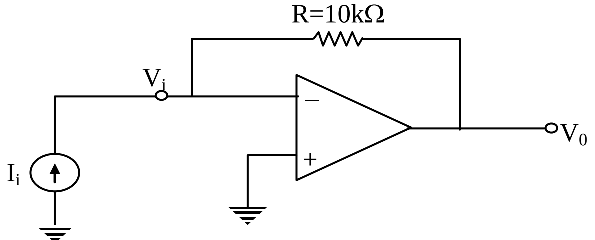
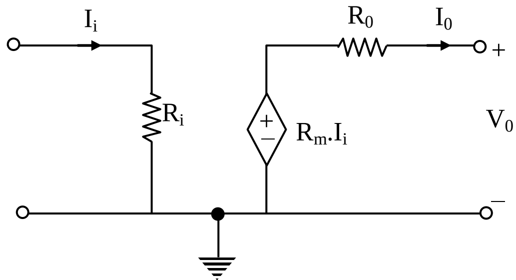


Fig.(a)

Trans resistance amplifier model is given by:



Open-circuit Trans resistance, $R_m = \left.\frac{V_0}{I_i}\right|_{I_0=0,\text{ i.e output is open circut}}$ V / A

The negative input terminal of the op-amp i.e V_i is a virtual ground, thus $V_i = 0$

$V_0 = V_i – R.I_i = 0 – R.I_i = –R.I_i$

$$R_m = \left.\frac{V_0}{I_i}\right|_{I_0=0} = \frac{-RI_i}{I_i} = -R \Rightarrow R_m = -R$$

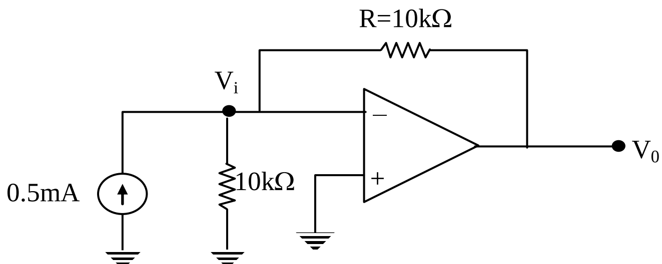
$$\therefore R_m = -10k\Omega$$

$R_i = \frac{V_i}{I_i}$ and V_i is a virtual ground, i.e., $V_i = 0$

Thus, $R_i = \frac{0}{I_i} = 0 \Rightarrow R_i = 0\Omega$

Since we are assuming that the op-amp in this trans resistance amplifier is ideal, the op-amp has zero output resistance and therefore the output resistance of this Trans resistance amplifier is also zero. i.e., $R_0 = 0\Omega$.

Connecting the signal source shown in Figure(a) to the input of amplifier, we have:



V_i is a virtual ground that is $V_i = 0$, thus the current flowing through the 10kΩ resistor connect between V_i and ground is zero.

$\therefore\ V_0 = V_i - R \times 0.5mA = 0 - (10k\Omega) \times (0.5mA)$

$\Rightarrow V_0 = -5V$

2(a)(i)

Sol: A. Mapping is the process by which the address are allocated to the I/O devices.

Memory mapped I/O	I/O mapped I/O
(i) 16-bit address is allotted to each I/O device.	(i) 8-bit address is allotted to each I/O device.
(ii) The I/O devices are accessed by memory read or memory write machine cycles.	(ii) The I/O devices are accessed by I/O read or I/O write machine cycles.
(iii) All instructions related to memory can be used to access I/O devices.	(iii) Only IN and OUT instructions can be used to access I/O devices.
(iv) Large no. of I/O devices can be interfaced.	(iv) Only small number of I/O devices can be interfaced.
(v) Data transfer can be made between all registers and I/O devices	(v) Data transfer can be made only between accumulator and I/O devices.
(vi) This scheme is used when memory requirement is less.	(vi) This scheme is used when complete memory space is required.

B The HOLD and HLDA pins in 8085 are used in interfacing the 8257-DMA controller IC with the processor.

A signal is sent by 8257 to HOLD pin in microprocessor, to request the microprocessor to stop its current process and allocate the buses for DMA transfer.

Microprocessor acknowledges the request for DMA data transfer by 8257, by sending a signal in HLDA to 8257 .i.e., HLDA is the acknowledgement signal for HOLD. It indicates whether the HOLD signal is received or not. After the execution of HOLD request, HLDA goes low.

2(a)(ii)

Sol: A. We know that the sampling period T_s is expressed as

$$T_S = \frac{1}{f_s} = \frac{1}{8\times10^3}\,\text{sec} = 0.125\times10^{-3}\,\text{sec} = 125\ \mu s$$

$$\tau = 0.1\ T_S = 12.5\ \mu s$$

Transmission bandwidth for PAM signal is expressed as

$$BW \geq \frac{1}{2\tau} \Rightarrow BW > \frac{1}{2\times12.5\times10^{-6}}$$

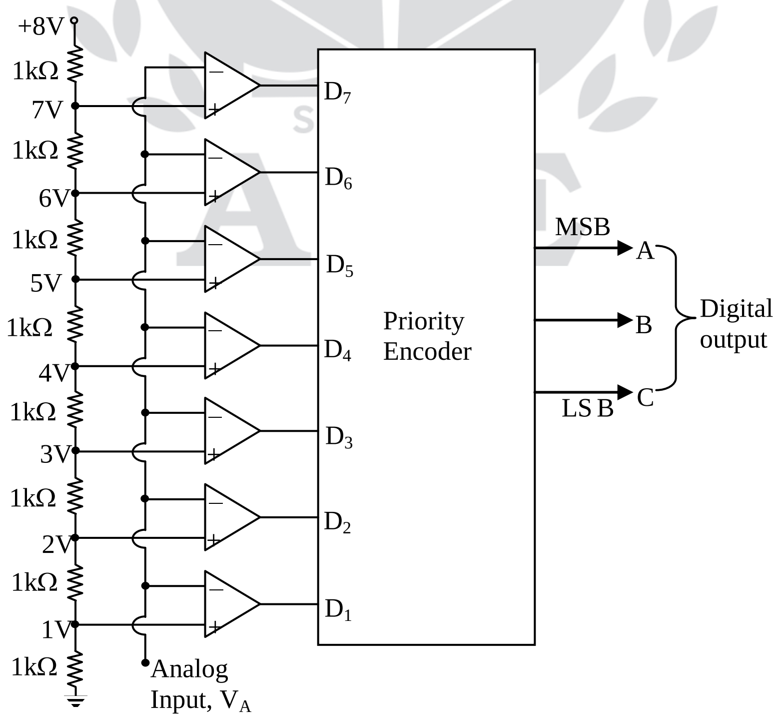
$$\Rightarrow BW > 40\text{ kHz}$$

B. $M = 64 \Rightarrow n = \text{no. of bits} = \log_2^{64} = 6$

$$B_{null} = nf_s = 6\times7000 = 42\text{ kHz}$$

2(b)

Sol: The flash converter is the highest speed ADC, but it requires much more circuitry than the other types. A n-bit flash ADC requires (2^n–1) comparators and 2^n resistors. The large number of comparators has limited the size of flash converters. Below figure represents 3-bit flash type ADC.



Analog input V_A (volts)	Comparator outputs D_1 D_2 D_3 D_4 D_5 D_6 D_7	Digital outputs A B C
$0 \le V_A < 1$	1 1 1 1 1 1 1	0 0 0
$1 \le V_A < 2$	0 1 1 1 1 1 1	0 0 1
$2 \le V_A < 3$	0 0 1 1 1 1 1	0 1 0
$3 \le V_A < 4$	0 0 0 1 1 1 1	0 1 1
$4 \le V_A < 5$	0 0 0 0 1 1 1	1 0 0
$5 \le V_A < 6$	0 0 0 0 0 1 1	1 0 1
$6 \le V_A < 7$	0 0 0 0 0 0 1	1 1 0
$V_A \ge 7$	0 0 0 0 0 0 0	1 1 1

When V_A < 1V, all comparators output will be HIGH, with V_A > 1V, one or more of the comparator outputs will be LOW. The comparator outputs fed into an active-HIGH priority encoder that generates a binary code corresponding to the highest-numbered comparator output that is Low. For example, when V_A is between 3 and 4V. D_1 , D_2 and D_3 will be Low and all others will be HIGH. The priority encoder will respond to only the Low at C_3 and will produce a binary output ABC = 011.

A flash converter uses no clock signal because no timing or sequencing is required. The conversion takes place continuously. When the value of analog input changes, the comparators output will change, thereby causing the encoder outputs to change.

Advantages:

(i) It is the fastest type of ADC

(ii) Construction is simple and easier to design

Disadvantages:

(i) It is not suitable for higher number of bits

(ii) To convert the analog input voltage into a digital signal of n-bit output, (2^n–1) comparators are required.

2(c)(i)

Sol: The speed of Induction Motor is given as

$$N_r = \frac{120f(1-s)}{P}$$

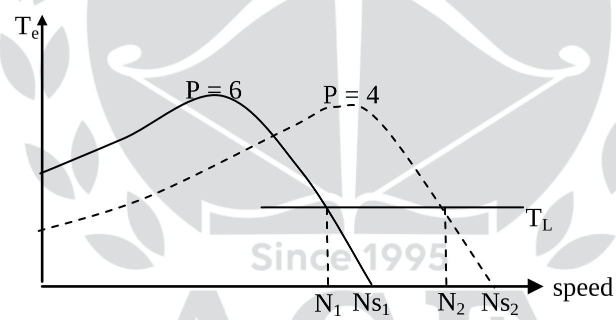
So obviously the speed of an induction motor can be controlled by varying any of the above three factors namely supply frequency, number of poles and slip.

The main methods employed for speed control of Induction motor are as follows. (Any 3)

a) Pole changing:

In this method the number of poles formed by stator magnetic circuit will be modified by changing backend or overhang connections.

The method of speed control by pole changing is suitable for cage motors only because the cage rotor automatically develops number of poles equal to the poles of stator windings. Whereas for slip ring motors, once the winding is done the number of poles on the rotor cannot be changed.



If poles↓, then Tst ↓, T_{max}↓, N_{mT}↑ , S_{mT} remains same.

Drawbacks:

→ Not applicable for slip ring motors

→ Wide variation of speed control is not possible

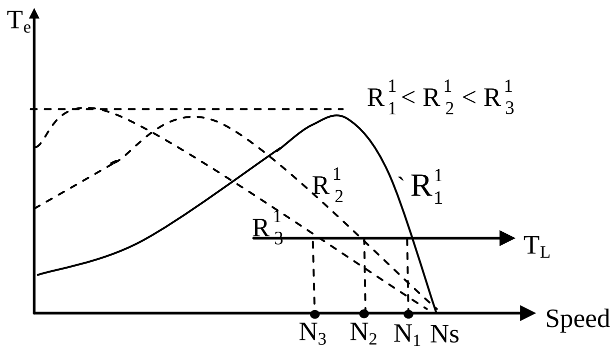
→ Switching transients may take place while changing number of poles.

b) Rotor resistance control method

In this method external resistance will be added into the rotor circuit through slip rings

When resistance is added, rotor current and elector magnetic torque reduces. Also it is possible to have large starting torques.

If $R_2\uparrow$, then $T_{st}\uparrow$, $N_{mT}\downarrow$, $S_{mT}\uparrow$ and T_{max} remains same.



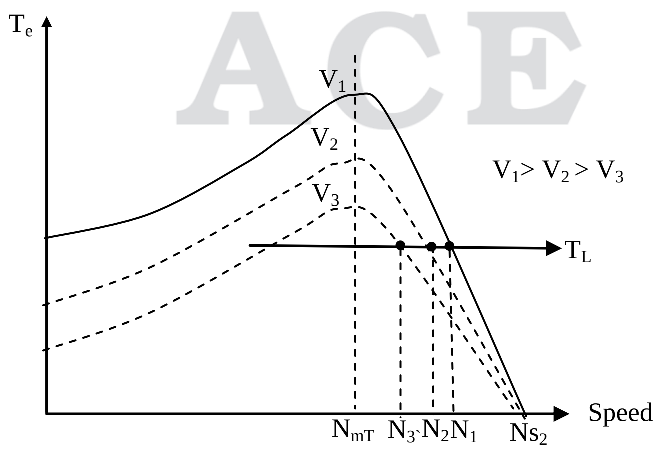
→ Not applicable for squirrel cage motors

→ Speed cannot be controlled above rated value

→ Using additional resistance increases power loss

c) Stator voltage control:

The torque developed by an induction motor is proportional to the square of the applied voltage. The variation of speed torque curves with respect to the applied voltage is shown in the figure below. These curves show that the slip at maximum torque, S_{mT} remains same, while the value of stall torque, T_{max} comes down with decrease in applied voltage. Also, starting torque is lower at lower voltages.



Draw backs:

→ Speed cannot be controlled above rated value

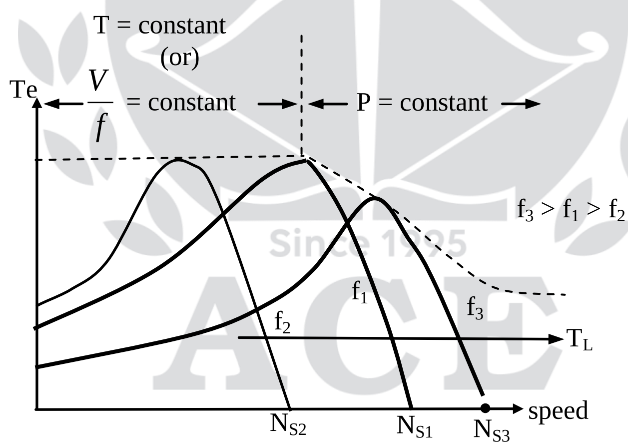
→ An auto transformer is required to control the supply voltage.

→ Starting torque decreases.

d) Supply frequency control:

The synchronous speed of an induction motor is given by $N_s = \dfrac{120\,f}{P}$. Therefore, the speed of motor can be controlled by varying the supply frequency. The emf induced in stator of an induction machine is given by $E = 4.44\ k\phi_m\ f_s\ N_1$

So, as f_s changes E_1 will also change to maintain the same air gap flux. If the stator voltage drop is neglected the terminal voltage V_1 is equal to E_1. In order to avoid saturation and to minimize losses, motor is operated at rated air-gap flux by varying V_1 with frequency so as to maintain $\dfrac{V}{f}$ ratio constant at rated value.



This type of control is know as constant volt per hertz, thus the speed control of induction motor using variable frequency supply requires a variable voltage power source.

2(c)(ii)

Sol: A. Method-1:

Slope, $m_1 = \dfrac{y_2 - y_1}{x_2 - x_1} = -1\,\text{Hz / MW}$

$\dfrac{f - 62}{P_{G1} - 0} = -1$

$f - 62 = -P_{G1}$

$62 - f = P_{G1}$ ………………(1)

$m_2 = \dfrac{f - 61}{-0 + P_{G2}} = -1$

$f - 61 = -P_{G2}$ ……(2)

Given that, $P_{G1} + P_{G2} = 3$ ……….. (3)

$62 - f - f + 61 = 3$

f = 60 Hz

(or)

Method-2:

In the graph given, let 'm' be the slope

y is frequency of parallel operating alternators

x is load in MW

C_1 & C_2 are no load frequencies of generators P_1 & P_2

$y = -mx_1 + C_1$ …….. (1)

$y = -mx_2 + C_2$ …….. (2)

y = slope of generator which is nothing but its regulation

By substituting values of G_1 in above equation (1)

$y = -1 \times x_1 + 62$

$y = -x_1 + 62$ …….. (a)

By substituting values of G_2 in above equation (2)

$y = -1 \times x_2 + 61$

$y = -x_2 + 61$ …….. (b)

By solving equations (a) & (b)

$y = -x_1 + 62$

$y = -x_2 + 61$

$x_1 - x_2 = 1$ …………… (c)

Total load = $P_1 + P_2 = 3$ MW

$x_1 + x_2 = 3$ MW ………….. (d)

$x_1 - x_2 = 1$ ………….. (c)

$x_1 + x_2 = 3$ ……………. (d)

By solving equations (c) & (d)

$x_1 = 2$ MW, $x_2 = 1$ MW

Operating frequency of system

$y = -2 + 62 = 60$

f = 60 Hz

B. From above solution, values of x_1 & x_2 are nothing but values of P_1& P_2

$\mathbf{P_1 = 2\ MW}$

$\mathbf{P_2 = 1\ MW}$

3(a)

Sol: Given data,

$B = 1.2$ Wb/m^2 , weight of core = 100 kg and weight of wire = 80 kg

With hot-rolled steel laminations:

Total flux ϕ_{max} = Flux density B_{m1} × Area A_1

$$\phi_{max} = 1.2A_1 \text{ or } A_1 = \frac{\phi_{max}}{1.2}\,m^2$$

The diameter of the circle around the core is given by $\frac{\pi}{4}d_1^2 = A_1 = \frac{\phi_{max}}{1.2}$

$$d_1 = \sqrt{\frac{4}{\pi}\cdot\frac{\phi_{max}}{1.2}}$$

Length of the turn around the core is $L_1 = \pi d_1 = \pi \cdot \sqrt{\frac{4}{\pi} \cdot \frac{\phi_{max}}{1.2}}$

With CRGO lamination:

$$\phi_{max} = 1.6 A_2 \text{ or } A_2 = \frac{\phi_{max}}{1.6} m^2$$

Diameter of the circle around the core is, $d_2 = \sqrt{\frac{4}{\pi} \cdot \frac{\phi_{max}}{1.6}}$

Length of the around the core is $L_2 = \pi d_2 = \pi \cdot \sqrt{\frac{4}{\pi} \cdot \frac{\phi_{max}}{1.6}}$

Now for laminations,

$$\frac{\text{Weight of CRGO laminations } (W_2)}{\text{Weight of h.r. laminations } (W_1)} = \frac{(\text{Core volume})_2 (\text{Density})}{(\text{Core volume})_1 (\text{Density})}$$

$$= \frac{(A_2)(\text{Height of the limb})}{(A_1)(\text{Height of the limb})} = \frac{\phi_{max}/1.6}{\phi_{max}/1.2} = \frac{1.2}{1.6} = \frac{3}{4}$$

$$\therefore W_2 = \frac{3}{4}(100) = 75 \text{ kg.}$$

$$\therefore \text{Percentage saving in core material} = \frac{100 - 75}{100} \times 100 = 25\%$$

Heights of the limbs are assumed equal in both cases. Now for wire,

$$\frac{\text{Weight of wire when using CRGO laminations } (W_2)}{\text{Weight of wire when using h.r. lamination } (W_1)} = \frac{(L_2)(\text{Wire cross-section})(\text{Turns})}{(L_1)(\text{Wire cross-section})(\text{Turns})}$$

$$= \frac{\pi\sqrt{4/\pi \cdot \phi_{max}/1.6}}{\pi\sqrt{4/\pi} \cdot \phi_{max}/1.2} = \frac{\sqrt{3}}{2} = 0.866$$

$\therefore W_2 = 80 \times 0.866 = 69.28$ kg.

$$\therefore \text{Percentage saving in wire material,} = \frac{80 - 69.28}{80} \times 100 = 13.4\%$$

Wire cross-section and the number of turns are assumed to be equal in both the cases.

3(b)(i)

Sol: Given: P = 4, A = 4, Z = 882,

$$\frac{PZ}{2\pi A} = \frac{882}{2\pi}$$

Armature current = 73 A,

Armature resistance = 0.188 Ω.

Armature resistance voltage drop = 73 × 0.188 = 13.7 V.

With an applied voltage of 230 V, induced emf = 230 – 13.7 = 216.3 V.

Field current = 1.6 A.

Speed = 1150 RPM = $\frac{1150\times 2\pi}{60}$ r/s.

Neglecting armature reaction,

$$\frac{Pz}{2\pi A} K\, I_f \omega_m = 216.3$$

Substituting numerical values,

$$K\left[\frac{441}{\pi}\times 1.6\times\frac{1150\times 2\pi}{60}\right] = 216.3$$

Torque developed = $K\frac{441}{\pi}\times 1.6\times 73$

$$= \frac{216.3\times 60}{1150\times 2\pi}\times 73 = 131.1 \text{ N-m/r.}$$

3(b)(ii)

Sol: In this problem, resistance and leakage reactance of the "primary" are given to be significantly larger than the corresponding values of the "secondary". Hence primary is taken to be the hv winding and secondary the ℓv winding.

Resistances and leakage reactances:

Rated phase voltage of primary

$= \frac{11000}{\sqrt{3}}$ V (Primaries connected in star, and line voltage rating = 11 kV).

Rated phase voltage of secondary

= 3300 V (secondaries connected in delta, and line voltage rating = 3300V).

Turns ratio of each phase [ℓv turns/ph)/(hv turns/ph)] = $\frac{3300\sqrt{3}}{11000}$ = 0.52

$\therefore$ hv resistance/ph ref to ℓv = $\left(0.3\times\sqrt{3}\right)^2\times 0.375$ = 0.10125 Ω

Similarly, hv reactance/ph ref to ℓv = $\left(0.3\times\sqrt{3}\right)^2$ × 9.5 = 2.565 Ω

Total resistance and reactance/ph ref ℓv are 0.19625 Ω and 4.565 Ω respectively.

Circuit:

Shorting the secondary terminals implies a balanced operation. Hence to calculate currents, it is sufficient if we consider one phase of the 3-phase Y/Δ transformer. The circuit is given in fig.1

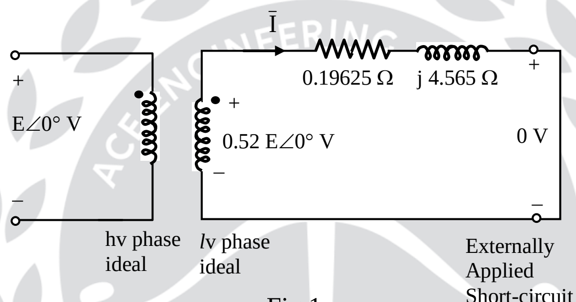


Fig.1

Calculation of hv applied voltage & power input:

It is given that I in fig.1

$$= \frac{1000\times 10^3}{3\times 3300} = \frac{10^4}{99}\text{A}$$

Also, $I = \frac{0.52E}{\sqrt{\left(0.1965^2 + 4.565^2\right)}} = 0.113\,E$

Hence E, the hv applied voltage/ph = $\frac{10^4}{99\times 0.113}$ = 893.9 V.

Applied line voltage on hv (primary side) = $\sqrt{3}\times 893.9 = 1.55$ kV

Power input under these conditions = 3(I^2 r_{eq}) (core losses are neglected under this reduced voltage operation).

$$= \frac{3\times 10^8\times 0.19625}{99^2} = 6007 \text{ W.}$$

3(c)(i)

Sol: The concept of parity is widely used in digital systems for error checking purposes. When digital information is transmitted from one point to another, perhaps by long wires, it is possible for some bits to become corrupted during the transmission process. For example, the sender may transmit a bit whose value is equal to 1, but the receiver observes a bit whose value is 0.

Suppose, a data item consists of 'n' bits, a simple error checking mechanism can be implemented by including an extra bit, P which indicates the parity of the n-bit item. Two kinds of parity can be used. For even parity, the P bit is given the value such that the total number of 1's in the n+1 transmitted bits (comprising the n-bit data and the parity bit P) is even. For odd parity the p bit is given the value that makes the total number of 1's odd. The sender generates the P bit based on the n-bit data item that is to be transmitted. The receiver checks whether the parity of the received item is correct.

Parity generating and checking circuits can be realized with XOR gates. For example, for a four bit data item consisting of bits $x_3x_2x_1x_0$, the even parity bit can be generated as

$$P = x_3 \oplus x_2 \oplus x_1 \oplus x_0$$

At the receiving end checking is done using

$$C = P \oplus x_3 \oplus x_2 \oplus x_1 \oplus x_0$$

If C = 0, then the received item shows the correct parity.

If C = 1, then an error has occurred. Note that observing C = 0 does not guarantee that the received item is correct. If the two or any even number of bits have their values inverted during the transmission, the parity of the data item will not be changed, hence the error will not be detected. But if an odd number of bits are corrupted, then the error will be detected.

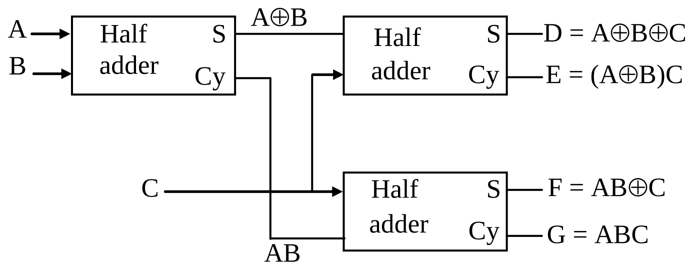
3(c)(ii)

Sol: $D = A \oplus B \oplus C$

$$E = \overline{A}BC + A\overline{B}C = C\left(\overline{A}B + A\overline{B}\right) = \left(A \oplus B\right)C$$

$$F = AB\overline{C} + \left(\overline{A} + \overline{B}\right)C = AB\overline{C} + \overline{A}\,\overline{B}C = AB \oplus C$$

$$G = ABC$$



3(c)(iii)

Sol: (a) $L \geq \frac{1}{2p} = \frac{1}{0.02} = 50$ levels

$\ell = \lceil \log_2 50 \rceil$ = 6 bits/sample

(b) $f_s = 2f_m = 2\times 4000 = 8000$ samples/s

Bit rate: R = 8000 samples/s × 6 bits/samples = 48000 bits/s

(c) 16-level pulses: $16 = M = 2^k$

k = 4 bits/pulse

Symbol Rate: $R_s = \frac{R}{\log_2 M} = \frac{48000 \text{ bits/s}}{4 \text{ bits/symbol}}$

= 12000 symbols/s

4(a)(i)

Sol: Note: $R_i = \frac{1}{G_i}$, $X_m = \frac{1}{B_m}$

Ratio of transformation, $a = \frac{2400}{240} = 10$

A. Referring the shunt parameters to LV side

$R_i\,(LV) = \frac{10\times 1000}{(10)^2} = 10\Omega$

$X_m\,(LV) = \frac{1.6\times 1000}{(10)^2} = 16\ \Omega$

$$\bar{I}_{0(LV)} = \frac{240\angle 0°}{100} - j\frac{240\angle 0°}{16}$$

$= 2.4 - j\,15 = 15.2\ \angle{-80.9°}$ A.

(or) I_0 = 15.2 A, pf = cos 80.9° = 0.158 lagging

B. LV shorted, HV excited, full-load current flowing: Shunt parameters can be ignored under this condition.

Equivalent series parameters referred to HV side:

$R = 0.2 + 2 \times 10^{-3} \times (10)^2 = 0.4\ \Omega$

$X = 0.45 + 4.5 \times 10^{-3} \times (10)^2 = 0.9\ \Omega$

$\bar{Z} = 0.4 + j\,0.9 = 0.985\ \angle 66°\ \Omega$

$I_{f1}\ (HV) = \dfrac{150 \times 1000}{2400} = 62.5$ A

$V_{SC}\ (HV) = 62.5 \times 0.958$

$= 61.56$ V

$P_{SC} = (62.5)^2 \times 0.4 = 1.56$ kW

$pf_{SC} = \cos 66° = 0.406$ lagging.

4(a)(ii)

Sol: 1. There must be some residual magnetism in generator poles. Due to retentivity property, all magnetic materials posses some amount of flux called "Residual magnetism", which is (5−10) % of rated value.

2. The connections of the field winding should be such that the field current strengthens the residual magnetism. If field terminals are wrongly connected, then separate the field terminals and excite with a low voltage for some time to re-establish residual magnetism. This process is called field flashing.

3. The resistance of the field circuit should be less than the critical resistance (Critical Resistance (R_c) is the total field resistance above which the generator fails to build up it's voltage). In other words, the speed of the generator should be higher than the critical speed. Critical speed is the

speed of the generator below which it fails to build up it's voltage without any external resistance in field circuit.

4. When the generator build–up voltage under load condition, the load resistance must be more than the critical load Resistance (R_{LC}).

If the resistance of the load is below critical load resistance, the generator fails to build up it's voltage because the load resistance is less than the equivalent shunt field resistance and then the armature current is more, more demagnetizing effect of armature reaction which may nullify the residual magnetism.

4(a)(iii)

Sol: Synchronous impedance of an alternator:

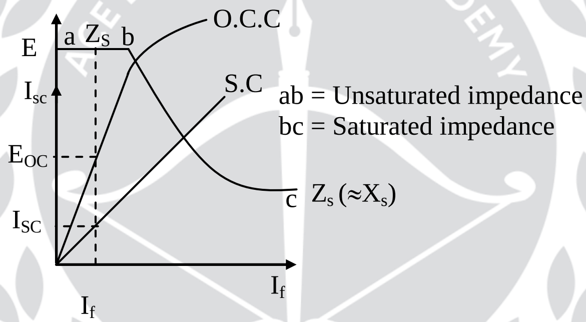


Fig: Determination of Synchronous impedance of an alternator

$$Z_S = \left.\frac{E_{OC}}{I_{SC}}\right|_{I_{f=same}}$$

$$= \frac{\text{Open circuit terminal voltage corresponding to } I_f}{\text{Short circuit current for the same } I_f}$$

In this method the Z_S is measured corresponding to rated short circuit armature current

Z_S (sat) $< Z_S$ (unsat)

$Z_S = \sqrt{R_a^2 + X_S^2}$

$R_a \rightarrow$ armature resistance

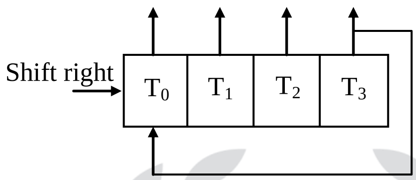
$X_S \rightarrow$ Synchronous reactance

$X_S = \sqrt{Z_S^2 - R_a^2}$

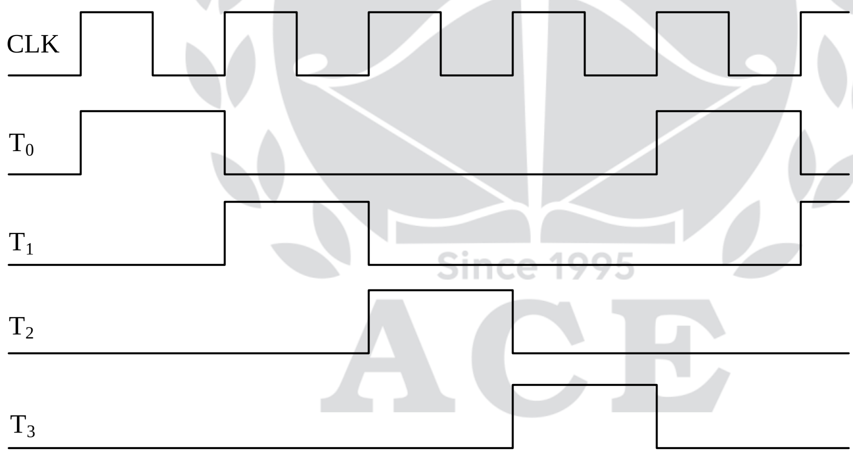
4(b)(i)

Sol: Ring counter:

A ring counter is a circular shift register with only one flip-flop being set at any particular time, all others are cleared. The single bit is shifted from one flip-flop to the next to produce the sequence of timing signals below figure shows a 4-bit shift register connected as a ring counter.

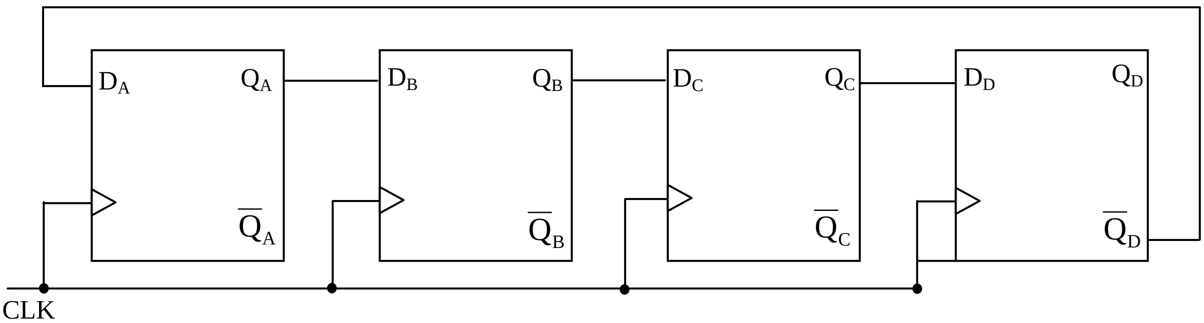


Let the initial value of the register is 1000. The single bit is shifted right with every clock pulse and circulates back from T_3 to T_0. Each flip-flop is in the 1 state once every four clock cycles and produces one of the four timing signals shown below. A n-bit ring counter goes through a sequence of n states.



Johnson Counter:

A k-bit ring counter circulates a single bit among the flip-flops to provide k distinguishable states. The number of states can be doubled if the shift register is connected as a switch tail ring counter. A switch tail ring counter is a circular shift register with the complement output of the last flip-flop connected to the input of the first flip-flop. Johnson counter [switch tail ring counter] shown in below figure.



The circular connection is made from the complement output of the rightmost flip-flop to the input of the leftmost flip-flop. The register shifts its contents once to the right with every clock pulse, and at the same time, the complement value of the D-flip flop is transferred into A flip-flop. Starting from cleared state, a 4-bit Johnson counter goes through a sequence of eight states.

In general, a k-bit switch-tail ring counter will go through a sequence of 2k states.

Clock	Flip-Flop outputs			
	A	B	C	D
0	0	0	0	0
1	1	0	0	0
2	1	1	0	0
3	1	1	1	0
4	1	1	1	1
5	0	1	1	1
6	0	0	1	1
7	0	0	0	1
8	0	0	0	0

4(b)(ii)

Sol: 1) The bandwidth required for the transmission of a PAM signal is very large in comparison to the maximum frequency present in the modulated signal.

2) Since the amplitude of the PAM pulses varies in accordance with the modulating signal, therefore the interference of noise is maximum in a PAM signal. This noise cannot be removed easily.

3) Since the amplitude of the PAM signal varies, therefore, this also varies the peak power required by the transmitter with modulating signal.

4(c)(i)

Sol: Given data:

$V_t = 400$ V, $I_S = 30$ A, $\omega = 120$ rad/sec,

$R_a = 1\ \Omega$, $R_{sh} = 250\ \Omega$ and $I_a = 1.5I_a$

In motoring mode:

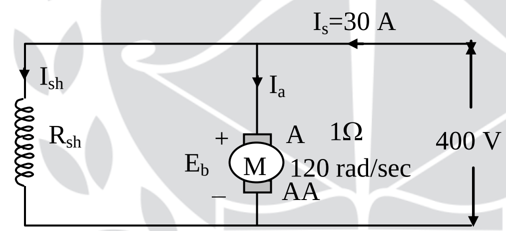


Fig. Motoring mode

$$I_{sh} = \frac{V_t}{R_{sh}} = \frac{400}{250} = \frac{8}{5}\ \text{A}$$

$$I_a = \left(30 - \frac{8}{5}\right)\text{A}$$

$$E_b = V - I_a R_a$$

$$= 400 - \left(\frac{142}{5}\right)\times 1 = 371.6\ \text{V}$$

In plugging mode:

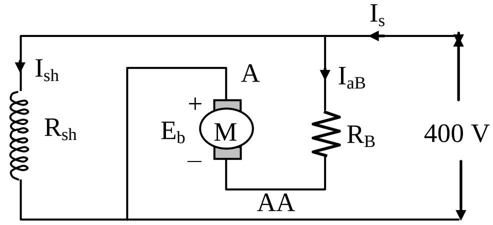


Fig. Plugging mode

$V + E_b = I_{aB}(R_B + R_a)$

$$R_B + R_a = \frac{400 + 371.6}{1.5 \times I_a}$$

$$R_B = \frac{400 + 371.6}{1.5 \times \left(\frac{142}{5}\right)} - 1 = 17.11\ \Omega$$

Braking torque,

$$\tau_B = \frac{\text{output power of motor}}{\text{speed}}$$

$$= \frac{E_b I_{aB}}{\omega}$$

$$= \frac{371.6 \times 1.5 \left(\frac{142}{5}\right)}{120} = 132\ \text{Nm}$$

4(c)(ii)

Sol: Let rated line voltage = V

Impedance/ph = Z

Full load line current, I_{fl} = Base line current

During running, motor will always be in Δ

Hence, Full load phase current $= \frac{I_{fl}}{\sqrt{3}}$

$$\text{Full load torque} = \frac{3\left(\frac{I_{fl}}{\sqrt{3}}\right)^2 r_2}{0.04\omega_s}$$

$$= \frac{I_{fl}^2 r_2}{0.04\omega_s} = \text{Base torque}$$

1. Direct switching:

$$\text{Starting phase current} = \frac{V}{z}$$

$$\text{Starting line current} = \frac{\sqrt{3}V}{z}$$

$$\text{p.u starting line current} = \frac{\sqrt{3}V}{zI_{fl}} = 6 \text{ p.u (given)}$$

$$\therefore \text{ We get } \quad \frac{V}{zI_{fl}} = \frac{6}{\sqrt{3}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{Starting torque} = \frac{3\left(\frac{V}{z}\right)^2 r_2}{\omega_s}$$

$$= \frac{3\left(\frac{V}{z}\right)^2 \frac{r_2}{\omega_s}}{\frac{I_{fl}^2 r_2}{0.04\omega_s}}$$

$$= \frac{3\left(\frac{V}{z}\right)^2 (0.04)}{I_{fl}^2}$$

$$= 3.\left(\frac{6}{\sqrt{3}}\right)^2 (0.04) \quad \ldots\ldots\ldots\text{using (1)}$$

$$= 36 \times 0.04$$

Hence, Starting torque = 1.44 pu

(ii)Y-Δ starting:

Starting phase current = $\frac{V}{\sqrt{3}z}$ = starting line current

p.u starting line current = $\frac{V}{\sqrt{3}z}\frac{1}{I_{fl}} = \frac{6}{3}$ = 2.

Starting torque = $\frac{3\left(\frac{V}{\sqrt{3}z}\right)^2 r_2}{\omega_s} = \left(\frac{V}{z}\right)^2 \frac{r_2}{\omega_s}$

p.u starting torque = $\frac{\left(\frac{V}{z}\right)^2 \frac{r_2}{\omega_s}}{\frac{I_{fl}^2}{0.04}\frac{r_2}{\omega_s}}$

$= \left(\frac{V}{ZI_{fl}}\right)^2 (0.04)$

$= \left(\frac{6}{\sqrt{3}}\right)^2 (0.04)$

Hence, Starting torque = 0.48 p.u

5(a)

Sol: i) Let f represent the system failure. Then

$P(\bar{f}) = (1-0.01)^{10} = 0.90438$

$P(f) = 1 - P(\bar{f}) = 0.0956$

ii) $P(\bar{f}) = 0.99 \text{ and } p(f) = 0.01$

If the probability of failure of a subsystem S_1 is P, then

$P(\bar{f}) = (1-P)^{10}$

$0.99 = (1\text{-}P)^{10}$

$P = 0.0010045$

5(b)

Sol: Let r and x be the equivalent resistance and reactance of the transformer (referred to the side with a rated voltage V).

Let I be the rated full load current referred to the same side as above.

(i) Unless otherwise specified, regulation is always found at full load. The approximate expression for voltage regulation at any lagging power factor cosθ is R = $\frac{I}{V}(r\cos\theta + x\sin\theta)$

The value of θ for maximum regulation is found by differentiating R w.r.t θ equating to zero. We obtain

$\frac{x}{r} = \tan\theta$ for maximum regulation

From the given data,

$$\left.\begin{aligned} \frac{I}{V}(0.8r + 0.6x) &= 0.04 \\ \frac{I}{V}(0.6r + 0.8x) &= 0.044 \end{aligned}\right\} \text{............ (1)}$$

From these equations, it is possible to obtain that $\frac{x}{r}$ = 2.

Thus tanθ = 2, θ = 63.44° and cosθ = 0.4472 lag for maximum regulation at lagging power factor.

(ii) At full load and unity power factor, power output = VI Watts

Copper loss = core loss = I^2r Watts

Efficiency = $\frac{VI}{VI + 2I^2r} \times 100\ \%$

$$= \frac{100}{1 + 2\left(\frac{I}{V}\right)r}\ \%$$

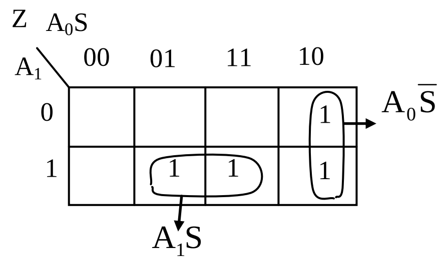
From eqns (1) we can find that $\frac{I}{V}r$ = 0.02

Hence efficiency = $\frac{100}{1.04}\%$ = 96.15%

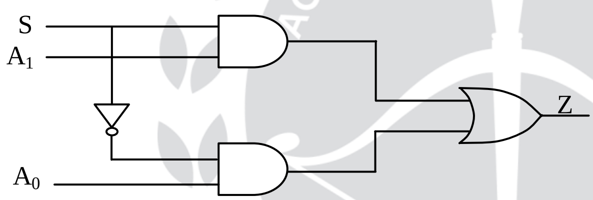
5(c)

Sol: (i)

A_1	A_0	S	Z
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1



$$Z = A_0\overline{S} + A_1S$$



(ii)

A_3	A_2	A_1	A_0	X
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0

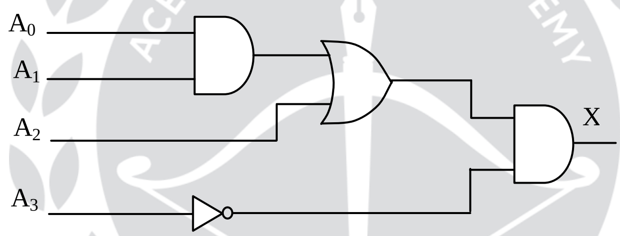
1	0	1	0	0
1	0	1	1	0
1	1	0	0	0
1	1	0	1	0
1	1	1	0	0
1	1	1	1	0

By inspection x will be 1 whenever $A_3 = 0$, $A_2 = 1$ (or) when $A_3 = A_2 = 0$ while $A_1 = A_0 = 1$

So, $X = \overline{A}_3A_2 + \overline{A}_3\overline{A}_2A_1A_0$

$$= \overline{A}_3\left(A_2 + \overline{A}_2A_1A_0\right) = \overline{A}_3\left(A_2 + A_1A_0\right)$$

$$X = \overline{A}_3\left(A_2 + A_1A_0\right)$$



5(d)

Sol: Equivalent circuit/ph:

$$\overline{V} = \frac{11000}{\sqrt{3}} = 6351\angle 0^\circ \text{ V}$$

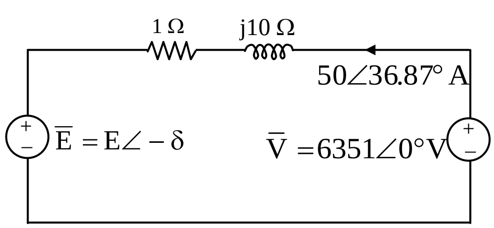


Fig. 1

Since problem specifies that excitation emf $\bar{E}$ lags the terminal voltage $\bar{V}$, motor operation is implied.

So, the current received by the motor is specified as $50\angle 36.87°$ A. (That is why the reference direction of $\bar{I}$ is shown as entering $\bar{E}$ at its '+' terminal. Of course we could have reversed the current direction in the figure, and written the value as $-(50\angle 36.87°$ A)).

(i) Calculation of excitation emf:

$6351\angle 0° = E\angle -\delta + [50\angle 36.87°](1+j10)$

Solving, **E = 6625 V**(δ=3.73°, $\bar{E} = 6625\angle -3.73°$)

(ii) The machine, acting as a motor, is drawing a leading current. Hence it is overexcited. **By reducing the excitation**, it can be made to draw current at upf. In that case $\bar{I}$ and $\bar{E}$ will change, but $\bar{I}$ will be in phase with $\bar{V}$.

(iii) Calculation of armature current and load angle:

At upf operation, let the current per phase drawn by the motor be I amp. Assuming that the power input per phase remains unchanged while the excitation is reduced,

$$6351 \times I \times 1 = 6351 \times 50 \times 0.8$$

I = 40 A

Replacing the current in the circuit of fig. 1 with this value and applying KVL,

$$6351\angle 0° = 40\angle 0°(1+j10) + E\angle -\delta.$$

E and δ can be calculated from this equation by separately equating the real and imaginary parts.

$E\cos\delta + 40 = 6351$ .... (1)

and $-E\sin\delta + 400 = 0$ .... (2)

δ = 3.63°

5(e)

Sol: i) N = 1 pulse occurs in T_o = 0.3452 ms

$$\text{Baud rate} = (D) = \frac{N}{T_o} = \frac{1}{0.3472 \times 10^{-3}} = 2880\,baud$$

ii) $L = 32 = 2^{\ell} \Rightarrow \ell = 5$

$R = \ell D = 5 \times 2880 = 14{,}400\,\text{bits / S}$

iii) $B_{null} = \dfrac{R}{\ell} = 2880\,\text{Hz}$

iv) For the unipolar NRZ line code,

There are N = 5 pulses in T_o = 0.3472 ms

$$D = \frac{5}{0.3472 \times 10^{-3}} = 14400\,\text{baud}$$

R = D because the unipolar NRZ line code is binary thus R = 14,400 bits/S

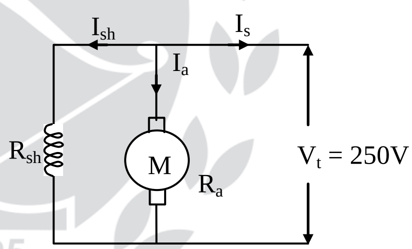
The Null bandwidth $B_{null} = \dfrac{R}{\ell}$ =14,400 Hz

6(a)

Sol: Given data,

N_f = 750r.p.m, V_t = 250V, I_s = 60A,

R_a = 0.4 Ω, R_{sh} = 125Ω and V_b = 2V



Now I_s = 6A

$$I_{sh} = \frac{V_t}{R_{sh}} = \frac{250}{125} = 2A$$

$\therefore I_a = I_s - I_{sh} = 4A$

The back e.m.f $= E_{bo} = V - I_aR_a - V_b$

$= 250 - 4 \times 0.4 - 2$

$= 246.4V$

Full load back e.m.f $= V - I_aR_a - V_b$

$= 250 - [60 - I_{sh}]\, 0.4 - 2 = 224.8V$

$$\frac{E_{b0}}{E_{bf}} = \frac{N_0}{N_f}$$

No-load speed $N_0 = \dfrac{246.4 \times 750}{224.8}$

= 822 r.p.m

(ii) For full load speed 600 r.p.m

$$= \frac{E_{bf}\,(\text{new})}{E_{bf}} = \frac{600}{750}$$

$$= E_{bf}\,(\text{new}) = \frac{224.8\times600}{750} = 179.84\text{V}$$

$179.84 = V_t - 58(R_a + R_{se}) - V_b$

$= 250 - 58\,(0.4 + R_{se}) - 2$

$R_{se} = 0.7752\Omega$

(iii) $\frac{E_b}{E_{bf}} = \frac{N}{N_f}\times\frac{\phi}{\phi_f}$

$E_b = V_t - 30\,(R_a) - V_b$

$= 250 - 30\times0.4 - 2$

$= 236\text{V}$

$$\therefore \frac{\phi}{\phi_f} = \frac{236\times750}{224.8\times900} = 0.8748$$

Percentage reduction in flux per pole

$$= \left(1-\frac{\phi}{\phi_f}\right)\times100 = 12.52\%$$

6(b)(i)

Sol: $\phi = \cos^{-1}0.8 = -36.9°$ (leading)

$$I_a = \frac{1000}{\sqrt{3}\times6.6} = 87.48\text{ A};\ V_1 = \frac{6.6}{\sqrt{3}} = 3.81\text{ kV}$$

$$\tan\psi = \frac{V_1\sin\phi - I_aX_q}{V_t\cos\phi + I_aR_a}$$

$$= \frac{-3.81\times0.6-0.08748\times16.2}{3.81\times0.8+0} = -1.215$$

$= \psi = -50.54°$

$\delta = \phi - \psi = -36.9° - (-50.54°) = 13.64°$

$I_d = I_a \sin\psi$

$= 0.08748 \times \sin(-50.54°) = -0.0675$ kA

$E_f = V_t\cos\delta - I_dX_d$;

$= 3.81\cos 13.64° + 0.0675 \times 25.6$

$= 5.43$ kV(phase) or 9.4 kV(line)

With excitation cut off, output is only reluctance power

$$P_e = P_e = V_t^2\left(\frac{X_d - X_q}{2X_dX_q}\right)\sin 2\delta$$

$$= (6.6)^2 \times \frac{25.6 - 16.2}{2\times 25.6\times 16.2}\times \sin 27.28^0 = \mathbf{226.26\ kW}$$

6(b)(ii)

Sol: The voltage equation for short circuited rotor is $I_2\, Z_2 = sE_{20}$

$40(\ 0.04 + j0.3s) = s \times 40$

$0.0016 + 0.09s^2 = s^2$

Solving for s

We have $s = \pm\ 0.0419$

Rotor power factor, $\cos\theta_2 = \dfrac{R_2}{\sqrt{R_2^2 + (sX_{20})^2}}$

$$\cos\theta_2 = \frac{0.04}{\sqrt{(0.04)^2 + (0.0419\times 0.3)^2}} = 0.954 \text{ lagging}$$

6(c)(i)

Sol: A. For (18,7) code to correct up to 3 errors

$$2^{n-k} \ge \sum_{i=0}^{3} {}^{n}c_i \qquad \text{(Hamming bound for correcting 3 errors)}$$

$$2^{18-7} \ge \sum_{i=0}^{3} {}^{18}c_i$$

$$2^{11} \ge {}^{18}c_0 + {}^{18}c_1 + {}^{18}c_2 + {}^{18}c_3$$

$$2^{11} \geq 1+18+153+816$$

$$2048 \geq 988$$

$\therefore$ there exists a possibility of 3 error correcting (18,7) code.

B. (i). Power required to achieve the desired SNR ratio.

(ii) Bandwidth of the channel

(iii). Amplitude and phase response of channel

(iv). Type of channel (linear or non-linear)

(v). Effects of external interference on the channel.

6(c)(ii)

Sol: Using 1 for true and 0 for false, we can express the three conditions as follows.

$$A = x_3(x_1 + \bar{x}_2) = x_3x_1 + x_3\bar{x}_2$$

$$B = x_1(\bar{x}_2 + \bar{x}_3) = x_1\bar{x}_2 + x_1\bar{x}_3$$

$$C = x_2(x_1 + \bar{x}_3) = x_2x_1 + x_2\bar{x}_3$$

Then, the desired output of the circuit can be expressed as f = AB+BC+CA. These product terms can be expressed as,

$$AB = (x_3x_1 + x_3\bar{x}_2)(x_1\bar{x}_2 + x_1\bar{x}_3)$$

$$= x_3x_1\bar{x}_2 + 0 + x_1x_3\bar{x}_2 + 0$$

$$AB = x_1\bar{x}_2x_3$$

$$BC = (x_1\bar{x}_2 + x_1\bar{x}_3)(x_2x_1 + x_2\bar{x}_3)$$

$$= 0 + 0 + x_1x_2\bar{x}_3 + x_1x_2\bar{x}_3$$

$$BC = x_1x_2\bar{x}_3$$

$$CA = (x_2x_1 + x_2\bar{x}_3)(x_3x_1 + x_3\bar{x}_2)$$

$$= x_1x_2x_3 + 0 + 0 + 0 \Rightarrow CA = x_1x_2x_3$$

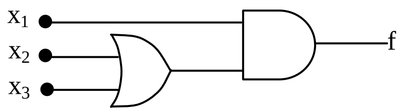
Therefore, f can be written as,

$$f = x_1\bar{x}_2x_3 + x_1x_2\bar{x}_3 + x_1x_2x_3$$

$$= x_1x_3(x_2 + \bar{x}_2) + x_1x_2\bar{x}_3$$

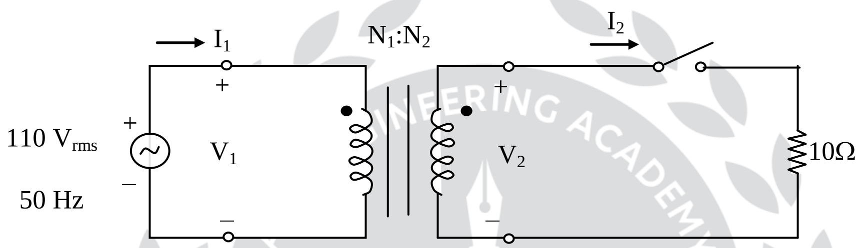
$f = x_1(x_3 + x_2\bar{x}_3)$

$f = x_1(x_3 + x_2)$



7(a)(i)

Sol: **Case I:** switch open



$$\frac{N_1}{N_2} = 5$$

Assuming zero voltage drop $V_1 = 110V$

When secondary is open, $I_2 = 0A$

From current transformation formula, $\frac{I_1}{I_2} = \frac{N_2}{N_1} = \frac{1}{5}$

$I_1 = 0A$

but $\frac{V_1}{V_2} = \frac{N_1}{N_2}$ (Voltage transformation)

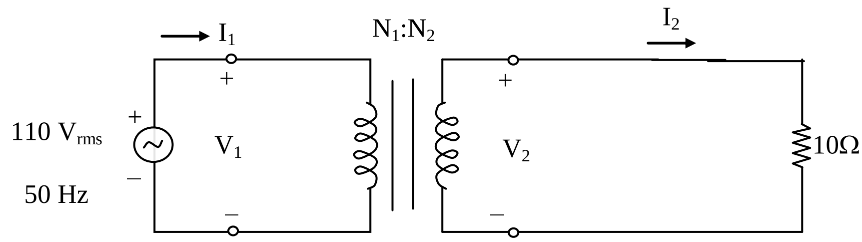
$$\frac{110}{V_2} = 5$$

$V_2 = 22V$

V_1= 110V **I_1 = 0A**

V_2 = 22V **I_2 = 0A**

Case II: When switch is closed:



$$\frac{N_1}{N_2} = 5$$

Assuming negligible voltage drop

V_1= 110V

From voltage transformation

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

$$V_2 = \frac{N_2}{N_1} \times 110\text{V} = \frac{1}{5} \times 110$$

V_2= 22V

From secondary side we can say that

$V_2 = I_2R_L = I_2(10)$

$22 = I_2(10)$

$I_2 = 2.2\text{A}$

From current transformation

$$\frac{I_1}{I_2} = \frac{N_2}{N_1} = \frac{1}{5}$$

$$I_1 = I_2 \times \frac{1}{5}$$

$$I_1 = \frac{2.2}{5}$$

I_1= 0.44A

V_1= 110V **I_1= 0.44A**

V_2 = 22V **I_2= 2.2A**

7(a)(ii)

Sol: There are three kinds of electric braking

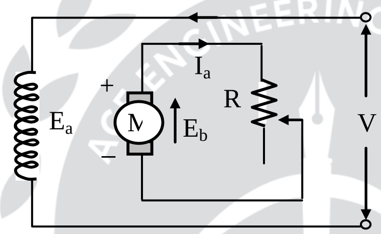
(a) Rheostatic or dynamic braking

(b) Plugging and

(c) Regenerative braking

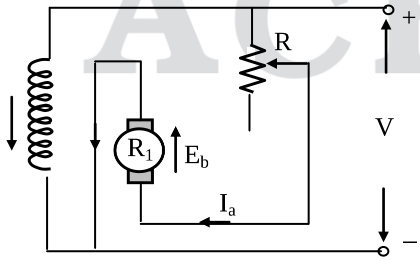
a) Rheostatic or Dynamic Braking (Shunt motor)

Figure shows the Rheostatic braking in which armature of the shunt motor is disconnected from the supply and it is connected across a variable resistance R. The field winding is kept undisturbed and his braking is controlled by varying the series resistance R. This method uses the generator action in a motor to bring it to lest.



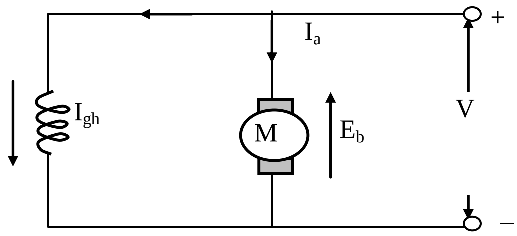
b) Plugging or Reverse (shunt motor)

In this method, the armature terminals are reversed to rotate the motor in reverse direction and the applied voltage V and the back emf E_b start acting in the same direction. To limit the armature current, a resistance is inserted in series with the armature during reversing the armature. The kinetic energy of the system is dissipated in the armature and braking resistances.



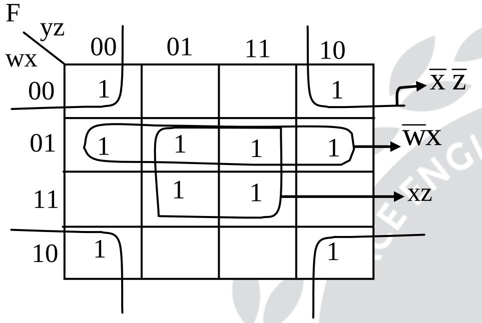
c) Regenerative Braking

In regenerative braking, E_b > V. Figure shows regenerative braking scheme. The I_a direction and armature torque T_B are reversed. Most of the braking energy is returned to the supply. Regenerative braking is used for down grade motion of an electric train. The kinetic energy of the system is dissipated in armature and braking resistor.



7(b)(i)

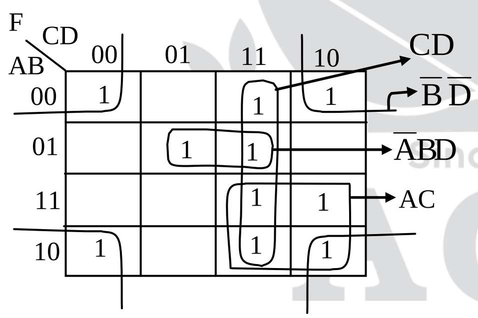
Sol: A. (a) F(W,X,Y,Z) = Σ(0,2,4,5,6,7,8,10,13,15)



Essential : $\overline{x}\overline{z}, \overline{w}x, xz$

$F = xz + \overline{w}x + \overline{x}\,\overline{z}$

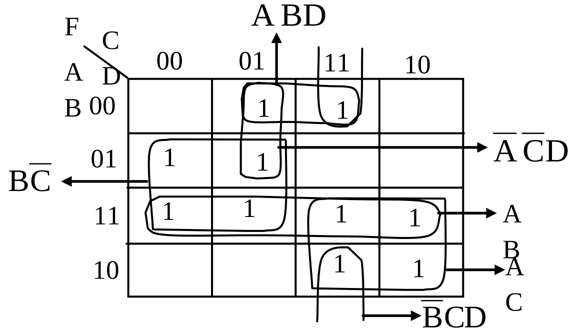
(b) F(A,B,C,D) = Σ(0,2,3,5,7,8,10,11,14,15)



Essential : $CD, AC, \overline{B}\,\overline{D}, \overline{A}BD$

$F = CD + AC + \overline{B}\,\overline{D} + \overline{A}BD$

(c) F(A,B,C,D) = Σ(1,3,4,5,10,11,12,13,14,15)



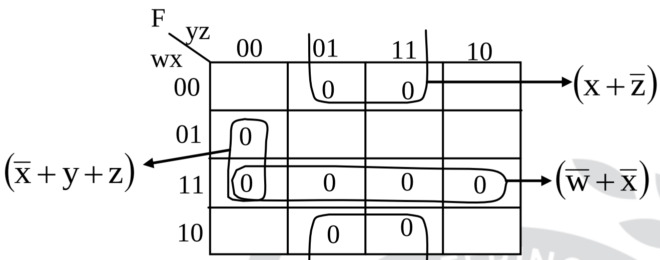
Essential: $B\bar{C}, AC$

Non-essential: $\bar{A}\bar{B}D, \bar{A}\bar{C}D, AB, \bar{B}CD$

$$F = AC + B\bar{C} + \bar{A}\bar{B}D$$

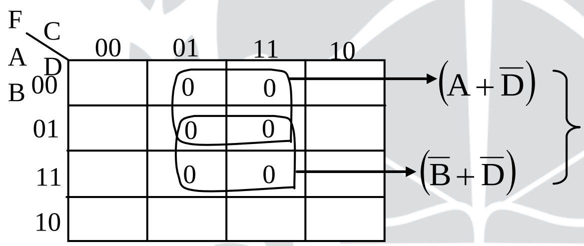
B. (a) Given that F(W,X,Y,Z) = Σ(0,2,5,6,7,8,10)

$$\Rightarrow F(W,X,Y,Z) = \pi(1,3,4,9,11,12,13,14,15)$$



$$F = (\bar{x}+\bar{z})(\bar{w}+\bar{x})(\bar{x}+y+z)$$

(b) F(A,B,C,D) = π(1,3,5,7,13,15)



$$F = (A+\bar{D})(\bar{B}+\bar{D})$$

7(b)(ii)

Sol: Simplification of switching functions using k-map method yields better results, however, if the number of variables is more than 5, the method becomes slightly tedious. An alternate and equally powerful method for such cases is "Variable Entered Mapping [VEM] method. In this method, the map includes entries like not only 1's, 0's and X's (don't cares) but also Boolean variables and Boolean expressions.

VEM method can be referred as an extension of the standard k-map. Consider the following example.

A \ BC	00	01	11	10
0	0	1	0	1
1	D	0	$\overline{D}$	1

Here 1 can be replaced as $D+\overline{D}$

$$\overline{A}\,\overline{B}C\left(D+\overline{D}\right)=\overline{A}\,\overline{B}CD+\overline{A}\,\overline{B}C\overline{D}=m_2,m_3$$

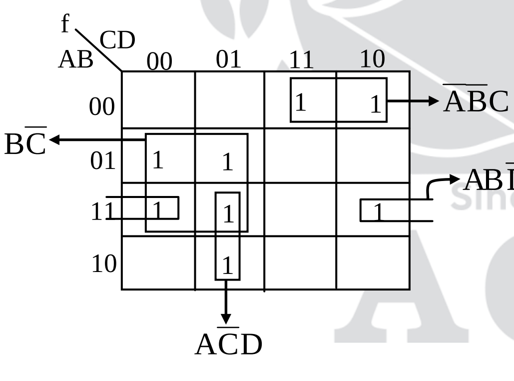
$$\overline{A}B\overline{C}\left(D+\overline{D}\right)=\overline{A}B\overline{C}\,D+\overline{A}B\overline{C}\,\overline{D}=m_5,m_4$$

$$A\overline{B}\,\overline{C}D=m_9$$

$$ABC\overline{D}=m_{14}$$

$$AB\overline{C}\left(D+\overline{D}\right)=AB\overline{C}D+AB\overline{C}\,\overline{D}=m_{13},m_{12}$$

f(A,B,C,D) = Σm (2,3,4,5,9,12,13,14)



$$f=B\overline{C}+A\overline{C}D+\overline{A}\,\overline{B}C+AB\overline{D}$$

7(c)

Sol: 3-ϕ, 7 MVA, 11kV, Y-connected alternator

δ = 40° (load angle) Zs = 0 + j12 Ω

[At synchronization E = V and same sequence]

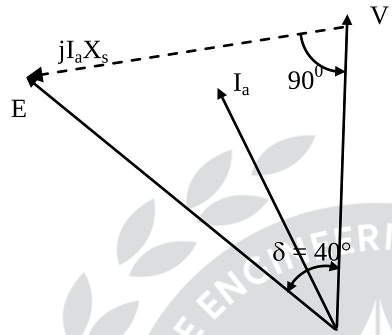
At the time of synchronization i.e. floating condition,

$$V_L = 11\text{kV} \Rightarrow V_{ph} = \frac{11\times10^3}{\sqrt{3}} = 6351\,\text{V}$$

Now stream input is increased, then $\delta\uparrow, P\uparrow, I_a\uparrow$;

$Z_s = 0 + j12\Omega$ and δ = 40°

Under this condition,



$$I_a = \frac{E\angle\delta - V\angle0°}{Z_s\angle\theta} = \frac{6351\angle40° - 6351\angle0°}{12\angle90°}$$

I_a = 362.02 ∠ 20°

pf=cosϕ = cos 20° = 0.9396 leading

(∵ E cosδ < V in floating condition)

$$P = \sqrt{3}V_L I_L \cos\phi = \frac{3EV}{X_s}\sin\delta$$

$$= \sqrt{3}\times 11\text{kV}\times 362\times 0.939$$

P = 6.48 MW

$$Q = \frac{3V}{X_s}(E\cos\delta - V)$$

$$= \frac{3\times6351}{12}(6351\times\cos40° - 6351)$$

= –2.35 MVAR

∴ Reactive power is absorbed from bus

∵ Steam input is constant, P = const = 6.48 MW

The reactive power can be made zero by increasing the excitation. E is increased to E′ such that machine operates at normal excitation and let the new load angle be δ′.

$E' \cos \delta' = V$ ……. (1)

Power is constant → E sin δ = constant

$E'\sin\delta' = E \sin \delta$ …….(2)

From (1) & (2)

$$\frac{(2)}{(1)} = \frac{E'\sin\delta'}{E'\cos\delta'} = \frac{E\sin\delta}{V} = \frac{6351\sin 40°}{6351} = 0.6427$$

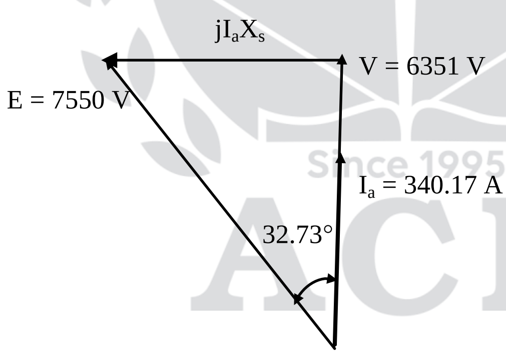
Tan δ′ = 0.64

⇒ δ′= 32.73°

$$E'\cos\delta' = V \Rightarrow E' = \frac{6351}{\cos(32.73°)} = 7549.6 \text{ V}$$

$$I'_a = \frac{E'\angle\delta' - V\angle 0°}{Z_s\angle\theta} = \frac{7549.6\angle 32.73 - 6351\angle 0°}{12\angle 90°}$$

$$I'_a = 340.17\angle 0°$$



8(a)(i)

Sol: A. At time t = 0, the voltage across the capacitor is zero, the output voltage as a function oftime is given by

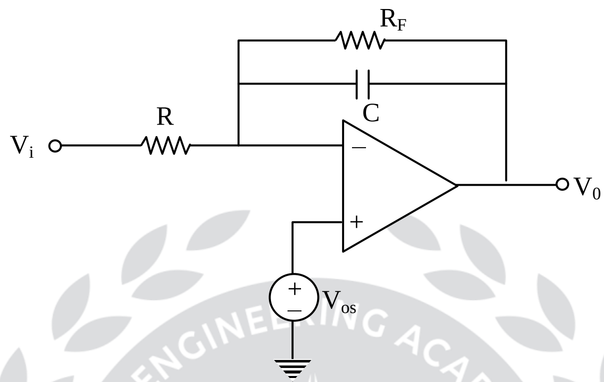
$$V_0 = V_{os} + \frac{V_{os}}{CR}t$$

Substitute the given values in the above equation, we get

$$\Rightarrow \ 12 = 2\text{mV} + \frac{2\text{mV}}{1\text{ms}} t$$

$$\Rightarrow \ t = \frac{12\text{V} - 2\text{mV}}{2\text{mV}} \times 1\text{ms} \cong 6$$

$\therefore$ t = 6sec



B. With the feedback resistor R_F to have at least ±10V of output signal swing available, we have to make sure that the output voltage due to V_{os} has a magnitude of atmost 2V.

We know that the output dc voltage due to V_{os} is given

$$V_0 = V_{os}\left(1 + \frac{R_F}{R}\right) \Rightarrow 2\text{V} = 2\text{mV}\left(1 + \frac{R_F}{10\text{k}\Omega}\right)$$

$$\Rightarrow \left(1 + \frac{R_F}{10\text{k}\Omega}\right) = 1000 \Rightarrow R_F = 10\text{M}\Omega.$$

The Corner frequency of the resulting STC network is,

$$\omega = \frac{1}{CR_F}$$

We know RC = 1ms and R = 10kΩ, then

$\Rightarrow$ C = 0.1μF

Thus, $\omega = \frac{1}{(0.1\mu\text{F}) \times (10\text{M}\Omega)} = 1 \text{ rad/s}$

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi} = 0.16\text{Hz}.$$

8(a)(ii)

Sol: Advantages of PPM

1. Due to constant amplitude of PPM pulses, the information is not contained in the amplitude. Hence, the noise added to PPM signal does not distort the information. Thus, it has good noise immunity.
2. It is possible to reconstruct PPM signal from the noise contaminated PPM signal. This is also possible in PWM but not possible in PAM.
3. Due to constant amplitude of pulses, the transmitted power remains constant. It does not change as it used to, in PWM.

Disadvantages of PPM

1. As the position of the PPM pulses is varied with respect to a reference pulse, a transmitter has to send synchronizing pulses to operate the timing circuits in the receiver. Without them, the demodulation would not be possible to achieve.
2. Large bandwidth is required to ensure transmission of undistorted pulses.

8(b)(i)

Sol: Approximate Torque equation of induction motor is

$$T_{em} = \frac{3}{\omega_s}\left[\frac{E_2^2}{\left(\frac{R_2}{s}\right)^2 + (X_2)^2}\right] \times \frac{R_2}{s}$$

If value of 's' is low (i.e N_r is closer to N_s), then $sX_2 << R_2$

$$\therefore T_{em} \propto \frac{sE_2^2}{R_2}$$

i.e $T_{em}\ \alpha\ s \Rightarrow$ linear relation for low slip

If value of 's' is high (i.e N_r is away from N_s) then $sX_2 >> R_2$

$$\therefore T_{em} \propto \frac{sE_2^2 R_2}{(sX_2)^2}$$

i.e., $T_{em} \propto \frac{1}{s} \rightarrow$ Rectangular hyperbola for high value of slip.

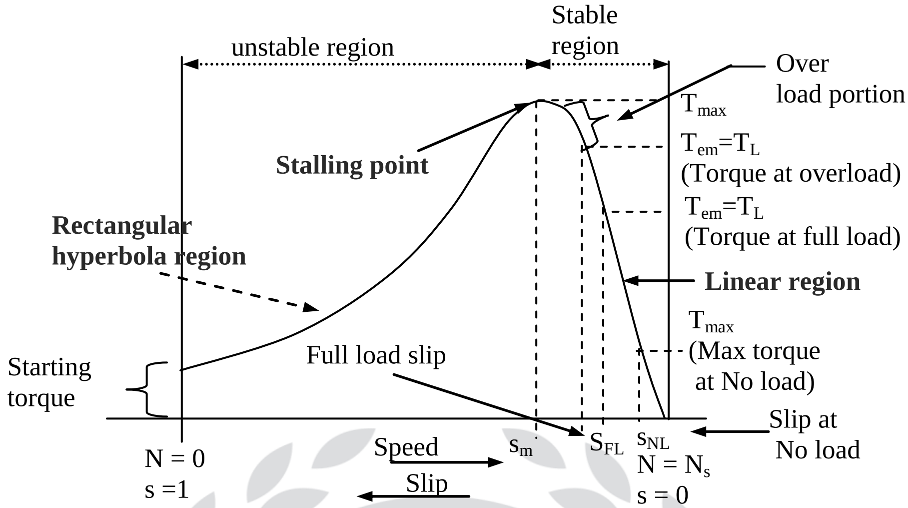


Fig: Torque-slip characteristics of Induction motor

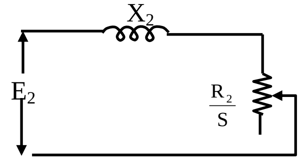
Maximum torque condition: $\frac{dT}{ds} = 0$

(or) T $\propto$ Rotor input power

$$T \propto 3 I_2^2 \frac{R_2}{s}$$

According to maximum power transfer theorem, the power delivered to $\frac{R_2}{s}$ is maximum only when $X_2 = \frac{R_2}{s}$

The rotor equivalent circuit is



i.e maximum Torque obtained at s = $\frac{R_2}{X_2}$

The slip at maximum torque is called breakdown slip

$S_m = \frac{R_2}{X_2}$

Now $T_{max} = \frac{180}{2\pi N_s} \times \frac{sE_2^2(sX_2)}{(sX_2)^2 + (sX_2)^2}$

(or) $T_{max} = \frac{3}{\omega_s} \times \frac{E_2^2}{2X_2}$

From the above formula we have observed that maximum torque is independent of rotor resistance.

8(b)(ii)

Sol: **A.** Capacity of Auto transformer

= VA consumed by loads

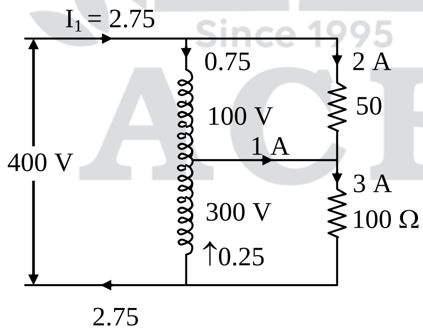
= 100 × 2 + 300 × 3

= 200 + 900 = 1100 VA

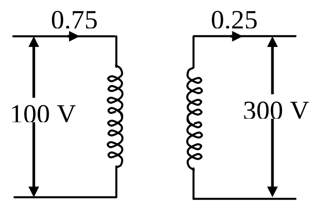
B. The input current of Auto transformer

$$I_1 = \frac{1100}{400} = 2.75\,A$$

by applying KCL at all node currents in various branches can be determined as shown in the figure,



C. The two winding transformer used for above AT should be 100/300 V



$\therefore$ VA rating of two winding transformer

$= 100 \times 0.75$

$= 75$ VA

8(c)

Sol: Given data:

25hp, 400V, 50 Hz and 4 pole

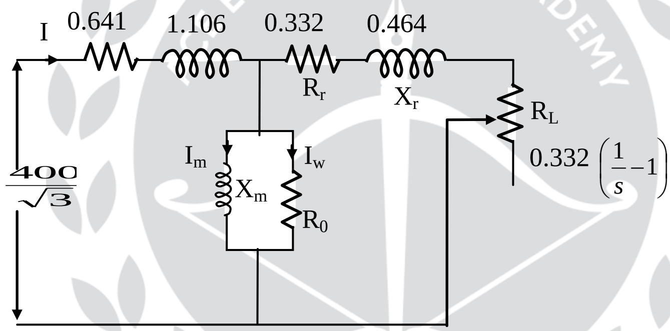
$R_s = 0.641\Omega$, $R_r = 0.332\Omega$, $X_s = 1.106\Omega$

$X_r = 0.464\Omega$ and $X_{mag} = 26.30\ \Omega$

Rotational losses = 1.1. kW

Core losses assumed negligible i.e. $I_w = 0A$

And slip = 0.022



$$R_L = 0.332\left(\frac{1}{0.022}-1\right) = 14.759\Omega$$

The total effective impedance per phase is

$$= \frac{(15.091 + j0.464)(j26.30)}{15.091 + j0.464 + j26.30} + (0.641 + j1.106)$$

$$= 14.0579\angle 33.68°$$

Stator current, $I_1 = \dfrac{V}{Z}$

$$= \frac{\frac{400}{\sqrt{3}}}{14.0579\angle 33.68°} = 16.42\angle -33.68° A$$

i) $s = \dfrac{N_s - N}{N_s}$ and $N_s = \dfrac{120\,f}{P}$

$\Rightarrow N_s = \dfrac{120 \times 50}{4} = 1500$ rpm

$N = N_s (1 - s) = 1500\,(1 - 0.022)$

$N = 1467$ rpm

ii) Stator current, I = 16.42 A

iii) $\phi = -33.68°$

$\Rightarrow$ power factor, $\cos\phi = \cos(-33.68°) = 0.8321$ lag

iv) $P_m = I_2^2 r_2^1 \left(\dfrac{1-s}{s}\right)$

$$I_2 = \frac{16.4277\angle -33.685° \times 26.30\angle 90°}{30.7254\angle 60.58°}$$

$= 14.062 \angle -4.2°$ A

$$r_2^1 \times \left(\frac{1-s}{s}\right) = \frac{0.332 \times 0.978}{0.022} = 14.759\Omega$$

$P_m = 14.062^2 \times 14.759 = 2918.4244$W

Net Mechanical power available at the shaft $= \left(\dfrac{2918.424}{1000}\right) \times 3 - 1.1$

$= 7.655$ kW

v) $P_{in} = 3VI\cos\phi = 3 \times \dfrac{400}{\sqrt{3}} \times 16.427 \times 0.8321 = 9.4705$ kW

vi) $\%\eta = \dfrac{\text{Shaft power}}{\text{Input power}} \times 100 = \dfrac{7655}{9470.5} \times 100 = 80.83\%$