



# ACE

## Engineering Academy

Leading Institute for ESE/GATE/PSUs

Hyderabad | Delhi | Ahmedabad | Bhopal | Pune | Bhubaneswar | Bengaluru  
Lucknow | Patna | Chennai | Vijayawada | Vizag | Tirupathi | Kukatpally | Kolkata

# ESE – 2019

## (MAINS)

Questions with Detailed Solutions

**ELECTRICAL ENGINEERING**

## PAPER – II

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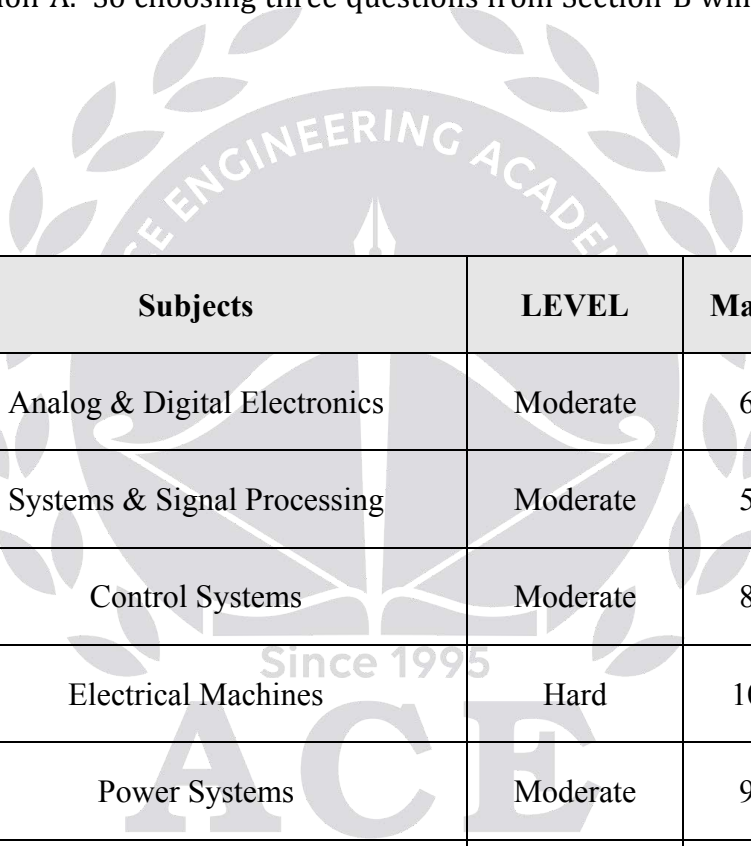
All Queries related to **ESE – 2019 MAINS** Solutions are to be sent to the following email address  
**hyderabad@aceenggacademy.com | Contact Us : 040-23234418,19,20**

# **ELECTRICAL ENGINEERING**

## **ESE MAINS-2019 PAPER-2**

### **PAPER REVIEW**

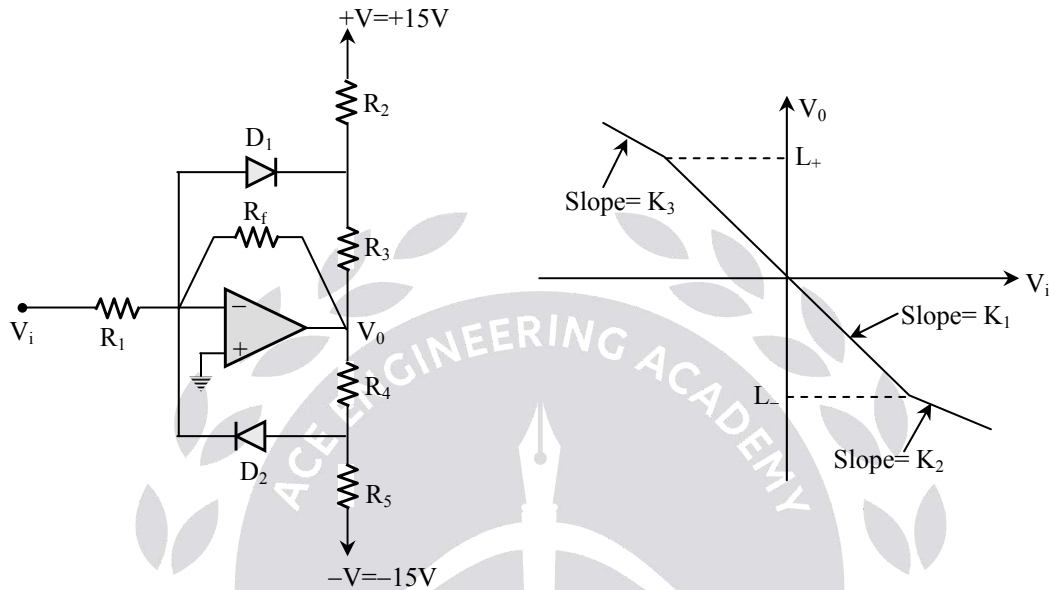
Overall paper was Moderate, in this paper in every subject some of the questions are easy and some are difficult and also subjects are not divided in section wise. Section-B is easy as compared to Section-A. So choosing three questions from Section-B will fetch you to score good marks.



| <b>Subjects</b>              | <b>LEVEL</b> | <b>Marks</b> |
|------------------------------|--------------|--------------|
| Analog & Digital Electronics | Moderate     | 64           |
| Systems & Signal Processing  | Moderate     | 52           |
| Control Systems              | Moderate     | 84           |
| Electrical Machines          | Hard         | 104          |
| Power Systems                | Moderate     | 92           |
| Power Electronics            | Moderate     | 84           |

**SECTION - A**

**1(a) Determine the values of slope  $K_1$ ,  $K_2$ ,  $K_3$  and the voltages  $L_+$  and  $L_-$  for the amplifier and its transfer characteristics shown in the figure given below: **12****



**( $R_1 = 30 \text{ k}\Omega$ ,  $R_2 = R_5 = 9 \text{ k}\Omega$ ,  $R_3 = R_4 = 3 \text{ k}\Omega$ ,  $R_f = 60 \text{ k}\Omega$ )**

**The diodes may be assumed to be ideal.**

**Sol: Case (i):** For the small values of  $V_i$  i.e. close origin 'O'

Step: 1 As  $V_i$  &  $V_0$  are small, the voltage at node 'A' is +Ve and voltage at node 'B' is -Ve. Therefore  $D_1$  and  $D_2$  will be OFF

$$\Rightarrow V_0 = -\frac{R_f}{R_1} V_i \dots\dots\dots (1)$$

$$\therefore \text{The slope, } K_1 = \frac{-R_f}{R_1} = -\frac{60k}{30k} = -2 \dots\dots\dots (2)$$

Case (ii): For  $V_i$  = positive

Step 2: As  $V_i$  increases,  $D_2$  remains OFF, but  $D_1$  will be ON

$$L_- = -V \left[ \frac{R_3}{R_2} \right] - V_{D_1} \left( 1 + \frac{R_3}{R_2} \right) \dots\dots\dots (3) \text{ [ Using super position principle node 'A' ]}$$

$$= -15V \left[ \frac{3k}{9k} \right] - 0 \dots\dots\dots (4) \quad [\because D_1 \text{ is ideal, } V_{D1} = 0]$$

$$L_- = -5V$$

Step 3:

$$\text{Slope, } K_2 = - \frac{R_f // R_3}{R_1} \dots\dots\dots (6)$$

$$= - \frac{60K // 3K}{30K}$$

$$K_2 = -0.095238$$

**Case (iii)**

Step 4: As  $V_i$  is  $-V_e$ ,  $D_1$  OFF  $D_2$  will be ON

$$L_+ = V \left( \frac{R_4}{R_5} \right) + V_{D_2} \left( 1 + \frac{R_4}{R_5} \right) \dots\dots\dots (9) \quad [\because \text{Super position principle at}]$$

Node (B)

$$= +15V \left[ \frac{3K}{9K} \right] + 0 \dots\dots\dots (10) \quad [\because D_2 \text{ is ideal, } V_{D2} = 0]$$

$$\therefore L_+ = +5V \dots\dots\dots (11)$$

**Step 5:**

$$\text{Slope, } K_3 = - \frac{R_f // R_4}{R_1} \dots\dots\dots (12)$$

$$= - \frac{60k // 3k}{30k} \dots\dots\dots (13)$$

$$K_3 = -0.095238 \dots\dots\dots (14)$$





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# MPSC (MES) MAINS 2019

(Civil Engineering)

Regular Batch starts on **15th July 2019**

## DISCOUNTS AVAILABLE

|                                     |     |
|-------------------------------------|-----|
| For ACE students of 2018-19 Session | 50% |
| For ACE students of 2017-18 Session | 30% |
| For ACE students of 2016 earlier    | 20% |

# MPSC (MES) MAINS FREE

## Orientation & Demo

### On 6<sup>th</sup> July 2019

#### IES GENERAL STUDIES BATCH

| Type of Batch | Timings                                                         | Date                       | Duration         | Venue  |
|---------------|-----------------------------------------------------------------|----------------------------|------------------|--------|
| Weekend Batch | 6 to 8 hours of classes<br>Sat: 10am to 7pm &<br>Sun 8am to 6pm | 13 <sup>th</sup> July 2019 | 4 to 5<br>Months | @ Pune |

**83**

Ranks in  
**Top 1000**  
from **Pune**

**121**

Ranks in  
**Top 2000**  
from **Pune**

**153**

Ranks in  
**Top 3000**  
from **Pune**

**1(b) Determine the total energy and average power of the following signal:**

**12**

$$x(t) = \begin{cases} 2 & -3 \leq t \leq 3 \\ 5-t & 3 \leq t \leq 5 \\ 0 & \text{otherwise} \end{cases}$$

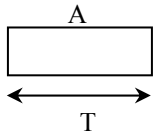
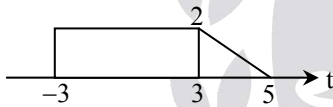
**Sol:**  $x(t) = \begin{cases} 2 & -3 \leq t \leq 3 \\ 5-t & 3 \leq t \leq 5 \\ 0 & \text{otherwise} \end{cases}$

$$E_{x(t)} = \int_{-\infty}^{\infty} |x(t)|^2 dt = \int_{-3}^3 (2)^2 dt + \int_3^5 (5-t)^2 dt$$

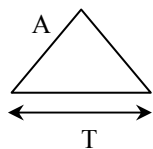
$$= 4(t) \Big|_{-3}^3 + \left( \frac{(5-t)^3}{-3} \right) \Big|_3^5$$

$$= 4(6) + \frac{8}{3} = 26.67 \text{ J}$$

**Alternative method:**



$$E = A^2 T$$



$$E = \frac{A^2 T}{3}$$

$$E = (2)^2(6) + \frac{(2)^2(2)}{3}$$

$$= 24 + \frac{8}{3}$$

$$= 24 + 2.67$$

$$= 26.67 \text{ Joules}$$

For an energy signal average power = 0

**1(c) Show the permissible area for the poles of a second order system which must simultaneously meet the following criteria:**

**12**

**(i) Maximum percent overshoot  $\leq 5\%$**

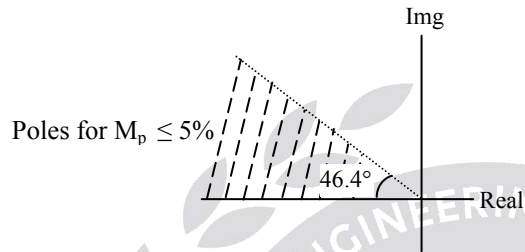
**(ii) Settling time for 2% criterion  $\leq 500 \text{ ms}$**

**Sol:**  $M_p = 5\% = 0.05$

$$M_p = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$$

$$\zeta = \frac{(\ln M_p)^2}{\pi^2 + (\ln M_p)^2} = 0.69$$

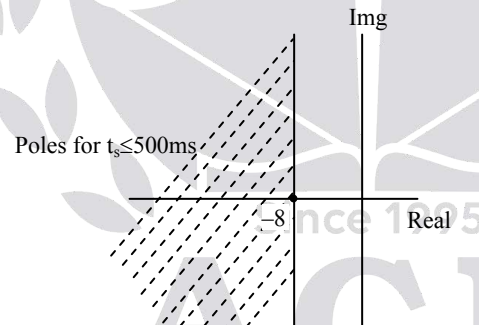
$$\phi = \cos^{-1} \zeta = 46.4^\circ \dots\dots\dots(1)$$



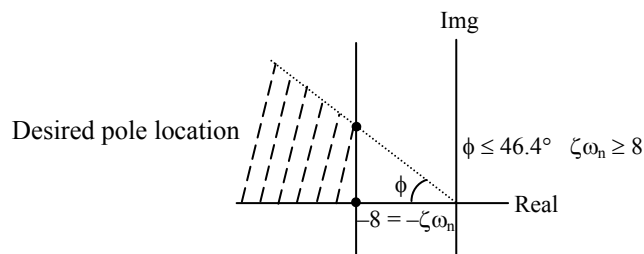
$$t_s \cong \frac{4}{\zeta\omega_n} \leq 500 \times 10^{-3}$$

$$\zeta\omega_n \geq \frac{4}{500 \times 10^{-3}} = 8 \dots\dots\dots(2)$$

$$\zeta\omega_n \geq 8$$



From (1) & (2) poles should lie in the following region



# REGULAR BATCHES

GATE+PSUs - 2020

**ABIDS DSNR** **KOTHAPET KKP**

24<sup>th</sup> June | 01<sup>st</sup> July | 08<sup>th</sup> July | 22<sup>nd</sup> July |  
05<sup>th</sup> August | 20<sup>th</sup> August 2019

## MPSC MAINS

CIVIL ENGINEERING

**REGULAR BATCH: 15th July 2019**

**FREE ORIENTATION SESSION & DEMO CLASS**

**06th July 2019, 10am TO 1pm @ PUNE**

**1(d) A 1000 VA, 440/220 V single-phase two-winding transformer is connected as autotransformer to supply a load at 440 V from a supply voltage of 660 V ac mains. Draw the schematic diagram of the autotransformer with proper labelling. If the full load unity power factor (pf) efficiency of the two-winding transformer is 96.2%, what will be the full-load efficiency of the autotransformer at 0.85 pf lagging? Also find the maximum primary and secondary currents of the autotransformer.** **12**

**Sol:** VA rating of two winding transformer ( $kVA_{TW}$ ) = 1000 VA

Voltage rating of two winding transformer = 440/220V

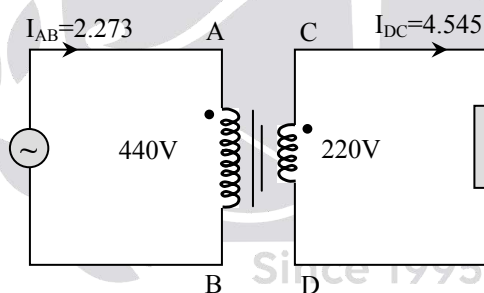
Voltage rating of auto transformer = 440/660 V

$\% \eta_{(TW \text{ TF at FL \& UPF})} = 96.2\%$

$\% \eta_{Auto \text{ TF at new FL \& 0.85 lag}} = ?$

Maximum primary current of auto transformer,  $I_{1max \text{ auto}} = ?$

Maximum secondary current of auto transformer  $I_{2max \text{ auto}} = ?$



$$\text{Current rating of winding 'AB'} = \frac{\text{VA rating}}{\text{V rating}} = \frac{1000}{440} = 2.273 \text{ A}$$

$$\text{Current rating of winding 'DC'} = \frac{\text{VA rating}}{\text{V rating}} = \frac{1000}{220} = 4.545 \text{ A}$$

In auto transformer to get voltage rating of 440/660V, two winding transformer should be connected in series additive polarity. Here two possibilities are there to get required voltage rating.

1. Connect A & D terminals with terminal 'B' is common to both primary and secondary.
2. Connect B & C terminals with terminal 'A' is common to both primary and secondary.

Here A & D terminals are connected with common 'B'

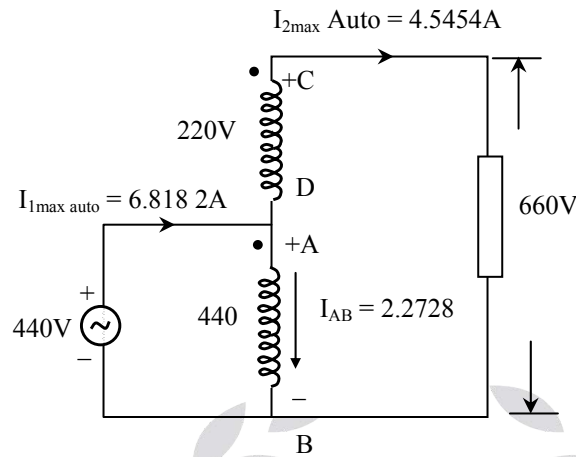


Fig. 440/660 V Auto transformer

$$K_{\text{auto}} = \frac{LV}{HV} = \frac{440}{660} = 0.667$$

Maximum kVA rating of auto transformer,

$$\begin{aligned} \text{kVA}_{\text{auto max}} &= \left( \frac{1}{1 - K_{\text{auto}}} \right) \text{kVA}_{\text{TWTF}} \\ &= \left( \frac{1}{1 - \frac{440}{660}} \right) \times 1000 \\ &= 3000 \text{ VA} \end{aligned}$$

$$\begin{aligned} \text{Maximum current drawn from supply, } I_{1\text{max auto}} &= \frac{\text{VA}_{\text{aut max}}}{\text{Primary voltage rating of auto}} \\ &= \frac{3000}{440} = 6.8182 \text{ A} \end{aligned}$$

$$\begin{aligned} \text{Maximum current delivered by auto transformer, } I_{2\text{ auto max}} &= \frac{\text{VA}_{\text{auto max}}}{\text{Secondary voltage rating of auto}} \\ &= \frac{3000}{660} = 4.5454 \text{ A} \end{aligned}$$

$$\begin{aligned} \text{Apply KCL to know current in common winding of auto transformer} &= I_{1\text{ max auto}} - I_{2\text{ max auto}} \\ &= 6.8182 - 4.5454 \\ &= 2.2728 \text{ A} \end{aligned}$$

$$\eta_{(\text{pu}) \text{ TW TF FL \& UPF}} = \frac{(\text{VA})_{\text{TW}} \cos \theta_2}{(\text{VA})_{\text{TW}} \cos \theta_2 + \text{Total loss in TWTF at FL}}$$



$$0.962 = \frac{1000 \times 1}{1000 + \text{Total loss in TW TF at FL}}$$

$$\text{Total loss in two winding transformer at FL} = \frac{1000}{0.962} - 1000 = 39.5 \text{ W}$$

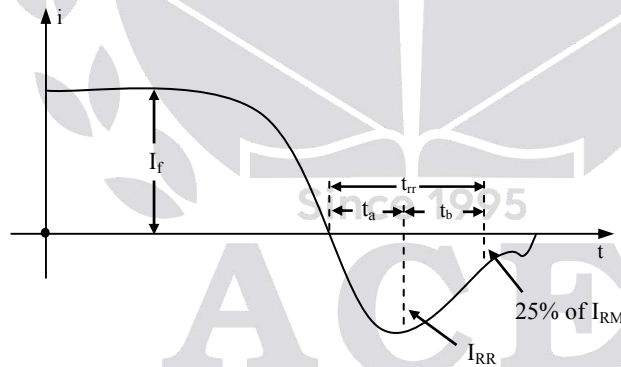
$$\text{Total loss in two winding transformer at FL} = \text{Total loss in auto transformer at new FL} = 39.5 \text{ W}$$

$$\begin{aligned} \eta_{\text{auto TF at new FL } 0.85 \text{ lag}} &= \frac{(VA)_{\text{auto}} \cos \theta_2}{(VA)_{\text{auto}} \cos \theta_2 + \text{Total loss in auto at new FL}} \times 100 \\ &= \frac{3000 \times 0.85}{3000 \times 0.85 + 39.5} \times 100 \\ &= 98.47\% \end{aligned}$$

- 1(e) The reverse recovery time of a diode is  $t_{rr} = 6 \mu\text{s}$ , and the rate of fall of the diode current  $di/dt = 10 \text{ A}/\mu\text{s}$ . If the softness factor  $SF = 0.5$ ,**
- (i) Find the storage charge  $Q_{RR}$ ,**
  - (ii) Find the peak reverse current  $I_{RR}$ , and**
  - (iii) Draw the labelled reverse recovery characteristics.**

12

**Sol:** Reverse characteristics of diode can be drawn as follows



$I_{RR}$  = maximum value of reverse current

$t_{rr}$  = Reverse recovery time

$$t_{rr} = t_a + t_b$$

During time " $t_a$ ", the function get's recovered and during time  $t_b$  the semiconductor layers gets recovered.

Given data:

$$t_{rr} = 6 \mu\text{s}$$



$$\frac{di}{dt} = 10 \text{ A}/\mu\text{s}$$

$$\text{S-factor} = \text{S.F} = 0.5$$

$$t_{\text{rr}} = t_a + t_b$$

$$S = \frac{t_b}{t_a} \Rightarrow 0.5 = \frac{t_b}{t_a}$$

$$t_b = 0.5 t_a$$

$$t_{\text{rr}} = t_a + 0.5 t_a$$

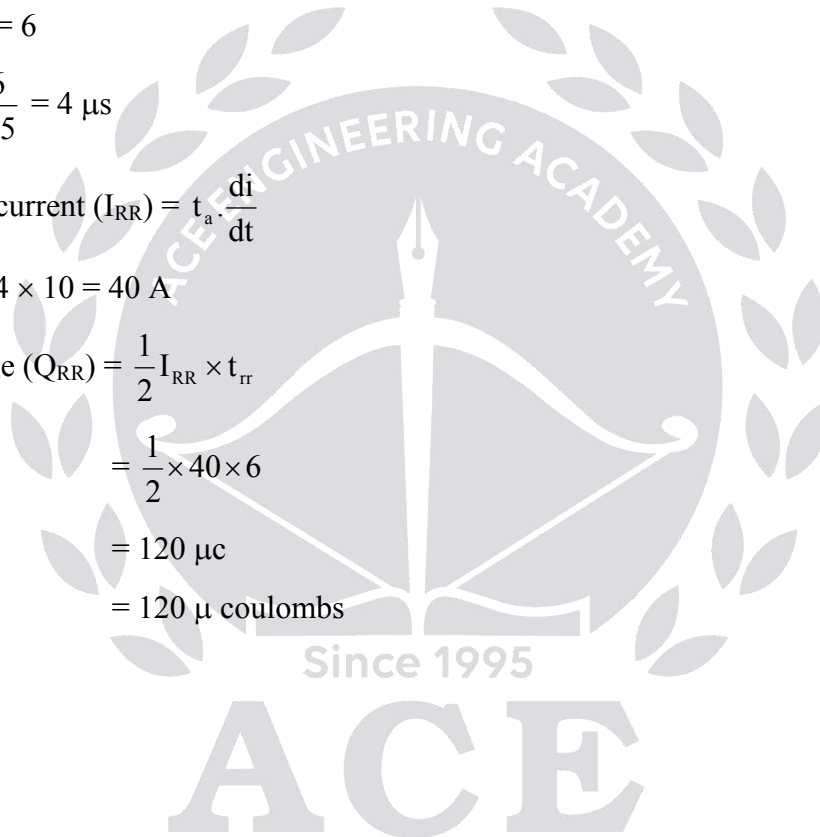
$$\Rightarrow 1.5 t_a = t_{\text{rr}} = 6$$

$$t_a = \frac{6}{1.5} = 4 \mu\text{s}$$

$$\text{Peak reverse current (I}_{\text{RR}}) = t_a \cdot \frac{di}{dt}$$

$$I_{\text{RR}} = 4 \times 10 = 40 \text{ A}$$

$$\begin{aligned} \text{Storage charge (Q}_{\text{RR}}) &= \frac{1}{2} I_{\text{RR}} \times t_{\text{rr}} \\ &= \frac{1}{2} \times 40 \times 6 \\ &= 120 \mu\text{C} \\ &= 120 \mu \text{ coulombs} \end{aligned}$$





# ACE

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Leading Institute for ESE/GATE/PSUs



@Kothapet



## New Batches @ Hyderabad

### Regular Batches For GATE + PSUs – 2020

| Type of Batch | Timings      | Date                         | Duration      | Streams & Venue                                                                            |
|---------------|--------------|------------------------------|---------------|--------------------------------------------------------------------------------------------|
| Regular Batch | 4 to 6 Hours | 8 <sup>th</sup> July 2019    | 5 to 6 Months | CS (Abids)<br>CE (Kothapet, Kukatpally)<br>IN, PI (Dilsukhnagar)<br>EC, EE, ME (DSNR, KKP) |
|               |              | 22 <sup>nd</sup> July 2019   |               |                                                                                            |
|               |              | 05 <sup>th</sup> August 2019 |               |                                                                                            |
|               |              | 20 <sup>th</sup> August 2019 |               |                                                                                            |

### Regular Batches For ESE + GATE + PSUs – 2020

| Type of Batch | Timings      | Date                      | Duration      | Streams & Venue                    |
|---------------|--------------|---------------------------|---------------|------------------------------------|
| Regular Batch | 6 to 8 Hours | 8 <sup>th</sup> July 2019 | 7 to 9 Months | EC, EE (DSNR)<br>ME, CE (Kothapet) |

### IES GENERAL STUDIES BATCH

| Type of Batch | Timings      | Date                       | Duration      | Venue   |
|---------------|--------------|----------------------------|---------------|---------|
| Regular Batch | 4 to 6 hours | 12 <sup>th</sup> July 2019 | 55 to 60 Days | @ Abids |

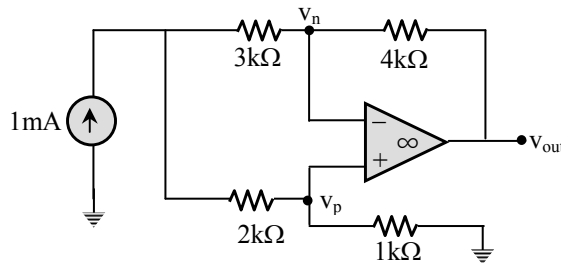
### Long Term Program for GATE + PSUs – 2021

| Type of Batch | Timings      | Date                                                 | Duration        | Streams & Venue                        |
|---------------|--------------|------------------------------------------------------|-----------------|----------------------------------------|
| Morning Batch | 6 am to 8 am | 12 <sup>th</sup> July & 10 <sup>th</sup> August 2019 | 15 to 16 Months | EC, EE, CE, ME, CSIT & IN @ Abids      |
| Morning Batch | 6 am to 8 am | 12 <sup>th</sup> July & 10 <sup>th</sup> August 2019 | 15 to 16 Months | EC, EE, ME @ Dilsukhnagar              |
| Evening Batch | 6 pm–8.30 Pm | 12 <sup>th</sup> July & 10 <sup>th</sup> August 2019 | 15 to 16 Months | EC, EE, ME @ Dilsukhnagar              |
| Morning Batch | 6 am to 8 am | 12 <sup>th</sup> July & 10 <sup>th</sup> August 2019 | 15 to 16 Months | CE @ Kothapet                          |
| Evening Batch | 6 pm–8.30 Pm | 12 <sup>th</sup> July & 10 <sup>th</sup> August 2019 | 15 to 16 Months | CE @ Kothapet                          |
| Morning Batch | 6 am to 8 am | 12 <sup>th</sup> July & 10 <sup>th</sup> August 2019 | 15 to 16 Months | EC, EE, CE, ME, CSIT & IN @ Kukatpally |

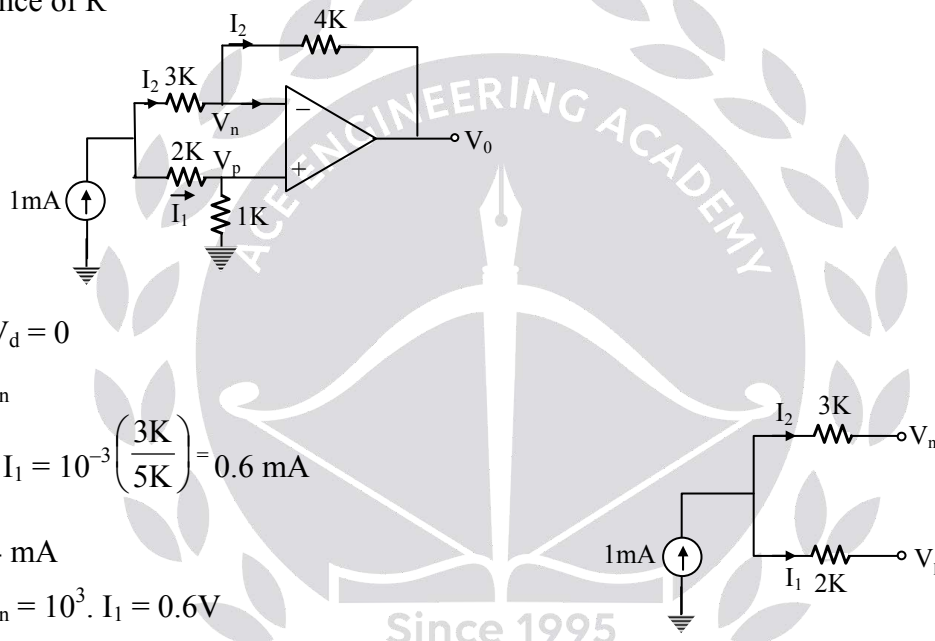
# MPSC (MES) MAINS 2019 (CE)

Regular Batch starts on **15th July 2019**

**2(a) Determine the value of  $v_p$ ,  $v_n$  and  $v_{out}$  in the circuit given below which uses an ideal operational amplifier. Find the resistance  $R$  that, when connected in parallel with the 1 mA source, will cause  $v_{out}$  to drop to half its value when  $R$  is not present.** **20**



**Sol:** In absence of  $R$



Since  $V_d = 0$

$V_p = V_n$

$$I_1 = 10^{-3} \left( \frac{3K}{5K} \right) = 0.6 \text{ mA}$$

$I_2 = 0.4 \text{ mA}$

$V_p = V_n = 10^3 \cdot I_1 = 0.6V$

Then  $V_n - V_0 = 4 \times 10^3 I_2$

$$V_0 = V_n - 4(0.4)$$

$$= 0.6 - 1.6$$

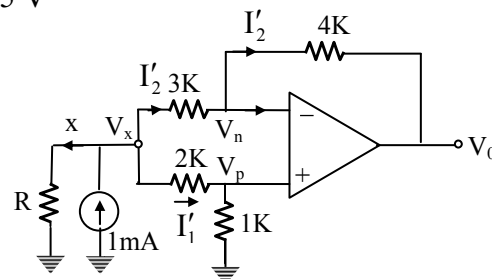
$$= -1V$$

$$V_0 = -1V$$

Now connect a resistor across 1 mA to get  $V_0 = -0.5 V$

Since  $V_d = 0$

$V_p = V_n$



$$I'_1 = (10^{-3} - x) \left[ \frac{3K}{5K} \right]$$

$$I'_1 = 0.6(10^{-3} - x)$$

$$I'_2 = 0.4(10^{-3} - x)$$

$$V_P = 10^3 I'_1$$

$$= 10^3 \times 0.6(10^{-3} - x)$$

$$V_P = 0.6 - 600x = V_n$$

$$\text{Then } V_n - V_0 = 4 \times 10^3 I'_2$$

$$V_n = V_0 + 4 \times 10^3 \times 0.4(10^{-3} - x)$$

$$= -0.5 + 1.6 - 1.6 \times 10^3 x$$

$$V_n = 1.1 - 1600x$$

$$\text{But } V_n = V_P$$

$$1.1 - 1600x = 0.6 - 600x$$

$$1.1 - 0.6 = 1600x - 600x$$

$$\Rightarrow x = \frac{0.5}{1000} = 0.5 \text{ mA}$$

$$V_P = 0.6 - 0.6 \times 0.5$$

$$V_P = 0.3 \text{ V} = V_n$$

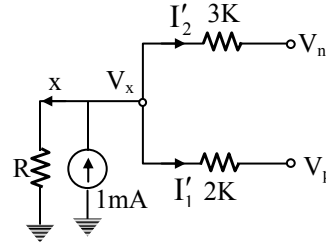
$$V_x - V_P = 2 \times 10^3 I'_1$$

$$V_x = V_P + 2 \times 10^3 \times 0.6(10^{-3} - 0.5 \times 10^{-3})$$

$$= 0.3 + 1.2 \times 0.5$$

$$= 0.9 \text{ V}$$

$$\text{Then } R = \frac{V_x}{x} = \frac{0.9}{0.5 \times 10^{-3}} = 1.8 \text{ k}\Omega$$



# SSC-JE (Paper-I)

## Online Test Series

Staff Selection Commission - Junior Engineer

**No. of Tests : 20**

Subject Wise Tests : 16 | Mock Tests - 4

**Civil | Electrical | Mechanical**

Starts From **10<sup>th</sup> July 2019**

All tests will be available till 27<sup>th</sup> September 2019

☎ 040 - 48539866 / 040 - 40136222

✉ testseries@aceenggacademy.com

# RRB (JE)-2019

## Online Test Series

### ▶ **STAGE - I**

Common for all Streams

No. of Tests : 20

Starts from 25<sup>th</sup> February 2019

### ▶ **STAGE - II**

CE | ME | EC | EE

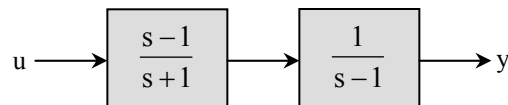
No. of Tests : 20

Starts from 6<sup>th</sup> May 2019

☎ 040 - 48539866 / 040 - 40136222

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**2(b) Check the controllability and observability of the system shown in the figure given below.  $u$  is the input and  $y$  is the output.** **20**



**Sol:** From the given block diagram

$$TF = \frac{Y(s)}{U(s)} = \frac{s-1}{(s+1)(s-1)} = \frac{s-1}{s^2-1}$$

$$\frac{Y(s)}{U(s)} \frac{G(s)}{G(s)} = \frac{s-1}{s^2-1}$$

$$\text{Let } \frac{Y(s)}{G(s)} = s-1$$

$$Y(s) = sG(s) - G(s)$$

$$y(t) = \frac{dg(t)}{dt} - g(t) \text{ ----- (1)}$$

$$\text{Let } \frac{G(s)}{U(s)} = \frac{1}{s^2-1}$$

$$s^2 G(s) - G(s) = U(s)$$

$$\frac{d^2 g(t)}{dt^2} - g(t) = u(t) \text{ ----- (2)}$$

Let the state variables are

$$x_1(t) = g(t) \text{ ----- (3)}$$

$$x_2(t) = \dot{g}(t) \text{ ----- (4)}$$

Differentiating the above equations

$$\dot{x}_1 = \dot{g}(t) = x_2(t) \text{ ----- (5)}$$

$$\dot{x}_2 = \ddot{g}(t) \text{ ----- (6)}$$

using equation (2) in (6)

$$\dot{x}_2 = g(t) + u(t)$$

$$\dot{x}_2 = x_1(t) + u(t) \text{ ----- (7)}$$

From (5) and (6) state equations

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$



using equations (3) and (4) in (1)

$$y(t) = x_2 - x_1 \text{ ----- (8)}$$

$$\therefore \text{ Output equation } y = \begin{bmatrix} -1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

$$\text{Controllability matrix } M = \begin{bmatrix} B & AB \end{bmatrix}$$

$$AB = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$M = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$$

$$|M| = -1 \text{ non zero}$$

$\therefore$  Controllable

$$\text{Observability matrix } N = \begin{bmatrix} C \\ CA \end{bmatrix}$$

$$CA = \begin{bmatrix} -1 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} = \begin{bmatrix} 1 & -1 \end{bmatrix}$$

$$N = \begin{bmatrix} -1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$|N| = 1-1 = 0$$

$\therefore$  Observable

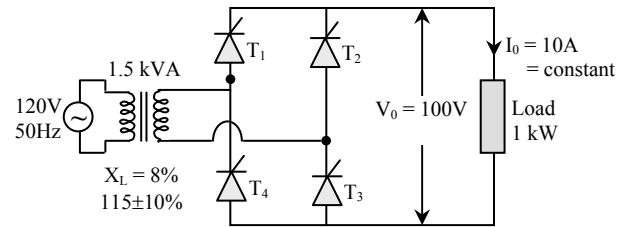
$\therefore$  System is controllable but not observable

**2 (c) A single-phase thyristor controlled bridge rectifier is supplying a dc load of 1 kW. A 1.5 kVA isolation transformer with a source side voltage rating of 120 V at 50 Hz is used. It has total leakage reactance of 8% based on its rating. The source voltage of nominally 115 V is in the range of  $\pm 10\%$ . Assuming load current is nearly constant, find**

- (i) The minimum turns ratio of the transformer, if the dc load voltage is to be regulated at constant value of 100 V,**
- (ii) The reduction in average load voltage due to commutation, and**
- (iii) The value of firing angle  $\alpha$  when the source voltage is  $115 + 10\%$  V.**

**20**

**Sol: (i)**



Source voltage  $V_S = 115 \pm 10\%$

$$= 126.5 \text{ V \& } 103.5 \text{ V}$$

Output voltage  $V_0 = \frac{2V_m}{\pi} \cos \alpha$  ( $\because I_0 = \text{constant}$ )

To get the minimum turns ratio  $\cos \alpha$  should be maximum.

Therefore  $\alpha = 0$

$$100 = \frac{2 \times V_m}{\pi}$$

$$\Rightarrow V_m = 50\pi$$

$$\therefore \text{ Turns ratio} = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{103.5 \times \sqrt{2}}{50\pi} = 0.931$$

(ii) Reduction in average load voltage =  $\frac{2\omega L_s I_0}{\pi}$

$$X_L = \omega L_s = 8\% = 0.08 \text{ pu}$$

$$X_{pu} = X_a \times \frac{\text{MVA}_b}{(\text{kV}_b)^2}$$

$$\text{kVA}_b = 1.5 \text{ kVA}$$

$$V_b = 120 \text{ V}$$

$$0.08 = X_a \times \frac{1.5}{1000 \times \left(\frac{120}{1000}\right)^2}$$

$$\Rightarrow X_a = 0.768 \Omega = X_L = \omega L_s$$

$$\therefore \text{ Voltage drop} = \frac{2 \times 0.768 \times 10}{\pi} = 4.889 \text{ V}$$

$$(iii) V_0 = \frac{2V_m}{\pi} \cos \alpha - \frac{2\omega L_s}{\pi} I_0$$

$$100 = \frac{2\sqrt{2} \times 126.5}{\pi} \cos \alpha - 4.889$$

$$109.778 = \frac{2\sqrt{2} \times 126.5}{\pi} \cos \alpha$$

$$\cos \alpha = 0.920$$

$$\alpha = 22.93^\circ$$

**3(a) A salient-pole synchronous motor (with negligible armature resistance and  $X_d = 23.2 \, \Omega$  and  $X_q = 14.5 \, \Omega/\text{phase}$ ) can support a maximum load of 563 kW without field excitation.**

**This motor is now excited with nominal field current and the motor is loaded with a load torque of 3.82 kN-m. If the motor draws armature current at 0.8 power factor (leading), determine excitation emf and corresponding power angle ( $\delta$ ).** **20**

**Sol:** Insufficient data in given question. If speed is given, the solution to this question is given below.

$$1. \quad X_d = 23.2 \, \Omega/\text{ph.} \quad \frac{1}{X_d} = 0.043, \quad X_q = 14.5 \, \Omega/\text{ph.} \quad \frac{1}{X_q} = 0.069$$

$$\frac{V^2}{2} (0.069 - 0.043) = \frac{563000}{3}$$

$$V^2 \left( \frac{0.026}{2} \right) = \frac{563000}{3}$$

$$V^2 = \frac{2 \times 563000}{3 \times 0.026} \Rightarrow V = 3800 \text{ volts}$$

**2. Nominal field current:** What does it mean?

It is assumed that nominal field current induces a  $E = V$

$$\therefore E = 3800 \text{ V}$$

This assumption cannot be valid since problem states that motor draws a leading current for which  $E > V$ .

3. Data about torque cannot be used since  $P$  &  $f$  are not given, we cannot find synchronous speed and hence we cannot find power developed. We can assume suitable values for  $P$  &  $f$ ; say 4-poles & 50 Hz, and work out the problem.

Assuming  $P = 4$ ,  $f = 50$  Hz,

$$\omega_s, \text{ synchronous speed (mech.rad/sec)} = \frac{4\pi f}{P} = \frac{4\pi \times 50}{4} = 50\pi \text{ rad/sec}$$

$\therefore$  Mechanical power developed =  $(3820) 50\pi$  watts

$$= 6 \times 10^5 \text{ watts} \quad (\text{for all 3 phases})$$

= Power input to motor, since all losses are neglected.

(resistance is given as zero, other losses are not mentioned)

$$\text{Power input/ph, } 2 \times 10^5 = 3800 \times I \times 0.85$$

$$\Rightarrow I = \frac{2 \times 10^5}{3800 \times 0.85} = 61.9 \text{ A}$$

$\therefore$  Armature current/ph =  $61.9 \angle 36.87^\circ \text{ A}$

**Phasor diagram:**

$$AH = 3800 \cos \delta$$

$$BH = 3800 \sin \delta$$

$$\text{Also } BH = 898 \cos(\theta + \delta)$$

$$= 898 \cos(36.87^\circ + \delta)$$

$$3800 \sin \delta = 898(0.8 \cos \delta - 0.6 \sin \delta)$$

$$\Rightarrow 0.8 \cos \delta - 0.6 \sin \delta = 4.23 \sin \delta$$

$$\Rightarrow 4.83 \sin \delta = 0.8 \cos \delta$$

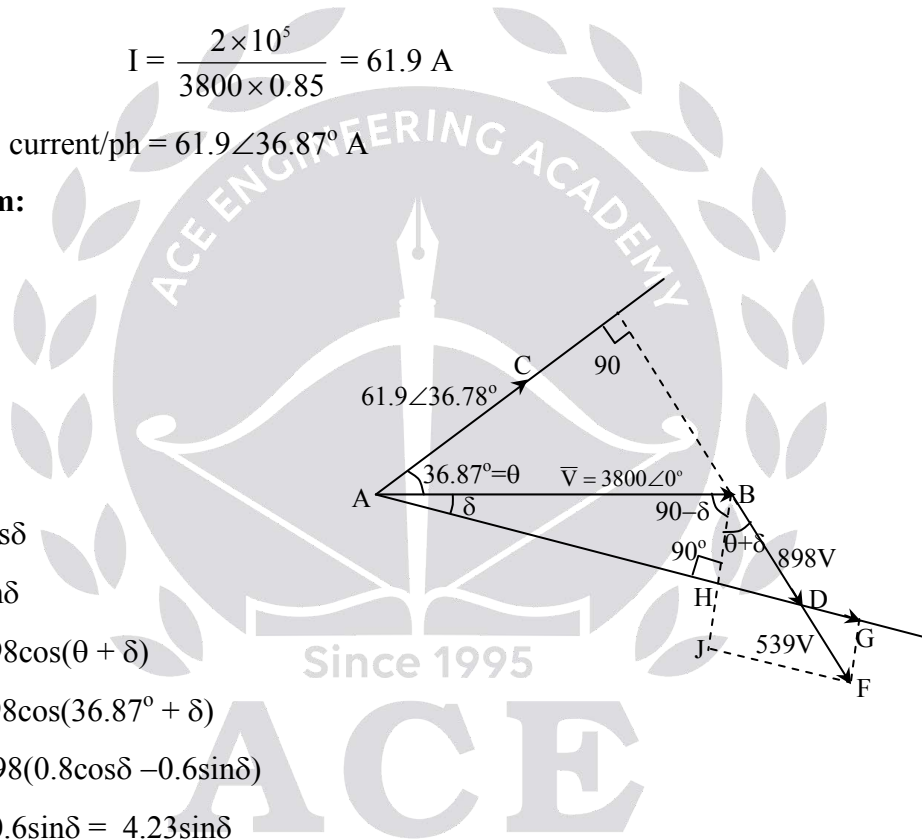
$$\Rightarrow \tan \delta = \frac{0.8}{4.83} = 0.1656$$

$$\delta = 9.4^\circ \text{ elec.}$$

$$AH = 3749 \text{ V}$$

$$HG = JF = 1437 \sin(36.87^\circ + 9.4^\circ) = 1038 \text{ V}$$

$$E = 3749 + 1038 = \mathbf{4786 \text{ V.}}$$







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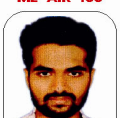


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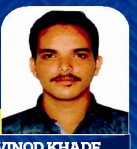
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**3(b) (i) Fourier transform of a periodic signal is given as**

$$X(j\omega) = j\delta\left(\omega - \frac{\pi}{3}\right) + 2\delta\left(\omega - \frac{\pi}{7}\right).$$

**Determine the fundamental angular frequency and the Fourier series coefficients. Then determine the corresponding time signal.**

**(ii) Determine the Laplace transform and the ROC for the signal  $x(t) = e^{at} u(t - k)$ .**

**20**

**Sol:** (i) FT of a periodic signal

$$X(\omega) = j\delta\left(\omega - \frac{\pi}{3}\right) + 2\delta\left(\omega - \frac{\pi}{7}\right)$$

$$\text{Fundamental frequency } \omega_0 = \text{GCD of } \frac{\pi}{3}, \frac{\pi}{7} \\ = \frac{\pi}{21}$$

$$\text{EFS } x(t) = \sum_{n=-\infty}^{\infty} C_n e^{jn\omega_0 t}$$

↓ FT

$$X(\omega) = 2\pi \sum_{n=-\infty}^{\infty} C_n \delta(\omega - n\omega_0) \dots\dots\dots (1)$$

$$X(\omega) = j\delta\left(\omega - \frac{7\pi}{21}\right) + 2\delta\left(\omega - \frac{3\pi}{21}\right)$$

↓  
7<sup>th</sup> harmonic

↓  
3<sup>rd</sup> harmonic

By comparison with equation (1)

$$2\pi C_7 = j$$

$$2\pi C_3 = 2$$

$$C_7 = \frac{j}{2\pi}$$

$$C_3 = \frac{1}{\pi}$$

$$\therefore x(t) = C_3 e^{j(3)(\pi/21)t} + C_7 e^{j(7)(\pi/21)t}$$

$$= \frac{1}{\pi} e^{j(\pi/7)t} + \frac{j}{2\pi} e^{j\pi/3 t}$$

(ii)  $x(t) = e^{at} u(t - k)$

$$x(t) = e^{a(t-k)} u(t - k)$$

$$= e^{ak} e^{a(t-k)} u(t - k)$$

$$x(t-t_0) \xrightarrow{\text{LT}} e^{-st_0} X(s) \text{ with ROC} = R$$

$$\text{LT}[x(t)] = X(s) = e^{ak} \left[ \frac{e^{-sk}}{s-a} \right]; \text{ROC: } \text{Re}\{s\} > \text{Re}\{a\}$$





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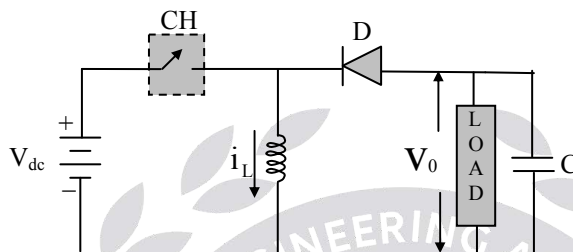
**3(c) A Buck-Boost converter is operating at 20 kHz with Inductor  $L = 50 \mu\text{H}$ . The output capacitor  $C$  is sufficiently large and source voltage  $V_d = 15 \text{ V}$ . The output is to be regulated at 10 V and the converter is supplying a load of 10 W. Find**

**(i) The duty ratio  $D$ , and**

**(ii) Maximum value of Inductor current.**

**20**

**Sol:**



frequency ( $f$ ) = 20 kHz

Inductance ( $L$ ) = 50  $\mu\text{H}$

Supply voltage ( $V_d$ ) = 15 V

Output voltage ( $V_0$ ) = 10 V

Load power ( $P_0$ ) = 10 W

$$\text{Load current} = \frac{P_0}{V_0} = \frac{10}{10} = 1 \text{ A}$$

$$\text{Load resistance (R)} = \frac{V_0}{I_0} = \frac{10}{1} = 10 \Omega$$

Inductor current varies with slope of  $\frac{V_s}{L}$  during ON time of switch and  $\frac{V_0}{L}$  during OFF time of switch.

The slope of current increasing is  $\frac{15}{L}$  and slope of decrement of current is  $\frac{10}{L}$ . So, current takes 1.5 times of ON time to decrease and come to steady state.

$$T_{\text{ON}} + T_{\text{OFF}} = T$$

$$T_{\text{ON}} + 1.5 T_{\text{ON}} = T$$

$$2.5 T_{\text{ON}} = T$$

$$2.5 DT = T$$

$$D = 0.4$$

Any duty cycle more than 0.4 is not suitable for this operation.

Critical value of duty cycle can be obtained as follows.

$$\frac{2L}{RT} = (1 - D_{cr})^2$$

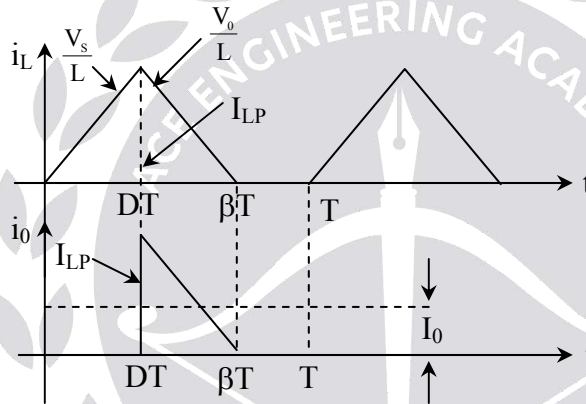
$$\frac{2 \times 50 \times 10^{-6}}{10 \times 50 \times 10^{-6}} = (1 - D_{cr})^2$$

$$D_{cr} = 0.5527$$

Any duty cycle more than 0.5527 makes inductor current to be continuous.

As per earlier conclusion duty cycle cannot be more than 0.4. Hence conduction is discontinuous.

### Discontinuous Conduction:



As the slope of ascending is 1.5 times than descending, it takes 1.5 times of turn on time ( $DT$ ) to get current to zero.

$$DT = T_{ON} \quad (\beta - D)T = T_{OFF}$$

$$(\beta - D)T = 1.5 DT$$

$$\beta = 2.5 D$$

$$\text{Peak value of inductor current } (I_{LP}) = \frac{V_s}{L} DT$$

$$\text{Average value of output current } (I_0) = \frac{\frac{1}{2} I_{LP} (\beta - D) T}{T}$$

$$I_0 = \frac{1}{2} I_{LP} (\beta - D)$$

$$I_0 = \frac{1}{2} \frac{V_s}{L} DT (\beta - D)$$

$$1 = \frac{1}{2} \times \frac{15}{50 \times 10^{-6}} \times D \times 50 \times 10^{-6} \times (2.5D - D)$$

$$1 = \frac{15}{2} \times 1.5 D^2$$

$$\Rightarrow D = 0.2981$$

Duty ratio  $D = 0.2981$

Maximum value of inductor current

$$\begin{aligned} (I_{LP}) &= \frac{V_s}{L} DT \\ &= \frac{15}{50 \times 10^{-6}} \times 0.2981 \times 50 \times 10^{-6} \\ &= 4.472 \text{ A} \end{aligned}$$

**4(a) The open loop transfer function of a unity feedback system is given by**

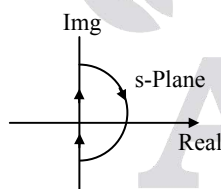
$$G(s)H(s) = \frac{K}{(s+20)(s^2-2s+1)}$$

**Use Nyquist stability criteria to find the range of K for closed loop stability.**

**20**

**Sol:**  $G(s)H(s) = \frac{k}{(s+20)(s^2-2s+1)} = \frac{k}{(s+20)(s-1)^2}$

Nyquist contour is shown below



Mapping of +ve imaginary axis of the Nyquist Contour.

Substitute  $s = j\omega$   $0 \leq \omega \leq \infty$

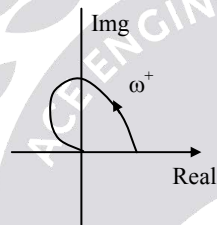
$$G(j\omega)H(j\omega) = \frac{k}{(j\omega+20)(j\omega-1)^2}$$

$$M = |G(j\omega)H(j\omega)| = \frac{k}{\sqrt{(\omega^2+400)(\omega^2+1)^2}}$$

$$\phi = \angle G(j\omega)H(j\omega) = -\left[ \tan^{-1} \frac{\omega}{20} + 2[180^\circ - \tan^{-1} \omega] \right]$$

$$\phi = 2 \tan^{-1} \omega - \tan^{-1} \frac{\omega}{20}$$

| $\omega$ | Magnitude (M)  | Phase angle ( $\phi$ ) |
|----------|----------------|------------------------|
| 0        | $\frac{k}{20}$ | $0^\circ$              |
| $\vdots$ |                |                        |
| $\infty$ | 0              | $90^\circ$             |

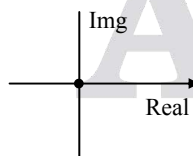


Mapping of radius 'R' semicircle of the Nyquist contour:

Substitute:  $s = Lt \underset{R \rightarrow \infty}{Re^{j\theta}}$   $\theta$  is from  $90^\circ$  to  $0^\circ$  to  $-90^\circ$

$$G(Re^{j\theta})H(Re^{j\theta}) = \frac{k}{(Re^{j\theta} + 20)(Re^{j\theta} - 1)^2} \cong 0$$

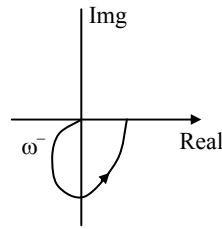
This section merges with the origin.



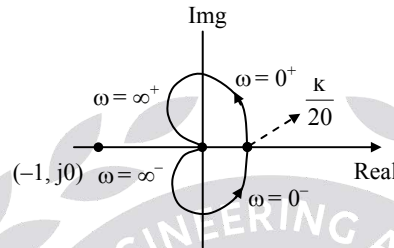
Mapping of the negative imaginary axis of Nyquist contour

Substitute  $s = j\omega$   $-\infty \leq \omega \leq 0$

This section becomes the mirror image of the positive imaginary axis and is drawn such that the Nyquist plot is symmetrical with respect to real axis.



Combining all the above three sections the Nyquist plot is shown below.



$N = 0$  from the plot

$P = 2$  (from the given  $G(s)H(s)$ )

$N = P - Z$

$Z = P - N = 2 - 0$

$Z = 2$

Closed loop system is unstable with two right half of s-plane poles.

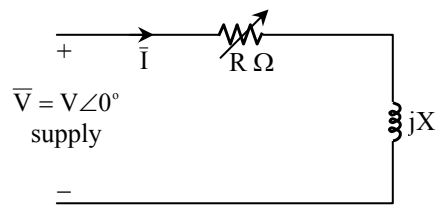
For all values of  $k$  system is unstable.

**4(b) Draw and elaborate (with appropriate mathematical justification) the graphical locus of induction motor (voltage, current and power) for a complete range of slip from approximate equivalent circuit model. Justify its circular nature for naming it as circle diagram of induction motor.**

**Also, state and explain with the help of the circle diagram, how to obtain rotor/stator copper losses, torque and slip at any arbitrary point on circle diagram.**

**20**

**Sol: 1. Locus of the tip of the current phasor in the circuit of fig. 1:**



$R$  varies from  $\infty$  to  $+\infty$ .

$\bar{V}$ ,  $X$  are constants

Fig. 1



$$\bar{I} = \frac{V}{R + jX} = \frac{V(R - jX)}{R^2 + X^2} = \frac{VR}{R^2 + X^2} - j \frac{VX}{R^2 + X^2} = I_x - jI_y.$$

The phasor  $\bar{I}$  is shown in fig. 2.

For  $R = 0$ ,  $\bar{I} = -j \frac{V}{X}$

For  $R = \pm\infty$ ,  $\bar{I} = 0$ .

What is the locus of the tip of the  $\bar{I}$  phasor as  $R$  varies?

## 2. Proof that locus of ( $I_x$ , $I_y$ ) point is a circle:

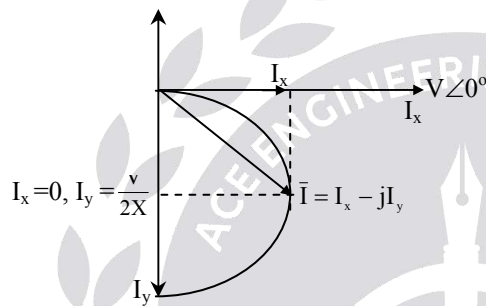


Fig. 2

We have  $I_x^2 + I_y^2 = \frac{V^2}{R^2 + X^2} \dots\dots\dots (1)$

$\therefore I_x^2 + I_y^2 - \frac{V^2}{R^2 + X^2} = 0 \dots\dots\dots (2)$

Adding  $\frac{V^2}{4X^2}$  to both sides, we get

$I_x^2 + I_y^2 - \frac{V^2}{R^2 + X^2} + \frac{V^2}{4X^2} = \frac{V^2}{4X^2} \dots\dots\dots (3)$

Now,  $\left(I_y - \frac{V}{2X}\right)^2 = I_y^2 + \frac{V^2}{4X^2} - 2 \frac{V}{2X} I_y$

$$= I_y^2 + \frac{V^2}{4X^2} - \frac{V}{X} \frac{VX}{R^2 + X^2}$$

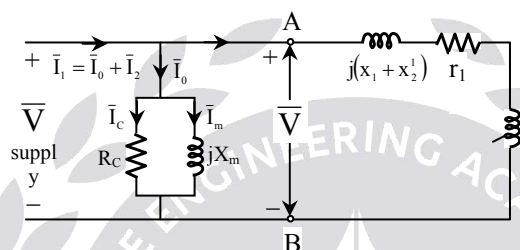
$$= I_y^2 + \frac{V^2}{4X^2} - \frac{V^2}{R^2 + X^2}$$

$\therefore (3)$  can be written as

$$I_x^2 + \left(I_y - \frac{V}{2X}\right)^2 = \left(\frac{V}{2X}\right)^2 \dots\dots\dots (4)$$

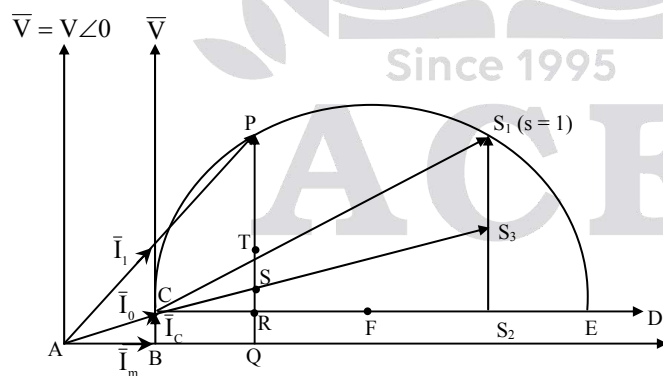
The locus of the point ( $I_x, I_y$ ) (which is the tip of the  $\bar{I}$  phasor of fig. 1. as  $R$  varies is a circle with center ( $I_x = 0, I_y = \frac{V}{2X}$ ) and radius  $\left(\frac{V}{2X}\right)$ . This is the mathematic basis for the circle diagram of the 3-phase induction motor.

**3. Now consider the approximate equivalent circuit/ph of a 3-phase induction motor.**



The circuit to the right of the points A and B is a constant reactance variable resistance series circuit, to which a constant voltage is applied. The locus of the tip of the phasor current  $\bar{I}_2$  is therefore a circle, with radius  $\frac{V}{2X}$  and center  $\frac{V}{2X}, 0$  where  $X = (x_1 + x_2')$ .

**4. Construction of the circle diagram using fig. 3:**



4.1 Draw  $\bar{V} = V\angle 0^\circ$ . (It is customary to draw  $\bar{V}$  vertically).

4.2 Show  $\bar{I}_c = \left(\frac{\bar{V}}{R_c}\right)$  and  $\bar{I}_m = \left(-\frac{j\bar{V}}{X_m}\right)$ . Show  $\bar{I}_0 = \bar{I}_m + \bar{I}_c$ .

4.3 From point C, show  $\bar{V}$  (for convenience).

4.4 Draw the line CD lagging  $\bar{V}$  by  $90^\circ$ . On this line, mark the point E such that  $E = \frac{V}{X}$ .

Mark F on CD such that  $CF = \frac{V}{2X}$

4.5 The locus of the tip of  $\bar{I}_2$  is a circle with center F and radius FC. Draw the circle.

4.6 For any point P on the circle,  $\overline{CP} = \bar{I}_2$  and  $\overline{OP} = \overline{OC} + \overline{CP} = \bar{I}_1$ .

4.7 The full circle can be completed, lower portion representing generation action.

### 5. Rotor/stator copper losses, torque, and slip at any point P on the circle:

5.1 At P, draw the vertical PQ

$\overline{QP}$  is the component of  $\bar{I}_1$  in phase with  $\bar{V}$ . So to a suitable scale, QP represents the power input.

QR = BC = core losses

$\therefore$  RP = Mechanical power developed, (which includes friction losses) + stator and rotor copper losses.

5.2 From a rotor blocked test, locate the point  $S_1$  on the circle for an applied voltage = rated voltage. At the point  $S_1$ ; slip = 1.

The rotor is not rotating. There is no mechanical power.

Draw the vertical  $S_1 S_2$  to give the stator copper losses + rotor copper loss at rotor blocked condition with applied voltage = rated value.

5.3 Locate the point  $S_3$  on  $S_1 S_2$  such that  $S_1 S_3$  = rotor copper loss and  $S_3 S_2$  = stator copper loss.

$$\frac{S_1 S_2}{S_3 S_2} = \frac{r_2'}{r_1}$$

5.4 Join  $CS_1$  and  $CS_3$

5.5 At the point P, PT = Mechanical power developed (output since mech losses are included in output).

TS = rotor copper losses corresponding to point of operation P,

SR = stator copper losses corresponding to P; and RQ = core losses (as given earlier)

(All these statements can be proved)

### 5.6 Torque and slip:

PS = PT + TS = Mech output + rotor copper loss

= Rotor power input

$$\text{Slip } s = \frac{\text{Rotor copper losses}}{\text{Rotor input}} = \frac{TS}{PS}$$

$$\text{Torque} = \frac{\text{Rotor input}}{\omega_s}$$

$$= \frac{PS}{\omega_s} \quad (\omega_s = \text{synchronous speed, mech r/sec}).$$

**4(c) Draw the wiring diagram showing currents for power and relaying circuit used for protecting a transformer of the rating 25 MVA, 220 Y/13.8 Δ kV, X = 10%. The transformer has a short-term overload capacity of 30 MVA. You are required to use CTs with common turns ratios such as 50/5A, 100/5A, 150/5A, 1000/5A, 1200/5A. If needed, auxiliary CT of adequate turns ratio may be used.** **20**

**Sol:** The full load current in primary

$$I_{L1} = \frac{25 \times 10^6}{\sqrt{3} \times 220 \times 10^3} = 65.6 \text{ A}$$

The full load current in secondary

$$I_{L2} = \frac{25 \times 10^6}{\sqrt{3} \times 13.8 \times 10^3} = 1045.92 \text{ A}$$

The primary CT ratio is 100/5

Since primary of power transformer is connected so primary side CT's must be connected in delta.

Since secondary of power transformer is Δ connected, so secondary side CT's must be connected in Y

$$\sqrt{3} V_{L1} I_{L1} = \sqrt{3} V_{L2} I_{L2}$$

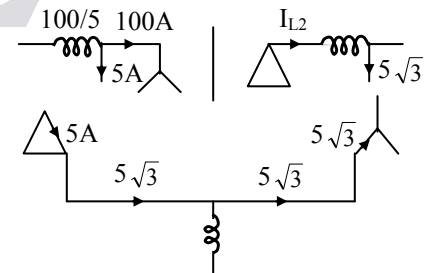
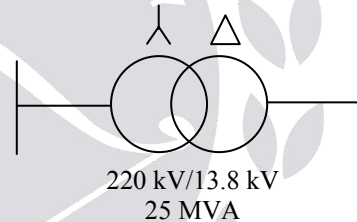
$$220 \times 100 = 13.8 I_{L2}$$

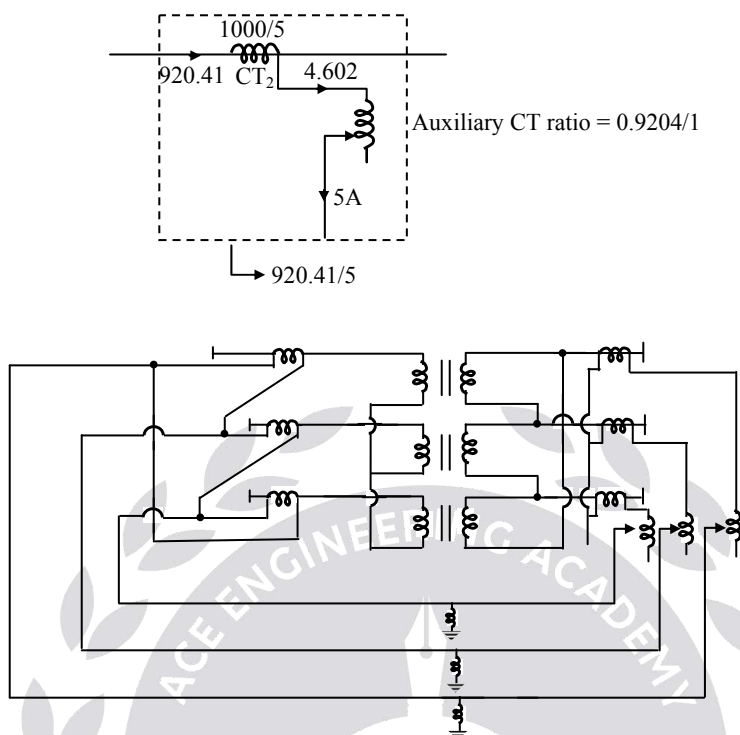
$$I_{L2} = 1594.262$$

$$\text{CT ratio on secondary side is} = \frac{1594.202}{5\sqrt{3}} = 920.41/5$$

So on secondary side CT ratio is 1000/5 but to get proper current auxiliary CT required

On secondary side of power transformer:





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**SECTION-B**

**5(a) The transfer function of a linear system is given by  $G(s) = \frac{10}{(s+1)(s+2)}$ . The sinusoidal steady state response of the system to an input is given by  $1 + \sin(t - 60^\circ) + 5 \sin(2t - 45^\circ)$ . Determine the input.**

**12**

**Sol:** Given output  $y(t) = 1 + \sin(t - 60^\circ) + 5 \sin(2t - 45^\circ)$

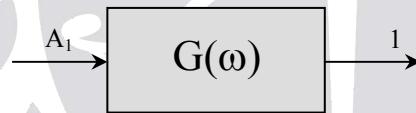
As the system is linear, there must be three different inputs to get the given output.

$$x(t) = A_1 + A_2 \sin(t + \phi_1) + A_3 \sin(2t + \phi_2)$$

$$G(s) = \frac{10}{(s+1)(s+2)}; G(\omega) = \frac{10}{(j\omega+1)(j\omega+2)}$$

$$|G(\omega)| = \frac{10}{\sqrt{(1+\omega^2)(\omega^2+4)}}$$

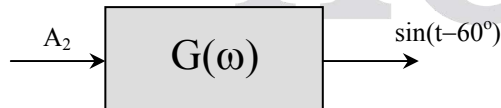
$$\angle G(\omega) = -\left[\tan^{-1}\left(\frac{\omega}{1}\right) + \tan^{-1}\left(\frac{\omega}{2}\right)\right]$$



$$|G(\omega)|_{\omega=0} = \frac{10}{\sqrt{(1+0)(0+4)}} = 5$$

$$\therefore A_1 \times 5 = 1$$

$$\therefore A_1 = \frac{1}{5}$$



$$|G(\omega)|_{\omega=1} = \frac{10}{\sqrt{(2)(5)}} = \sqrt{10}$$

$$A_2 \sqrt{10} = 1 \Rightarrow A_2 = \frac{1}{\sqrt{10}}$$

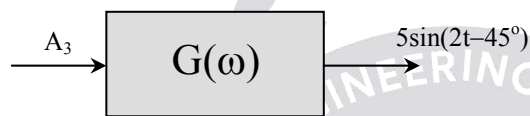


$$\begin{aligned}\angle G(\omega)|_{\omega=1} &= -\left[\tan^{-1}\left(\frac{1}{1}\right) + \tan^{-1}\left(\frac{1}{2}\right)\right] \\ &= -[45^\circ + 26.56^\circ] \\ &= -71.56^\circ\end{aligned}$$

$$\phi_1 - 71.56 = -60^\circ \Rightarrow \phi_1 = -60^\circ + 71.56^\circ$$

$$\therefore \phi_1 = 11.56^\circ$$

$$\therefore \text{Input} = \frac{1}{\sqrt{10}} \sin(t + 11.56^\circ)$$



$$|G(\omega)|_{\omega=2} = \frac{10}{\sqrt{(1+2^2)(2^2+4)}} = \frac{10}{\sqrt{5 \times 8}} = \frac{10}{\sqrt{40}} = \frac{\sqrt{10}}{2}$$

$$A_3 \frac{\sqrt{10}}{2} = 5$$

$$\therefore A_3 = \sqrt{10}$$

$$\begin{aligned}\angle G(\omega)|_{\omega=2} &= -\left[\tan^{-1}(2) + \tan^{-1}\left(\frac{2}{2}\right)\right] \\ &= -(63.434^\circ + 45^\circ) \\ &= -108.43^\circ\end{aligned}$$

$$\phi_2 - 108.43^\circ = -45^\circ$$

$$\therefore \phi_2 = 63.43^\circ$$

$$\therefore \text{Input is } \sqrt{10} \sin(2t + 63.43^\circ)$$

$\therefore$  Total input of the system is

$$x(t) = \frac{1}{5} + \frac{1}{\sqrt{10}} \sin(t + 11.56^\circ) + \sqrt{10} \sin(2t + 63.43^\circ)$$

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**5(b) Draw phasor diagram of an over-excited salient-pole synchronous motor having armature resistance  $R_a$ , d-axis and q-axis reactances  $X_d$  and  $X_q$  respectively. Also prove, for lagging power factor**

$$\tan(\phi - \delta) = \frac{V_t \sin \phi - I_a X_q}{V_t \cos \phi - I_a R_a}$$

**Where  $V_t$  is the terminal voltage applied to motor,  $\phi$  being the power factor angle,  $\delta$  is power angle and  $I_a$  is armature current.**

**12**

**Sol:** Overexcited salient pole synchronous motor with  $R_a$ ,  $X_d$ ,  $X_q$ :

$$\bar{V} - R_a \bar{I} - \bar{I}_q j X_q - \bar{I}_d j X_d = \bar{E}$$

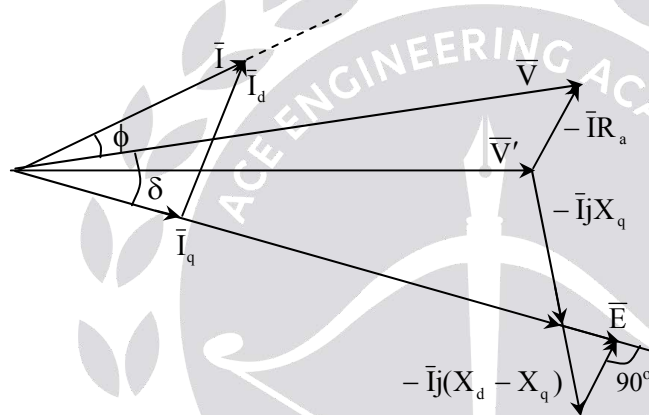
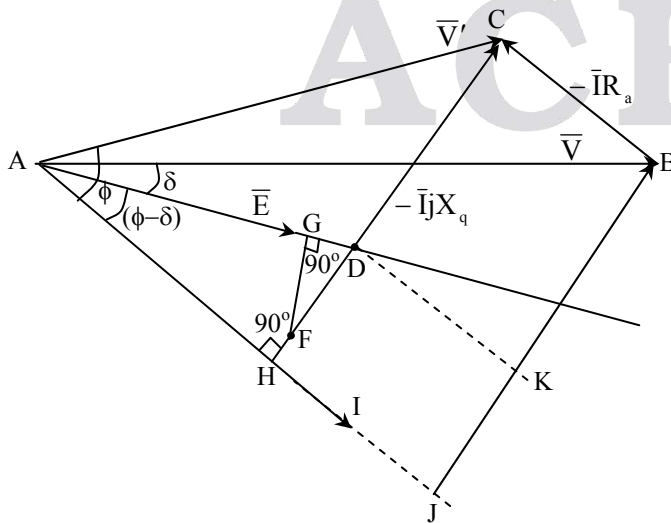


Fig. Phasor diagram with  $\bar{I}$  leading  $\bar{V}$  by  $\phi$

**Phasor diagram with  $\bar{I}$  lagging  $\bar{V}$ :**



$$\overline{DF} = \bar{I} [j(X_d - X_q)]$$

$$BJ = V \sin \phi$$

$$CD = BK = IX_q$$

$$\therefore KJ = DH = V \sin \phi - IX_q$$

$$\text{But from fig, } \tan(\phi - \delta) = \frac{DH}{AH} = \frac{V \sin \delta - IX_q}{AH}$$

$$\text{We must show that } AH = V \cos \phi - IR_a$$

$$\text{But from fig, } AJ = V \cos \phi.$$

$$JH = BC = IR_a \text{ (in magnitude)}$$

$$\therefore AH = V \cos \phi - IR_a$$

$$\text{Hence, } \tan(\phi - \delta) = \frac{DH}{AH} = \frac{V \sin \delta - IX_q}{V \cos \phi - IR_a}$$

**5(c) A flyback converter has the following circuit parameters:**

$$V_s = 24 \text{ V}$$

$$N_1/N_2 = 3$$

$$L_m = 500 \mu\text{H}$$

$$R = 5 \Omega$$

$$C = 200 \mu\text{F}$$

$$f = 25 \text{ kHz}$$

$$V_0 = 10 \text{ V}$$

**Find**

**(i) The average magnetizing current, and**

**(ii) The critical value of magnetizing inductor**

**12**

**Sol:** Given data,

$$V_s = 24 \text{ V}, \frac{N_1}{N_2} = 3$$

$$L_m = 500 \mu\text{H}, R = 5 \Omega$$

$$C = 200 \mu\text{F}, f = 25 \text{ kHz}$$

$$V_0 = 10 \text{ V}$$

(i) Average magnetizing current ( $I_m$ )

$$I_0 = \frac{V_0}{R} = \frac{10}{5} = 2$$

Fly back converter operation is similar to buck boost converter

$$\frac{V_0}{V_s} = \frac{N_2}{N_1} \frac{D}{1-D}$$

$$\frac{D}{1-D} = \frac{N_1}{N_2} \cdot \frac{V_0}{V_s} = (3) \cdot \frac{10}{24}$$

$$\frac{D}{1-D} = \frac{5}{4}$$

$$\Rightarrow D = \frac{5}{9} = 0.555$$

$$\begin{aligned} \text{Average value of magnetizing current} &= \frac{I_0}{1-D} \left( \frac{N_2}{N_1} \right) \\ &= \frac{2}{1-0.555} \left( \frac{1}{3} \right) \\ &= 1.5 \text{ A} \end{aligned}$$

(ii) Critical value of inductor current can be obtained by  $\frac{2L_{cr}}{RT} = (1-D)^2$

$$\Rightarrow \frac{2 \times L_{cr}}{5 \times 40 \times 10^{-6}} = (1-0.555)^2$$

$$L_{cr} = 19.75 \mu\text{H}$$

**5(d) A 220 kV three-phase transmission line is 90 km long. The resistance is 0.1  $\Omega$ /km and the inductance is 1.0 mH/km. Use the short transmission line model to find**

**(i) Voltage at the sending end, and**

**(ii) Voltage regulation at the sending end.**

**12**

**Sol:** (i) (Data insufficient)

To calculate voltage @ sending end either the rating of transmission line or load current should be given.

(ii) Sending end voltage regulation = 0

When load is changed from no load to full load, receiving end voltage is changed but not sending voltage

$$\text{i.e., } (V_s)_{\text{fullload}} = (V_s)_{\text{no load}}$$

$$\therefore (V_{\text{reg}})_{\text{sending end}} = 0$$

**5(e) A 12-bit dual-slope ADC utilizes a 1 MHz clock and has  $V_{\text{ref}} = 10$  V. Its analog input voltage is in the range of 0 to – 10 V. Find out the time required to convert an input signal equal to the full-scale value. Also find the integrator time constant if the peak voltage reached at the output of the integrator is 10 V.**

**12**

**Sol:**  $t_A = (2^{n+1} - 1) T_{\text{clk}}$

$$= (2^{12+1} - 1) \frac{1}{f_{\text{c/k}}}$$

$$= \frac{(2^{13} - 1)}{1 \times 10^6}$$

$$= \frac{8191}{10^6}$$

$$= 8191 \times 10^{-6}$$

$$= 8.191 \times 10^{-3}$$

$$= 8.191 \text{ ms}$$

$$\cong 8.2 \text{ ms}$$

**6(a) A 50 Hz, 4-pole turbogenerator rated 500 MVA, 22 kV has an inertia constant of 7.5 MJ/MVA.**

**Find**

- (i) Rotor acceleration, if the input to the generator is suddenly raised to 400 MW for an electrical load of 350 MW,**
- (ii) The speed of rotor in rpm, if the rotor acceleration calculated in part (i) is constant for a period of 10 cycles, and**
- (iii) The change in torque angle  $\delta$  in elect.degrees.**

**20**



**Sol:** Given,

$$f = 50 \text{ Hz}$$

$$S = 500 \text{ MVA}$$

$$V = 22 \text{ kV}$$

$$H = 7.5 \text{ MJ/MVA}$$

$$(i) P_e = 350 \text{ MW}$$

$$P_m = 400 \text{ MW}$$

Swing equation in actual units and electrical degrees is

$$\frac{GH}{180^\circ f} \frac{d^2\delta}{dt^2} = P_m - P_e$$

$$\frac{(500) \times (7.5) \times 10^6}{180^\circ \times (50)} \cdot \frac{d^2\delta}{dt^2} = (400 - 350)^\circ \times 10^6$$

$$\therefore \frac{d^2\delta}{dt^2} = 120 \text{ elec deg/sec}^2$$

$\uparrow$   
 Rotor acceleration

$$(ii) \left( \frac{d^2\delta}{dt^2} \right)_{\text{mech}} = \frac{2}{P} \left( \frac{d^2\delta}{dt^2} \right)_{\text{elec}} = \frac{2}{4} (120)$$

$$\left( \frac{d^2\delta}{dt^2} \right)_{\text{mech}} = 60 \text{ mech deg/sec}^2$$

$$= \frac{60}{360} \text{ rotations/sec}^2$$

$$= \frac{\left( \frac{1}{6} \right) \text{ rotations}}{\left( \frac{1}{60} \right)^2 \text{ min}^2}$$

$$\left( \frac{d^2\delta}{dt^2} \right)_{\text{mech}} = \frac{3600}{6} = 600 \text{ rotations/min}^2$$

$$\text{Time} = t = 10 \text{ cycles} = 10 \times \frac{1}{50} = \frac{1}{5} = \frac{1}{5} \times \frac{1}{60} \text{ min}$$

$$t = \frac{1}{300} \text{ min}$$

$$\text{Initial speed } N_0 = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

$$\begin{aligned} \text{Final speed } N_1 &= N_0 + \left( \frac{d^2\delta}{dt^2} \right) t \\ &= 1500 + 600 \times \frac{1}{300} \end{aligned}$$

$$N_1 = 1502 \text{ rpm}$$

(iii) change in torque angle is

$$\begin{aligned} \Delta\delta &= \frac{1}{2} \alpha_e t^2 \\ &= \frac{1}{2} \times 120 (\text{elec.deg/sec}^2) \times \left( \frac{1}{5} \right)^2 \text{sec}^2 \end{aligned}$$

$$\Delta\delta = 2.4 \text{ electrical degrees.}$$

**6(b) The full bridge inverter is used to produce a 50 Hz voltage across a series RL load using Bipolar PWM. The dc input to the bridge is 200 V, the frequency modulation  $m_f$  is 21 and amplitude modulation  $m_a$  is 0.8. The load has resistance of  $R = 10 \Omega$  and inductance  $L = 20 \text{ mH}$ . Find**

**(i) The amplitude of fundamental voltage and current, and**

**(ii) Total harmonic distortion in load current.**

**20**

**Assume harmonics ( $>25^{\text{th}}$  order) are insignificant and normalized voltage is**

| $m_a = 1$       |      | 0.9  | 0.8  | 0.7  | 0.6  | 0.5  |
|-----------------|------|------|------|------|------|------|
| $n = 1$         | 1.0  | 0.9  | 0.8  | 0.7  | 0.6  | 0.5  |
| $n = m_f$       | 0.6  | 0.71 | 0.82 | 0.92 | 1.01 | 1.15 |
| $n = m_f \pm 2$ | 0.32 | 0.27 | 0.22 | 0.17 | 0.13 | 0.09 |

**Sol:** Full bridge inverter is operating with bipolar PWM.

DC input voltage ( $V_d$ ) = 200 V

Frequency modulation ( $m_f$ ) = 21

Amplitude modulation ( $m_a$ ) = 0.8

Load: Resistance ( $R$ ) =  $10 \Omega$

Inductance (L) = 20 mH

Fundamental frequency (f) = 50 Hz

$$\begin{aligned}\text{Inductive reactance at 50 Hz} &= 2\pi \times 50 \times 20 \times 10^{-3} \\ &= 6.28 \Omega\end{aligned}$$

$$\begin{aligned}\text{Impedance at fundamental frequency} &= \sqrt{10^2 + 6.28^2} \\ &= 11.8 \Omega\end{aligned}$$

$$\begin{aligned}\text{(i) Amplitude of fundamental voltage (V}_{01\text{ m}}) &= m_a \cdot V_d \\ &= 0.8 \times 200 = 160 \text{ V}\end{aligned}$$

$$\begin{aligned}\text{Amplitude of fundamental current (I}_{01\text{ m}}) &= \frac{V_{01\text{ m}}}{Z} \\ &= \frac{160}{11.8} = 13.56 \text{ A}\end{aligned}$$

$$\text{RMS value of fundamental current (I}_1) = \frac{13.56}{\sqrt{2}} = 9.59 \text{ A}$$

$$\begin{aligned}\text{(ii) RMS value of 21}^{\text{st}} \text{ harmonic (V}_{21}) &= 0.82 \times 200 \times \frac{1}{\sqrt{2}} \\ &= 115.9 \text{ V}\end{aligned}$$

$$\begin{aligned}\text{RMS value of 19}^{\text{th}} \text{ harmonic (V}_{19}) &= 0.22 \times 200 \times \frac{1}{\sqrt{2}} \\ &= 31.31 \text{ V}\end{aligned}$$

$$\begin{aligned}\text{RMS value of 23}^{\text{rd}} \text{ harmonic (V}_{23}) &= 0.22 \times 200 \times \frac{1}{\sqrt{2}} \\ &= 31.31 \text{ V}\end{aligned}$$

$$\begin{aligned}\text{Impedance of 21}^{\text{st}} \text{ harmonic (Z}_{21}) &= \sqrt{R^2 + X_{21}^2} \\ &= \sqrt{10^2 + (21 \times 6.28)^2} = 132.25 \Omega\end{aligned}$$

$$Z_{19} = \sqrt{10^2 + (19 \times 6.28)^2} = 119.7 \Omega$$

$$Z_{23} = \sqrt{10^2 + (23 \times 6.28)^2} = 144.78 \Omega$$

$$\text{RMS value of 21}^{\text{st}} \text{ harmonic} = I_{21} = \frac{V_{21}}{Z_{21}}$$

$$I_{21} = \frac{115.9}{132.25} = 0.8763 \text{ A}$$

$$I_{19} = \frac{V_{19}}{Z_{19}} = \frac{31.31}{119.7} = 0.2615 \text{ A}$$

$$I_{23} = \frac{V_{23}}{Z_{23}} = \frac{31.31}{144.78} = 0.216 \text{ A}$$

$$\text{RMS value of current} = \sqrt{I_1^2 + I_{19}^2 + I_{21}^2 + I_{23}^2}$$

$$= \sqrt{9.59^2 + 0.2615^2 + 0.8763^2 + 0.216^2}$$

$$I_{\text{or}} = 9.636 \text{ A}$$

$$\text{Total harmonic distortion} = \frac{\sqrt{I_{\text{or}}^2 - I_1^2}}{I_1} \times 100\% = \frac{\sqrt{9.636^2 - 9.59^2}}{9.59} \times 100\% = 9.79\%$$

**6(c) Design a circuit that takes as input two 2-bit numbers,  $N_1$  and  $N_2$  for comparison and generates three outputs:**

**$N_1 = N_2$ ,  $N_1 < N_2$  and  $N_1 > N_2$ . These three binary outputs are represented by  $F_{\text{eq}}$ ,  $F_{\text{lt}}$  and  $F_{\text{gt}}$  respectively. Realize the output in Sum of Products (SoP) form. 20**

**Sol:** Let us consider  $N_1$  is  $A_1 A_0$  &  $N_2$  is  $B_1 B_0$

| 0  | $A_1$ | $A_0$ | $B_1$ | $B_0$ | $F_{\text{eq}}$ | $F_{\text{lt}}$ | $F_{\text{gt}}$ |
|----|-------|-------|-------|-------|-----------------|-----------------|-----------------|
| 0  | 0     | 0     | 0     | 0     | 1               | 0               | 0               |
| 1  | 0     | 0     | 0     | 1     | 0               | 1               | 0               |
| 2  | 0     | 0     | 1     | 0     | 0               | 1               | 0               |
| 3  | 0     | 0     | 1     | 1     | 0               | 1               | 0               |
| 4  | 0     | 1     | 0     | 0     | 0               | 0               | 1               |
| 5  | 0     | 1     | 0     | 1     | 1               | 0               | 0               |
| 6  | 0     | 1     | 1     | 0     | 0               | 1               | 0               |
| 7  | 0     | 1     | 1     | 1     | 0               | 1               | 0               |
| 8  | 1     | 0     | 0     | 0     | 0               | 0               | 1               |
| 9  | 1     | 0     | 0     | 1     | 0               | 0               | 1               |
| 10 | 1     | 0     | 1     | 0     | 1               | 0               | 0               |
| 11 | 1     | 0     | 1     | 1     | 0               | 1               | 0               |
| 12 | 1     | 1     | 0     | 0     | 0               | 0               | 1               |
| 13 | 1     | 1     | 0     | 1     | 0               | 0               | 1               |
| 14 | 1     | 1     | 1     | 0     | 0               | 0               | 1               |
| 15 | 1     | 1     | 1     | 1     | 1               | 0               | 0               |

$$F_{eq} = \sum m (0, 5, 10, 15)$$

$$F_{it} = \sum m (1, 2, 3, 6, 7, 11)$$

$$F_{gt} = \sum m (4, 8, 9, 12, 13, 14)$$

| A <sub>1</sub> A <sub>0</sub> | B <sub>1</sub> B <sub>0</sub> |    |    |    |
|-------------------------------|-------------------------------|----|----|----|
|                               | 00                            | 01 | 11 | 10 |
| 00                            | 1                             |    |    |    |
| 01                            |                               | 1  |    |    |
| 11                            |                               |    | 1  |    |
| 10                            |                               |    |    | 1  |

$$F_{eq} = \bar{A}_1 \bar{A}_0 \bar{B}_1 \bar{B}_0 + \bar{A}_1 A_0 \bar{B}_1 \bar{B}_0 + A_1 A_0 B_1 B_0 + A_1 \bar{A}_0 B_1 \bar{B}_0$$

| A <sub>1</sub> A <sub>0</sub> | B <sub>1</sub> B <sub>0</sub> |    |    |    |
|-------------------------------|-------------------------------|----|----|----|
|                               | 00                            | 01 | 11 | 10 |
| 00                            | 1                             | 1  | 1  |    |
| 01                            |                               | 1  | 1  |    |
| 11                            |                               |    |    |    |
| 10                            |                               |    |    | 1  |

$$F_1 = \bar{A}_1 B_1 + \bar{A}_1 \bar{A}_0 B_0 + \bar{A}_0 B_1 B_0$$

| A <sub>1</sub> A <sub>0</sub> | B <sub>1</sub> B <sub>0</sub> |    |    |    |
|-------------------------------|-------------------------------|----|----|----|
|                               | 00                            | 01 | 11 | 10 |
| 00                            |                               |    |    |    |
| 01                            | 1                             |    |    |    |
| 11                            | 1                             | 1  |    | 1  |
| 10                            | 1                             | 1  |    |    |

$$F_{gt} = A_1 \bar{B}_1 = A_0 \bar{B}_1 \bar{B}_0 + A_1 A_0 \bar{B}_0$$



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|---------------|-----------------------------------------|---------------------------|---------------|-------------|
| Regular Batch | Six Days a Week<br>6 to 8 Hours Per Day | 8 <sup>th</sup> July 2019 | 5 to 6 Months | @ Bengaluru |

### INTEGRATED PROGRAM GATE + PSUs – 2021

| Type of Batch | Timings                                  | Date                        | Duration        | Venue       |
|---------------|------------------------------------------|-----------------------------|-----------------|-------------|
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**7(a) For a causal system specified by the transfer function**

$$H(z) = \frac{z}{z - 0.5}$$

**Determine the zero state response to the input**

$$r(k) = (0.8)^k u(k) + (2)^{k+1} u\{-(k+1)\}.$$

**20**

**Sol:**  $H(z) = \frac{z}{z - 0.5}$  ROC of  $H(z)$  is  $|z| > 0.5$

Input  $r(k) = (0.8)^k u(k) + (2)^{k+1} u\{-(k+1)\}.$

$$\begin{array}{ccc} \downarrow & & \downarrow \\ |z| > 0.8 & & |z| < 2 \end{array}$$

Input ROC:  $0.8 < |z| < 2$ , ROC of  $H(z)$  is  $|z| > 0.5$

$\therefore$  ROC of  $Y(z) = 0.8 < |z| < 2$

$$a^n u(n) \leftrightarrow \frac{1}{1 - az^{-1}} ; |z| > |a|$$

$$-a^n u(-n-1) \leftrightarrow \frac{1}{1 - az^{-1}} ; |z| < |a|$$

Input  $r(k) = (0.8)^k u(k) + (2)^{k+1} u\{-(k+1)\}.$

$\downarrow$  Z.T

$$\begin{aligned} R(z) &= \frac{1}{1 - 0.8z^{-1}} - \frac{2}{1 - 2z^{-1}} ; 0.8 < |z| < 2 \\ &= \frac{1 - 2z^{-1} - 2 + 1.6z^{-1}}{(1 - 0.8z^{-1})(1 - 2z^{-1})} \\ &= \frac{-1 - 0.4z^{-1}}{(1 - 0.8z^{-1})(1 - 2z^{-1})} \end{aligned}$$

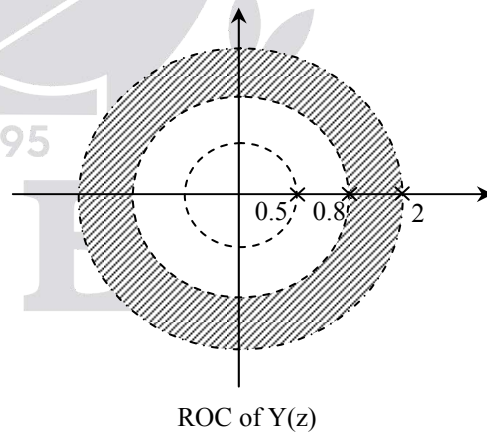
$Y(z) = R(z)H(z)$ ; ROC:  $0.8 < |z| < 2$

$$\begin{aligned} Y(z) &= \frac{-1 - 0.4z^{-1}}{(1 - 0.8z^{-1})(1 - 2z^{-1})(1 - 0.5z^{-1})} \\ &= \frac{A}{1 - 0.5z^{-1}} + \frac{B}{1 - 2z^{-1}} + \frac{C}{1 - 0.8z^{-1}} \end{aligned}$$

By partial fractions,  $A = \frac{8}{3}$ ,  $B = \frac{-8}{3}$ ;  $C = -1$

Inverse Z-transform of  $Y(z)$

$$y(n) = \frac{8}{3} (0.8)^n u(n) - \frac{8}{3} (2)^n [-u(-n-1)] - (0.5)^n u(n)$$



# ESE / GATE / PSUs 2020 - 2021

## ADMISSIONS OPEN

### GATE + PSUs - 2020

|                                            |                                                                                           |
|--------------------------------------------|-------------------------------------------------------------------------------------------|
| Regular Batches @ <b>Dilsukhnagar</b>      | 08 <sup>th</sup> & 22 <sup>nd</sup> July, 05 <sup>th</sup> & 20 <sup>th</sup> August 2019 |
| Regular Batch @ <b>Kukatpally</b>          | 01 <sup>st</sup> July 2019                                                                |
| Regular Batches @ <b>Pune</b>              | 01 <sup>st</sup> & 15 <sup>th</sup> July 2019                                             |
| Weekend & Regular Batches @ <b>Chennai</b> | 06 <sup>th</sup> July 2019                                                                |
| Regular Batch @ <b>Bengaluru</b>           | 08 <sup>th</sup> July 2019                                                                |

### ESE + GATE + PSUs - 2020

|                                     |                            |
|-------------------------------------|----------------------------|
| Regular Batch @ <b>Dilsukhnagar</b> | 08 <sup>th</sup> July 2019 |
| Regular Batch @ <b>Pune</b>         | 01 <sup>st</sup> July 2019 |

### GATE + PSUs - 2021

|                                                 |                                                      |
|-------------------------------------------------|------------------------------------------------------|
| Morning Batches @ <b>Abids</b>                  | 12 <sup>th</sup> July & 10 <sup>th</sup> August 2019 |
| Morning & Evening Batches @ <b>Dilsukhnagar</b> | 12 <sup>th</sup> July & 10 <sup>th</sup> August 2019 |
| Morning & Evening Batches @ <b>Kukatpally</b>   | 12 <sup>th</sup> July & 10 <sup>th</sup> August 2019 |
| Weekend Batches @ <b>Pune</b>                   | 6 <sup>th</sup> July & 17 <sup>th</sup> August 2019  |
| Weekend Batch @ <b>Chennai</b>                  | 6 <sup>th</sup> July 2019                            |
| Weekend Batch @ <b>Bengaluru</b>                | 3 <sup>rd</sup> August 2019                          |
| Weekend Batch @ <b>Vijayawada</b>               | 7 <sup>th</sup> July 2019                            |
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| Weekend Batch @ <b>Vizag</b>                    | 20 <sup>th</sup> July 2019                           |

### ESE + GATE + PSUs - 2021

|                                |                                                      |
|--------------------------------|------------------------------------------------------|
| Morning Batches @ <b>Abids</b> | 12 <sup>th</sup> July & 10 <sup>th</sup> August 2019 |
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### IES GENERAL STUDIES BATCH

|                              |                            |
|------------------------------|----------------------------|
| Regular Batch @ <b>Abids</b> | 12 <sup>th</sup> July 2019 |
| Weekend Batch @ <b>Pune</b>  | 13 <sup>th</sup> July 2019 |

### GENCO / TRANSO / DISCOMS BATCH

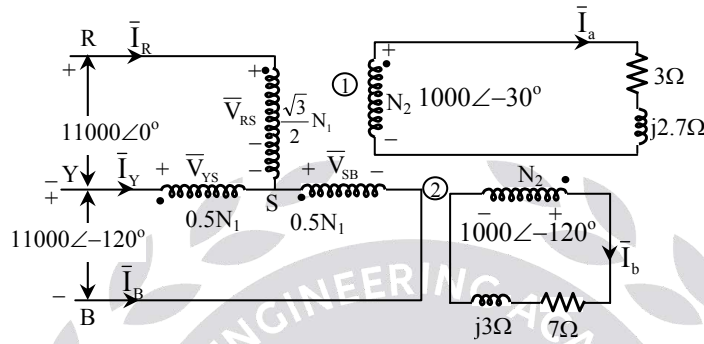
|                              |                            |
|------------------------------|----------------------------|
| Regular Batch @ <b>Abids</b> | 14 <sup>th</sup> July 2019 |
|------------------------------|----------------------------|

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**7(b) An unbalanced 2- $\phi$ , 1000 V, 50 Hz induction motor has unequal winding impedances  $Z_a = 3 + j2.7$  and  $Z_b = 7 + j3 \Omega$ . This motor is supplied by Scott-connected transformer combination from a 3-phase 11 kV system. Calculate phase currents  $I_a$  and  $I_b$  of the motor and line currents on 3-phase supply side.**

**20**

**Sol:**



$$\bar{V}_{RS} - \bar{V}_{YS} = 11000 \angle 0^\circ$$

$$\bar{V}_{YS} = \bar{V}_{SB} = \frac{11000}{2} \angle -120^\circ$$

$$\begin{aligned} \bar{V}_{RS} &= 11000 \angle 0^\circ + \frac{11000}{2} \angle -120^\circ \\ &= \frac{\sqrt{3}}{2} 11000 \angle -30^\circ \end{aligned}$$

$$\left[ \frac{\sqrt{3}}{2} \times 11000 \angle -30^\circ \right] \frac{N_2}{\frac{\sqrt{3}}{2} N_1} = 1000 \angle -30^\circ$$

$$\frac{N_2}{N_1} = \frac{1}{11}$$

**Motor phase currents:**

$$\bar{I}_a = \frac{1000 \angle -30^\circ}{3 + j2.7} = 247.8 \angle -72^\circ \text{ A}$$

$$\bar{I}_b = \frac{1000 \angle -120^\circ}{7 + j3} = 131.3 \angle -143.2^\circ \text{ A}$$

**Transformer currents::**

$$\bar{I}_R = \frac{2}{\sqrt{3}} \frac{1}{11} (247.8 \angle -72^\circ) = 26 \angle -72^\circ \text{ A} \dots\dots\dots(1)$$

$$\bar{I}_Y \left( \frac{N_1}{2} \right) - \bar{I}_B \left( \frac{N_1}{2} \right) = \bar{I}_b N_2$$

$$\begin{aligned} \bar{I}_Y - \bar{I}_B &= \bar{I}_b N_2 \left( \frac{2}{N_1} \right) \\ &= \frac{2}{11} \bar{I}_b = \frac{2}{11} 131.3 \angle -143.2^\circ \text{ A} \end{aligned}$$

$$\bar{I}_Y - \bar{I}_B = 23.8 \angle -143.2^\circ \dots\dots\dots(2)$$

$$\bar{I}_R + \bar{I}_Y + \bar{I}_B = 0 \dots\dots\dots(3)$$

From (1) & (3)

$$\bar{I}_Y + \bar{I}_B = -26 \angle -72^\circ = 26 \angle 108^\circ$$

By solving equations (2) & (3)

$$\bar{I}_Y = 14.5 \angle 158.8^\circ \text{ A}$$

$$\bar{I}_B = 20.25 \angle 74.2^\circ \text{ A}$$

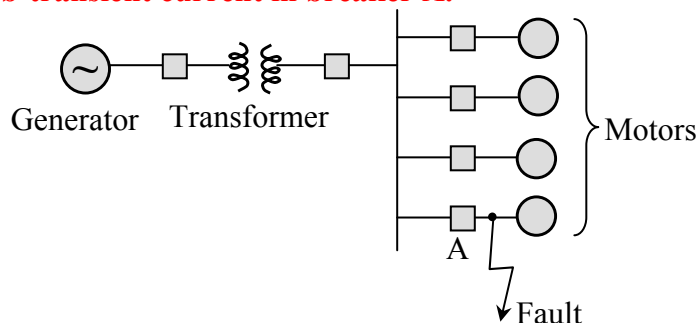
$$\bar{I}_R = 26 \angle -72^\circ \text{ A}$$

**7(c) A 25 MVA, 13.8 kV generator with  $x_d'' = 15\%$  is connected through a 25 MVA, 13.8/6.9 kV transformer with leakage reactance of 10% to a bus which supplied four identical motors as shown in the figure. The sub-transient reactance  $X_d''$  of each motor is 20% on base of 5 MVA, 6.9 kV. Find**

**(i) The sub-transient current in the fault, and**

**(ii) The sub-transient current in breaker A.**

**20**

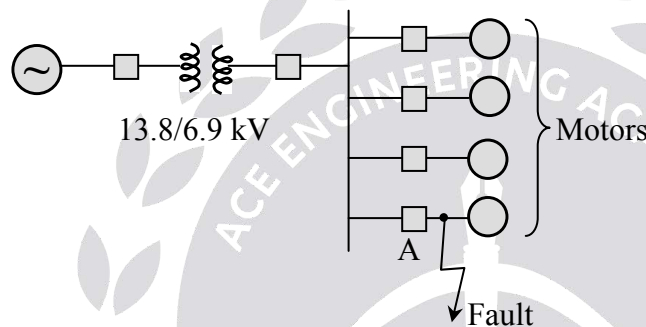


**Sol:** Given,

|              | <b>VA-rating</b> | <b>V-rating</b> | <b>X''</b> |
|--------------|------------------|-----------------|------------|
| Generator:   | 25 MVA           | 13.8 kV         | 15%        |
| Transformer: | 25 MVA           | 13.8 kV/6.9 kV  | 10%        |
| Motor:       | 5 MVA            | 6.9 kV          | 20%        |

Network is:

$S_B = 25 \text{ MVA}$        $S_B = 25 \text{ MVA}$   
 $V_B = 13.8 \text{ kV}$        $V_B = 6.9 \text{ kV}$       base quantities



let  $S_B = 25 \text{ MVA}$   
 $V_B = 13.8 \text{ kV}$  } @ generator

The corresponding bases at other locations of power system shown above is represented on the circuit. For generator and transformer, base and rated quantities are same hence their pu reactances do not change. But for motor rated and base powers are not same. Hence for motor, new values of reactances should be calculated in its new values by using the formula.

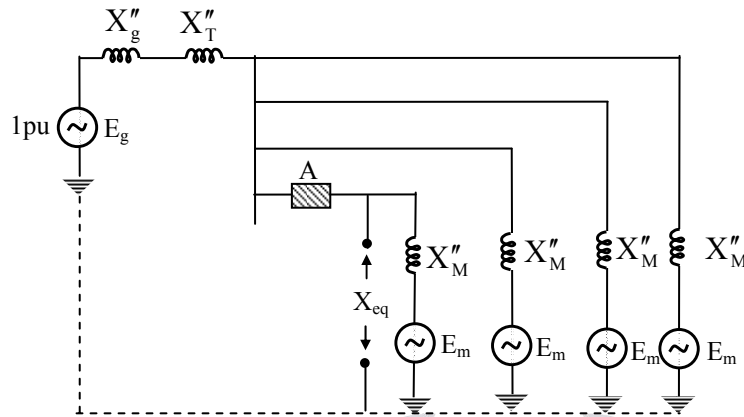
$$X_m(\text{new}) = X_m(\text{old}) \cdot \frac{S_{\text{new}}}{S_{\text{old}}}$$

$$= 20 \cdot \frac{(25)}{5}$$

$$X_m(\text{new}) = 100\% = 1 \text{ pu}$$

Hence the reactances of motor adjusted in the new base of  $S_B = 25 \text{ MVA}$  is 100%

Reactance diagram as seen from fault is (voltage sources are replaced by their equivalent reactance)



As seen from fault location equivalent reactance is

$$X_{eq} = (X_g'') \parallel (X_T'') \parallel (X_M'') \parallel (X_M'') \parallel (X_M'')$$

$$= (1) \parallel (1) \parallel (1) \parallel (1) \parallel (0.15 + 0.1)$$

$$X_{eq} = 0.125$$

$$\Rightarrow I_f (\text{pu}) (\text{fault current}) = \frac{1}{X_{eq}} = \frac{1}{0.125} = 8 \text{ pu}$$

$$I_f (\text{pu}) = 8 \text{ pu}$$

$\Rightarrow$  At motor location,

$$I_B (\text{base}) = \frac{S_B}{\sqrt{3} V_3} = \frac{25 \times 10^6}{\sqrt{3} \times 6.9 \times 10^3} = 2.092 \text{ kA}$$

$$\Rightarrow I_f (\text{actual}) = I_f (\text{pu}) \times I_B$$

$$= 8 \times 2.092$$

$$I_f (\text{actual}) = 16.73 \text{ kA}$$

$$\Rightarrow I_A = I_f - I_m = 8 - \frac{1}{1} = 7 \text{ pu}$$

$$I_A = 7 \text{ pu}$$

$\therefore$  Current through circuit breaker A is

$$I_A = 7 \times 2.092 = 14.64 \text{ kA}$$





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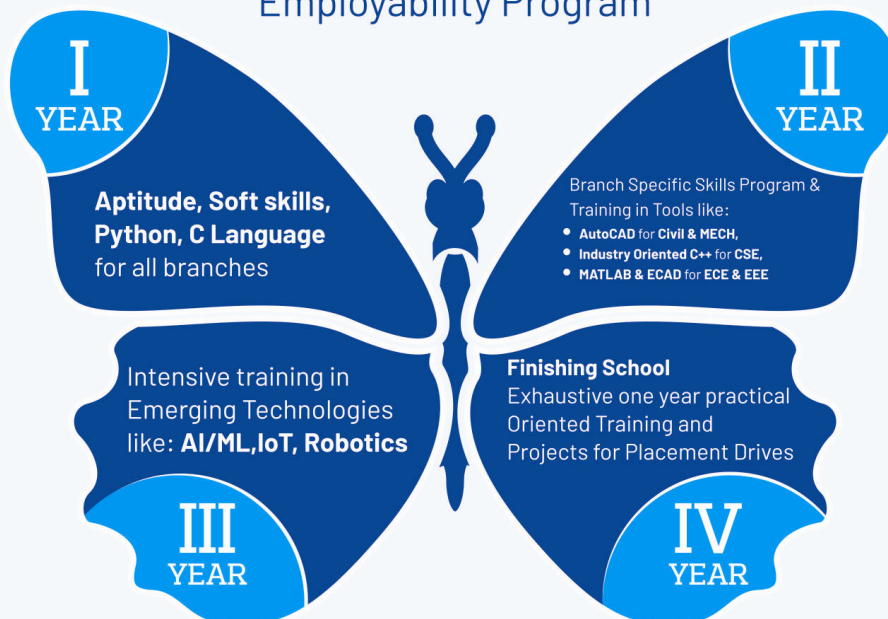


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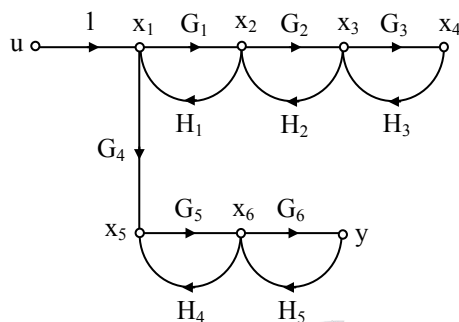
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**8(a) Find the transfer function  $\frac{Y(s)}{U(s)}$  using Mason's Gain formula. Also find  $\frac{X_5(s)}{U(s)}$ .**

**20**



**Sol:** Number of forward paths from  $U(s)$  to  $Y(s) = 1$

Number of Loops = 5

Two non touching loops = 7

Three non touching loops = 2

$$\frac{Y(s)}{U(s)} = \frac{M_1 \Delta_1}{\Delta}$$

Forward path gain

$$M_1 = G_4 G_5 G_6$$

Loops  $L_1 = G_1 H_1$

$$L_2 = G_2 H_2$$

$$L_3 = G_3 H_3$$

$$L_4 = G_5 H_4$$

$$L_5 = G_6 H_5$$

Two non touching loops =  $L_1 L_3 = G_1 H_1 G_3 H_3$

$$L_1 L_4 = G_1 H_1 G_5 H_4$$

$$L_1 L_5 = G_1 H_1 G_6 H_5$$

$$L_2 L_4 = G_2 H_2 G_5 H_4$$

$$L_2 L_5 = G_2 H_2 G_6 H_5$$

$$L_3 L_4 = G_3 H_3 G_5 H_4$$

$$L_3 L_5 = G_3 H_3 G_6 H_5$$

The non touch loops =  $L_1 L_3 L_4 = G_1 H_1 G_3 H_3 G_5 H_4$

$$L_1 L_3 L_5 = G_1 H_1 G_3 H_3 G_6 H_5$$

Four, five etc... non touching loops do not exist

$$\therefore \Delta = 1 - (L_1 + L_2 + L_3 + L_4 + L_5) + (L_1 L_3 + L_1 L_4 + L_1 L_5 +$$

$$L_2 L_4 + L_2 L_5 + L_3 L_4 + L_3 L_5) - (L_1 L_3 L_4 + L_1 L_3 L_5)$$

$$\Delta = 1 - (G_1 H_1 + G_2 H_2 + G_3 H_3 + G_5 H_4 + G_6 H_5) + (G_1 H_1 G_3 H_3 + G_1 H_1 G_5 H_4 + G_1 H_1 G_6 H_5 +$$

$$G_2 H_2 G_5 H_4 + G_2 H_2 G_6 H_5 + G_3 H_3 G_5 H_4 + G_3 H_3 G_6 H_5) - (G_1 H_1 G_3 H_3 G_5 H_4 + G_1 H_1 G_3 H_3 G_6 H_5)$$

$$\Delta_1 = 1 - (L_2 + L_3)$$

$$\Delta_1 = 1 - (G_2 H_2 + G_3 H_3)$$

$$\frac{Y(s)}{U(s)} = \frac{M_1 \Delta_1}{\Delta}$$

$$= \frac{G_4 G_3 G_6 (1 - (G_2 H_2 + G_3 H_3))}{1 - (G_1 H_1 + G_2 H_2 + G_3 H_3 + G_5 H_4 + G_6 H_5) + (G_1 H_1 G_3 H_3 + G_1 H_1 G_5 H_4 + G_1 H_1 G_6 H_5 + G_2 H_2 G_5 H_4 + G_2 H_2 G_6 H_5 + G_3 H_3 G_5 H_4 + G_3 H_3 G_6 H_5) - (G_1 H_1 G_3 H_3 G_5 H_4 + G_1 H_1 G_3 H_3 G_6 H_5)}$$

Number of forward paths from U(s) to X<sub>5</sub>(s) = 1

$$\frac{X_5(s)}{U(s)} = \frac{M_1 \Delta_1}{\Delta}$$

Where  $M_1 = G_4$

$$\Delta_1 = 1 - (L_2 + L_3 + L_5) + (L_2 L_5 + L_3 L_5)$$

$$= 1 - (G_2 H_2 + G_3 H_3 + G_6 H_5) + (G_2 H_2 G_6 H_5 + G_3 H_3 G_6 H_5)$$

$$\frac{X_5(s)}{U(s)} = \frac{G_4 (1 - (G_2 H_2 + G_3 H_3 + G_6 H_5) + (G_2 H_2 G_6 H_5 + G_3 H_3 G_6 H_5))}{1 - (G_1 H_1 + G_2 H_2 + G_3 H_3 + G_5 H_4 + G_6 H_5) + (G_1 H_1 G_3 H_3 + G_1 H_1 G_5 H_4 + G_1 H_1 G_6 H_5 + G_2 H_2 G_5 H_4 + G_2 H_2 G_6 H_5 + G_3 H_3 G_5 H_4 + G_3 H_3 G_6 H_5) - (G_1 H_1 G_3 H_3 G_5 H_4 + G_1 H_1 G_3 H_3 G_6 H_5)}$$





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|                             |                              |                                   |                                  |                                |
|-----------------------------|------------------------------|-----------------------------------|----------------------------------|--------------------------------|
| AIR 1<br>PRADIP SINGH<br>CE | AIR 1<br>KIRAN KARANNA<br>PI | AIR 1<br>RAJAT SONI<br>EC         | AIR 1<br>PRANAV SHARMA<br>CSIT   | AIR 1<br>SHASHANK MANOJ<br>IN  |
| AIR 2<br>KUNAL G<br>EE      | AIR 2<br>MURDER POKHRA<br>EE | AIR 2<br>ARAND RISHY GEORGE<br>EC | AIR 2<br>PRITANVA GUPTA<br>IN    | AIR 2<br>VISHAY SINGH<br>PI    |
| AIR 3<br>ANANT KUMAR<br>ME  | AIR 3<br>MOHIT MANOHAR<br>CE | AIR 3<br>SUDHANU MALHOTRA<br>EC   | AIR 3<br>PRATEEK KADWANI<br>CSIT | AIR 3<br>VINEET GOUDWALA<br>IN |
| AIR 3<br>ROHIT KUMAR<br>PI  |                              |                                   |                                  |                                |

and many more...

**OUR ESE - 2018 TOP RANKERS**

|                          |                           |                             |                          |
|--------------------------|---------------------------|-----------------------------|--------------------------|
| AIR 1<br>SHASHANK<br>E&T | AIR 1<br>CHIRAG JHA<br>EE | AIR 1<br>VINAY PRANAV<br>CE | AIR 1<br>AMAN JAIN<br>ME |
|--------------------------|---------------------------|-----------------------------|--------------------------|

and many more...

**TOTAL SELECTIONS : 350 | E&T : 89 | EE : 80 | CE : 92 | ME : 89**

**HEAD OFFICE**

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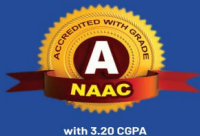


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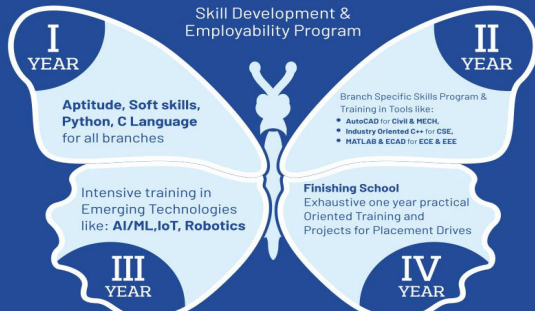
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B.Tech (UG) CSE\* 180 ECE\* 180 CIVIL 120 MECH\* 120 EEE\* 60 IT\*\* 60

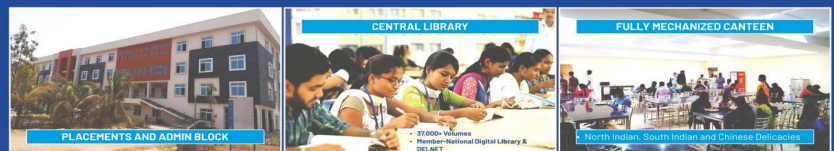
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Department Technical Clubs: • CIVIL-Spanzors • EEE-Phasors • MECH-Mechazays • ECE-Tektronix • CSE-Cybernetics



**OUR EMINENT RECRUITERS (A.Y. 2018-19)**

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- Wipro - 18
- Amazon - 16
- Cognizant - 13
- Cyient - 03
- Xiaomi - 31
- Mu Sigma - 01
- Hitachi - 02
- AAIC - 05
- Infosys - 01
- Optum - 03

and many more..

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- Microsoft Innovation Centre
- TCS-ION Program
- HCL Technologies Pvt.Ltd.
- Larsen Toubro (L&T)
- Cyient
- Aspiring Minds
- CoCubes
- eLitmus
- TASK

and many more..



**8(b) A 440 V, 50 Hz, 6-pole, Y-connected induction motor has following parameters per phase referred to the stator:**

$$R_s = R'_r = 0.3 \Omega, X_s = X'_r = 1.0 \Omega \text{ and } X_m = 40 \Omega$$

**The nominal full load slip is 0.05.**

**The motor is to be braked by plugging from its initial full load condition. Determine initial braking torque without braking resistor ( $R_B$ ).**

**Also find the value of  $R_B$  so that braking current is limited to 1.5 times the full load current.**

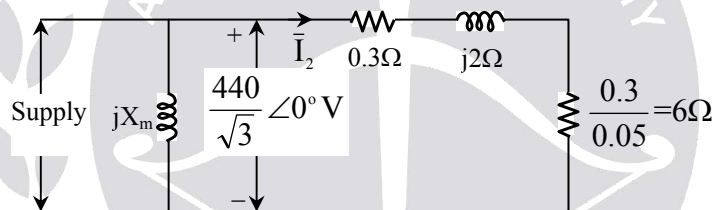
**What will be the corresponding braking torque as a ratio of full load torque?**

**Note: Assume braking resistor  $R_B$  is connected to rotor circuit.**

**20**

**Sol:** 6-pole, 50 Hz  $\rightarrow \omega_s = \frac{4\pi f}{P} = \frac{4\pi \times 50}{6} = \frac{100\pi}{3}$  mech rad/sec

From given data, approximate equivalent circuit per phase (without  $R_b$ ) is shown below.



$$I_2 = \frac{440}{\sqrt{3} \sqrt{6.3^2 + 4}} = 38.43 \text{ A}$$

$$\text{Corresponding developed torque (}= \text{load torque)} = \frac{3 \times 38.43^2 \times 6 \times 3}{100\pi} = 253.9 \text{ N-m}$$

Now two of the supply lines are interchanged, reversing the direction of rotation of the stator mmf. (This is called plugging). The rotor now quickly comes to a stop, when the supply is to be removed.

Immediately after plugging, slip = 2 – 0.05 = 1.95.

New developed torque (which opposes rotor rotation)

$$= \frac{3 \times \left( \frac{440}{\sqrt{3}} \right)^2 (0.3) \times 3}{1.95 \times 100 \left[ \left( 0.3 + \frac{0.3}{1.95} \right)^2 + 4 \right]} = \frac{440^2 \times 0.9}{195(4.2)} = 212.7 \text{ N-m}$$

Load torque opposes rotation, as always

Total braking torque = 212.7 + 253.9 = 466.6 N-m

**Braking resistance  $R_b$  introduced into the rotor circuit at the same instant as plugging:**

Before plugging,  $T_d = \text{load torque} = 253.9 \text{ N-m}$

Immediately after plugging, slip changes to 1.95, as before.

$$\text{New rotor current} = \frac{\left(\frac{440}{\sqrt{3}}\right)}{\sqrt{\left(0.3 + \frac{0.3 + R_b}{1.95}\right)^2 + 4}} = 1.5 \times 38.43 = 57.65 \text{ A (given)}$$

$R_b$  can be found from the above and works out to  $6.8 \Omega$ .

New developed torque (which opposes rotation)

$$= \frac{3 \times 57.65^2 \times 7.1 \times 3}{1.95 \times 100\pi} = 346.7 \text{ N-m.}$$

Adding the load torque, which also opposes rotation, total braking torque =  $346.7 + 253.9 = 600 \text{ N-m}$ .  
(Adding  $R_b$  both reduces the rotor current as well as increases braking torque).

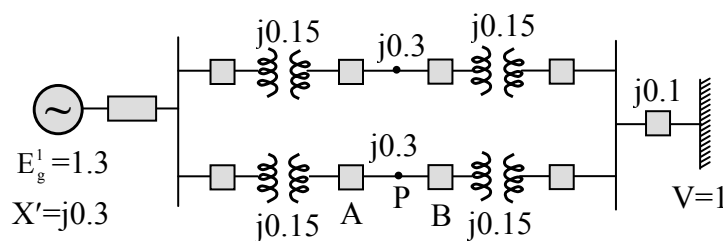
**8(c) A generator is connected by a double line to an infinite bus, the voltage of which is  $V = 1 \text{ pu}$  as shown in the figure. Per unit values of reactances and voltages are indicated in the figure. A three-phase short circuit occurs at the point P. The circuit breakers A and B open simultaneously and remain open. The mechanical power supplied to the generator before the fault is  $P_m = 1 \text{ pu}$ .**

**(i) Determine the electrical powers  $P_{e1}$ ,  $P_{e2}$  and  $P_{e3}$  before, during and post the fault**

**(ii) Draw on the same graph, power angle curve for  $P_{e1}$ ,  $P_{e2}$  and  $P_{e3}$ .**

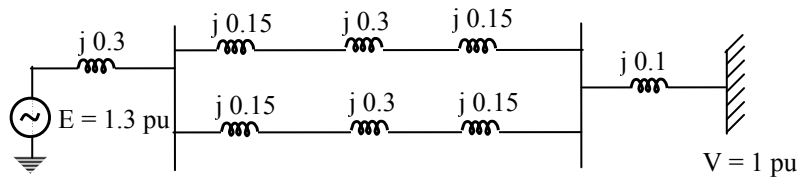
**(iii) Calculate the angles  $\delta_0$ ,  $\delta_1$  and  $\delta_{\max}$  where  $\delta_0$  is the initial power angle,  $\delta_1$  is the post fault power angle and  $\delta_{\max}$  is the maximum power angle.**

20





**Sol: (i) Before fault: (Reactance diagram)**



$$P_{e_1} = \frac{EV}{X_{eq1}}$$

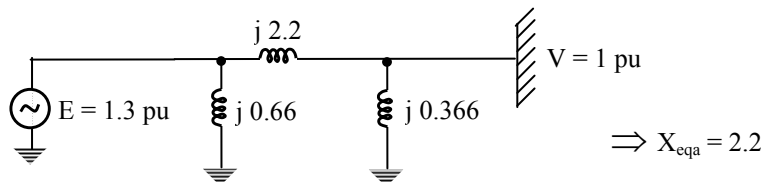
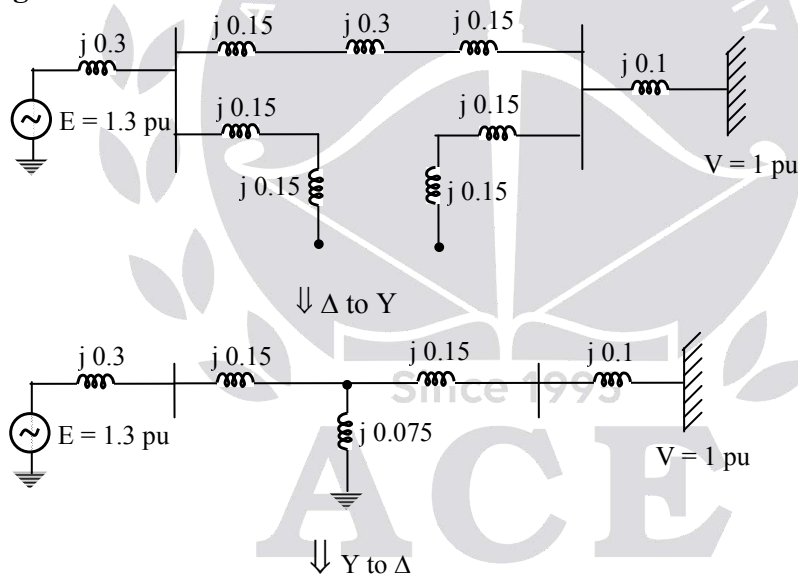
$$P_{e_1} = \frac{1.3 \times 1}{0.7}$$

$$P_{e_1} = 1.857$$

$$X_{eq1} = 0.3 + (0.15 + 0.3 + 0.15) \parallel (0.15 + 0.3 + 0.15) + 0.1$$

$$X_{eq1} = 0.7$$

**During fault:**



$$P_{e_2} = \frac{EV}{X_{eq2}} = \frac{1.3 \times 1}{2.2} = 0.591 \text{ pu}$$

$$P_{e_2} = 0.591 \text{ pu}$$

**Post fault:**

$$P_{e_3} = \frac{EV}{X_{eq3}}$$

$$P_{e_3} = \frac{1.3 \times 1}{1}$$

$$P_{e_3} = 1.3$$

$$X_{eq3} = 0.3 + (0.15 + 0.3 + 0.15) + 0.1$$

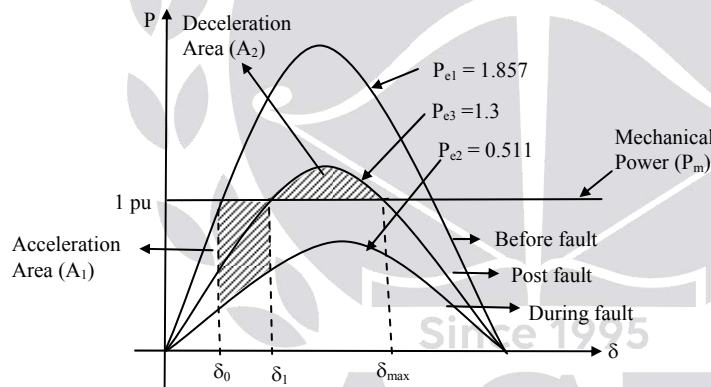
$$X_{eq3} = 1 \text{ pu}$$

$$\therefore P_{e_1} = 1.857$$

$$P_{e_2} = 0.591$$

$$P_{e_3} = 1.3$$

(ii)



(iii)  $P_{e_1} \sin \delta_0 = P_m$

$$1.857 \sin \delta_0 = 1$$

$$\delta_0 = 32.58^\circ$$

$$P_{e_3} \sin \delta_1 = P_m$$

$$1.3 \sin \delta_1 = 1$$

$$\delta_1 = 50.3^\circ$$

$$\delta_{\max} = 180^\circ - \delta_1$$

$$\delta_{\max} = 129.7^\circ$$



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## Hearty Congratulations to our **GATE-2019 Toppers**

|                                          |                                       |                                      |                                       |                                            |                                       |                                        |                                             |                                          |                                         |                                        |                                      |
|------------------------------------------|---------------------------------------|--------------------------------------|---------------------------------------|--------------------------------------------|---------------------------------------|----------------------------------------|---------------------------------------------|------------------------------------------|-----------------------------------------|----------------------------------------|--------------------------------------|
|                                          | <b>AIR 1</b><br>PRAKASH SINGH<br>CE   | <b>AIR 1</b><br>SURYANARAYANA<br>PI  | <b>AIR 1</b><br>RAJAT SONI<br>EC      | <b>AIR 1</b><br>PRANAV SHARMA<br>CSIT      | <b>AIR 1</b><br>SHASHANK MANGAL<br>IN |                                        |                                             |                                          |                                         |                                        |                                      |
| <b>AIR 2</b><br>VINAY SELAM<br>PI        | <b>AIR 2</b><br>ANAND JERRY<br>EC     | <b>AIR 2</b><br>PRIYANKA GUPTA<br>IN | <b>AIR 2</b><br>KUNAL O<br>EE         | <b>AIR 2</b><br>MUDESH POONIA<br>EE        | <b>AIR 3</b><br>JOSHI HANMOHANA<br>CE | <b>AIR 3</b><br>ANOT KESHAB<br>ME      | <b>AIR 3</b><br>SHUBHAM NAIRYA<br>EC        | <b>AIR 3</b><br>VINET OODHAM<br>IN       | <b>AIR 3</b><br>PRATEEK ADARWAL<br>CSIT | <b>AIR 3</b><br>RISHI KHANNA<br>PI     | <b>AIR 4</b><br>SIDARTH WADHWA<br>ME |
| <b>AIR 4</b><br>CHETAN HANMOHANA<br>EC   | <b>AIR 4</b><br>CHAITANYA KUMAR<br>EC | <b>AIR 4</b><br>ARJUN K<br>IN        | <b>AIR 4</b><br>RAJ SHAWANI<br>IN     | <b>AIR 5</b><br>CHANDRI PAUL<br>ME         | <b>AIR 5</b><br>RUTVIK LATHEA<br>XE   | <b>AIR 5</b><br>AYUSH JHAM<br>PI       | <b>AIR 5</b><br>SAYANTAN BHATTACHARYA<br>EE | <b>AIR 5</b><br>PRADIP KUMAR VERMA<br>EE | <b>AIR 6</b><br>RAJ JUNEJA<br>PI        | <b>AIR 6</b><br>PRIYANSHU SHARMA<br>EC | <b>AIR 6</b><br>RAMESH KAMULA<br>IN  |
| <b>AIR 6</b><br>HARI SHRAWNGI<br>CSIT    | <b>AIR 7</b><br>CHIRAG RATHI<br>CE    | <b>AIR 7</b><br>SHREYANS MITTA<br>CE | <b>AIR 7</b><br>AMIT LAL SHARMA<br>PI | <b>AIR 7</b><br>ANUJ MEENA<br>PI           | <b>AIR 7</b><br>ANKIT KUMAR<br>EC     | <b>AIR 7</b><br>SAURAB CHOLLETTI<br>EC | <b>AIR 7</b><br>SAISH KALASKAR<br>IN        | <b>AIR 7</b><br>SHWETA YADAV<br>IN       | <b>AIR 7</b><br>DEEPTA ROY<br>EE        | <b>AIR 7</b><br>SHUBHAM MITTAL<br>EE   | <b>AIR 9</b><br>ATULYA JYOTI<br>PI   |
| <b>AIR 9</b><br>RANJIT KUMAR SINGH<br>EC | <b>AIR 9</b><br>DEEP ADWARYA<br>IN    | <b>AIR 9</b><br>B. SREKAR<br>IN      | <b>AIR 9</b><br>ARIKA RAY<br>CSIT     | <b>AIR 9</b><br>RAVI SHANKAR MEENA<br>CSIT | <b>AIR 10</b><br>ASIF KHAN<br>CE      | <b>AIR 10</b><br>MAHESH TENDON<br>ME   | <b>AIR 10</b><br>SHUBHAM PANDE<br>PI        | <b>AIR 10</b><br>MANMOHAN JORJA<br>PI    | <b>AIR 10</b><br>GARVIT GUPTA<br>XE     | <b>AIR 10</b><br>GEETH GEORGE<br>EE    | and many more...                     |

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|                                       |                                  |                                |                                  |                                    |                                    |                                  |                                   |
|---------------------------------------|----------------------------------|--------------------------------|----------------------------------|------------------------------------|------------------------------------|----------------------------------|-----------------------------------|
|                                       | <b>AIR 1</b><br>SHASHANK E&T     | <b>AIR 1</b><br>CHIRAG JHA EE  | <b>AIR 1</b><br>VINAY PRAKASH CE | <b>AIR 1</b><br>AMAN JAIN ME       |                                    |                                  |                                   |
| <b>AIR 2</b><br>CHERUKURI SAIDEEP E&T | <b>AIR 2</b><br>SHADAB AHAMAD EE | <b>AIR 2</b><br>PUNIT SINGH CE | <b>AIR 2</b><br>CHIRAG SINGLA ME | <b>AIR 3</b><br>RAMESH KAMULA E&T  | <b>AIR 3</b><br>SRILAN VARMA EE    | <b>AIR 3</b><br>PRAVEEN KUMAR CE |                                   |
| <b>AIR 3</b><br>MAYUR PATIL ME        | <b>AIR 4</b><br>JAPIT SINGH E&T  | <b>AIR 4</b><br>ANKIT GARG EE  | <b>AIR 4</b><br>AMIT KUMAR ME    | <b>AIR 5</b><br>HARENDRA KUMAR E&T | <b>AIR 5</b><br>KARTHIK KOTTURU EE | <b>AIR 5</b><br>RISHABH DUTT CE  | <b>AIR 5</b><br>VITTHAL PANDEY ME |
| ESE 2018 TOTAL SELECTIONS             |                                  | <b>347</b>                     | E & T TOTAL <b>89</b>            | E E TOTAL <b>78</b>                | C E TOTAL <b>88</b>                | M E TOTAL <b>89</b>              | & MANY MORE...                    |

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