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Important Questions for GATE 2022

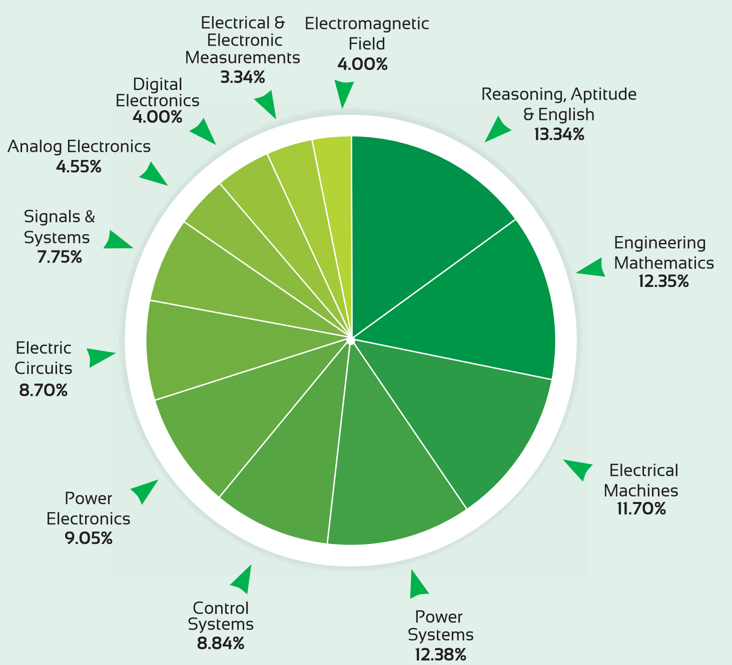
ELECTRICAL ENGINEERING

Day 2 of 8

Q.26 - Q.50 (Out of 200 Questions)

Power Systems

SUBJECT-WISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Reasoning, Aptitude & English	13.34%
Engineering Mathematics	12.35%
Electrical Machines	11.70%
Power Systems	12.38%
Control Systems	8.84%
Power Electronics	9.05%
Electric Circuits	8.70%
Signals & Systems	7.75%
Analog Electronics	4.55%
Digital Electronics	4.00%
Electrical & Electronic Measurements	3.34%
Electromagnetic Fields	4.00%
Total	**100%**

Power Systems

Q.26 A load is absorbing 150 MW power at 0.75 lagging power factor, and an overexcited synchronous motor is added to improve the pf to 0.95 lag. This motor consumes 100 kW. Then the reactive VARs supplied by the motor is ________ MVAR (Give answer upto 3 decimals)

Q.27 The total susceptance and total reactance of a lossless overhead EHV line, operating at 50 Hz are given by 1.4 p.u. and 0.025 p.u. respectively. The approximate length of the line is
(The velocity of wave propagation is 3×10^5 km/s)
(a) 146.4 km (b) 178.6 km
(c) 162.6 km (d) 152.1 km

Q.28 Two generators rated 200 MW and 400 MW are operating in parallel. The droop characteristics of their governors are 4% and 5%, respectively from no-load to full load. Assuming that generators are operating at 50 Hz at no load. If a load of 600 MW is to be shared between the two generators then the system frequency in steady state is ________ Hz.

Q.29 A 100/5 A bar primary current transformer supplies an overcurrent relay set at 25% pick up and it has a burden of 5 VA. The secondary voltage is ________V.

Q.30 A 3-core, 3-phase metal sheathed cable had a capacitance of 0.8 μF between shorted conductors and sheath, capacitance between two conductors shorted with the sheath and the third conductor is 0.4 μF. Then the capacitance (in μF) between any two conductors is
(a) 0.1 (b) 0.2667
(c) 0.0666 (d) 0.1333

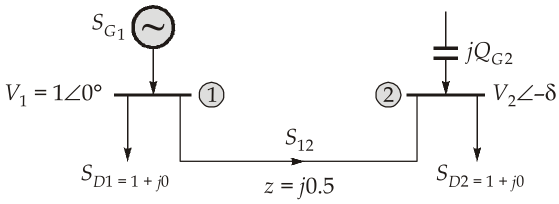
Q.31 A single core cable 1 km long has a core diameter of 0.4 cm and diameter under sheath 1.6 cm. The relative permittivity of the insulating material is 4. The power factor on open circuit is 0.08 and the supply voltage is 11 kV, 50 Hz. Then the dielectric loss is
(a) 80.7 W (b) 488.28 W
(c) 161.4 W (d) 2014.7 W

Q.32 A balanced star connected load takes 100 A from a balance 3 – ϕ, 4-wire supply. The symmetrical components of the line currents I_{R0}, I_{R1} and I_{R2} are respectively
(a) 0, 100 and 0 (b) 100, 0 and 0
(c) 0, 100 and 100 (d) 100, 100 and 100

Q.33 A three-phase, 400 V/11 kV, Y-Δ connected transformer is protected by differential protection scheme. The CTs on the LV side have a current ratio of 1000/5. The CTs ratio on the HV side is ________ .

Q.34 In a string of three identical suspension insulator units supporting a transmission line conductor. If the self capacitance of each unit is denoted as C farad. The capacitance of each conductor pin to ground can be taken as 0.15 C farads. If the maximum permissible voltage per unit is 20 kV. Then the string efficiency (in percentage) is ________ .

Q.35 For the system shown in below figure, all quantities are per phase values and are in per unit. If magnitude of voltage at bus-2 is 1 p.u, then the reactive power supplied by the capacitor, Q_{G2} is _______ pu. (Answer upto three decimals)



Q.36 For the power system shown below, specification of the components are as follows:

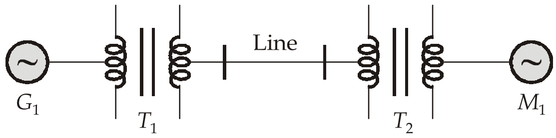
G_1 = 11 kV, 40 MVA, X = 5%

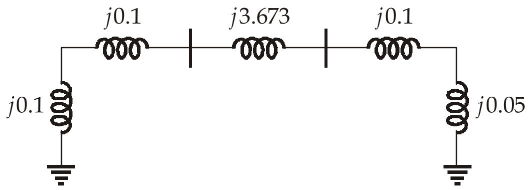
$T_1 = \dfrac{11\text{kV}}{33\text{kV}}$, 80 MVA, X = 10%; $\quad T_2 = \dfrac{33\text{kV}}{11\text{kV}}$, 80 MVA, X = 10%

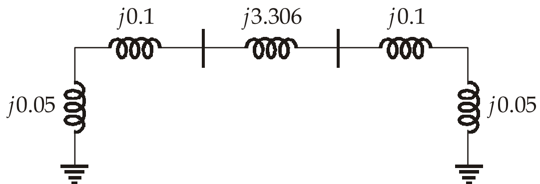
M_1 = 11 kV, 40 MVA, X = 5%

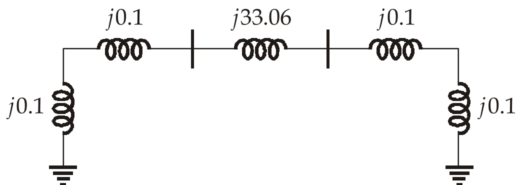
Line reactance, X = 50 Ω

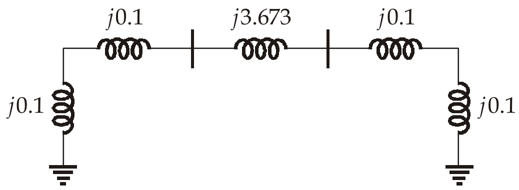
The reactance diagram on base MVA = 80 MVA is



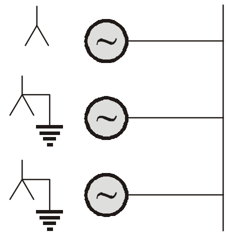
(a)


(b)


(c)


(d)


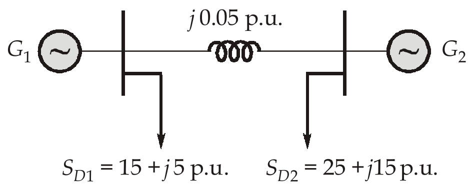
Q.37 There are three generators connected in parallel. For each generator positive, negative and zero sequence reactance are 0.5 p.u., 0.4 p.u. and 0.25 p.u. respectively. For a pre-fault voltage of 1.0 p.u., the single line to ground fault current magnitude if fault is occurred at terminals of generators is ________ p.u. (Give answer upto 3 decimals).



Q.38 A 50 Hz synchronous generator is connected to an infinite bus through a line. The per unit reactances of the generator and the line are $j0.3$ p.u. and $j0.2$ p.u. respectively. The generator no load voltage is 1.1 p.u. and that the infinite bus is 1.0 p.u. The inertia constant of the generator is 3 MW-sec/MVA.

If the generator is loaded to 60% of its maximum power transfer capacity and a small perturbation is given, then the resulting natural frequency of oscillations is _________ Hz.

Q.39 In the system shown below,



If the station loads are equalized by the flow of power in the cable and generator G_1 can generate a maximum of 20 p.u. real power, then the power factor at station 2 is _______ lagging. (Desired voltage profile is flat i.e. $|V_1| = |V_2| = 1$ p.u.)

Q.40 A 112-bus power system has 91 *PQ* buses and 20 PV buses. In the general case, to obtain the load flow solution using Newton-Raphson method in polar co-ordinates, the minimum number of simultaneous equations to be solved are

(a) 224
(b) 204
(c) 202
(d) 206

Q.41 A generator of negligible resistance having 1 p.u. voltage behind transient reactance is subjected to different types of faults when its neutral is solidly grounded.

Type of fault	Resulting fault current in p.u.
L - L	2 p.u.
L - G	3 p.u.

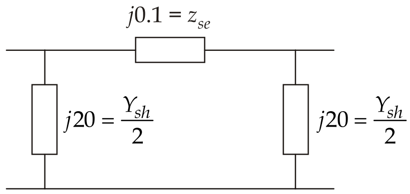
Then the value of zero sequence reactance (in p.u) is ________

Q.42 A 100 MVA, 50 Hz synchronous generator having inertia constant H = 5 kW-s/KVA on full load at unity power factor. The load is suddenly reduced to 60 MW. Due to time lag in governor system, the steam valve begins to close after 0.5 second. The change in frequency that occurs in this time is _______ Hz.

Q.43 For the 4-bus system, containing transmission lines and transformers, the admittance matrix is

$$Y_{\text{bus}} = \begin{bmatrix} -j20 & j20 & 0 & 0 \\ j20 & -j60 & j40 & 0 \\ 0 & j40 & -j60 & j20 \\ 0 & 0 & j20 & -j25 \end{bmatrix}$$

If a transmission line having π-equivalent circuit as shown below is connected between 2[nd] and 4[th] buses. Then the modified Y_{bus} matrix will be



Where, Z_{se} = series impedance of transmission line.
Y_{sh} = shunt admittance of transmission line.

(a) $\begin{bmatrix} -j20 & j20 & 0 & 0 \\ j20 & -j50 & j40 & 0 \\ 0 & j40 & -j60 & j20 \\ 0 & 0 & j20 & -j15 \end{bmatrix}$

(b) $\begin{bmatrix} -j20 & j20 & 0 & 0 \\ j20 & -j40 & j40 & 0 \\ 0 & j40 & -j60 & j20 \\ 0 & -j20 & j20 & -j15 \end{bmatrix}$

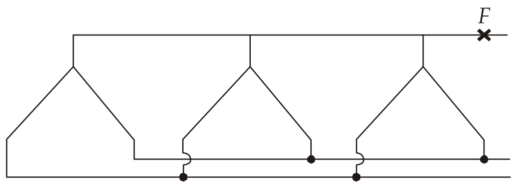
(c) $\begin{bmatrix} -j20 & j20 & 0 & 0 \\ j20 & -j50 & j40 & -j20 \\ 0 & j40 & -j60 & j20 \\ 0 & -j20 & j20 & -j15 \end{bmatrix}$

(d) $\begin{bmatrix} -j20 & j20 & 0 & 0 \\ j20 & -j40 & j40 & -j20 \\ 0 & j40 & -j60 & j20 \\ 0 & -j20 & j20 & -j5 \end{bmatrix}$

Q.44 A 50 Hz generator is delivering 60% of power that it is capable of delivering through a transmission line to an infinite bus. A fault occurs that increases the reactance between the generator and the infinite bus to 400% of the value before the fault. When fault is isolated, the maximum power that can be delivered is 75% of the original maximum value. For this condition critical clearing angle (in degrees) is

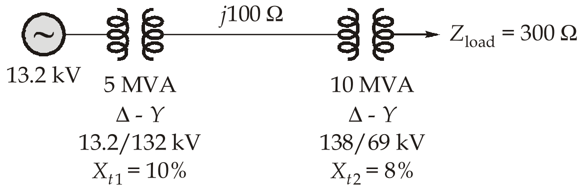
(a) 67.33°
(b) 54.17°
(c) 36.86°
(d) 51.32°

Q.45 Three 6.6 kV, 3-ϕ, 10 MVA alternators are connected to a common bus. Each alternator has a positive, negative and zero sequence reactances as 0.15 p.u., 0.1 p.u., 0.05 p.u. respectively. A single line to ground fault occurs at point *F*, as shown in figure below.



I_f is the fault current when all the alternator neutrals solidly grounded. I_f' is the fault current when only one neutral is solidly grounded and other two neutrals are isolated. Then the value of $|I_f - I_f'|$ = ________ kA.

Q.46 Consider a system with the one-line diagram shown in below figure. The three phase transformer name plate ratings are listed. The transformer reactances are given in percent, (10% = 0.1 p.u.). The transmission line and load impedances are in actual ohms. The generator terminal voltage (magnitude) is 13.2 kV (line-line) then the load voltage is ________ kV.

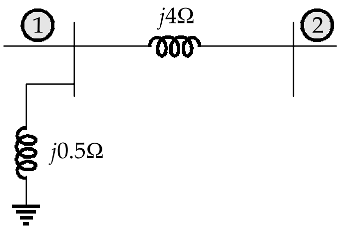


Q.47 For the Y-bus matrix of a 4-bus system given in per unit, the buses which do not have shunt elements are

$$Y_{BUS} = j\begin{bmatrix} -5 & 2.5 & 2 & 0 \\ 2.5 & -9 & 1 & 5 \\ 2 & 1 & -9 & 4 \\ 0 & 5 & 4 & -9 \end{bmatrix}$$

(a) 3 and 4 (b) 2 and 3
(c) only 2 (d) only 4

Q.48 A two bus system is as shown below,



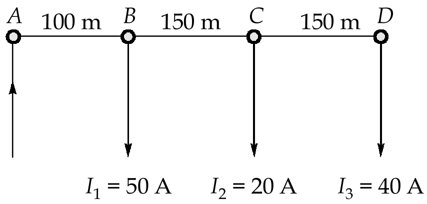
Corresponding Z-bus matrix is $Z = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 \end{bmatrix}$

If the line between bus 1 and bus 2 is replaced with another line having reactance j2, then modified Z_{bus} is

(a) $\begin{bmatrix} j0.5 & j2.5 \\ j0.5 & j2.5 \end{bmatrix}$ (b) $\begin{bmatrix} j2.5 & j0.5 \\ j0.5 & j2.5 \end{bmatrix}$

(c) $\begin{bmatrix} j0.5 & j2.5 \\ j2.5 & j4.5 \end{bmatrix}$ (d) $\begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j2.5 \end{bmatrix}$

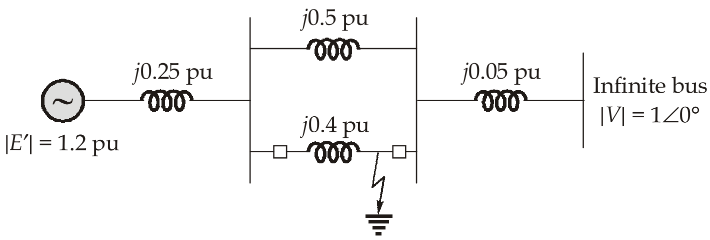
Q.49 A DC distributor has 0.25 Ω resistance per 1000 meters, the voltage at the point A to maintain 500 V at point D, will be



(a) 506.5 V
(b) 510.4 V
(c) 472.6 V
(d) 491.6 V

Multiple Select Questions (MSQ)

Q.50 A three phase fault occurs at the point as shown in figure :



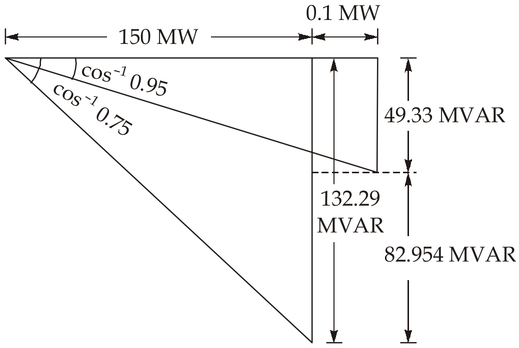
The generator is delivering 1.0 pu power at the instant preceding the fault. The value of critical clearing angle for clearing the fault with simultaneous opening of the breakers 1 and 2 is

(a) Pre-fault operating power angle is 32.3°.
(b) During fault power transfer from source to infinite bus is zero.
(c) Post-fault transfer reactance is 0.8 pu.
(d) Critical clearing angle is 55.8°

■■■■

Detailed Explanations

26. **82.954 (82.500 to 83.500)**



Without Synchronous motor:

$$Q_1 = S_1 \sin \phi_1$$

$$= \frac{150}{0.75}\sin(\cos^{-1} 0.75)$$

$$Q_1 = 132.29 \text{ MVAR}$$

With Synchronous motor:

$$Q_2 = S_2 \sin \phi_2$$

$$= \frac{150 + 0.1}{0.95}\sin(\cos^{-1} 0.95)$$

$$Q_2 = 49.33 \text{ MVAR}$$

$$\text{VAR supplied by motor} = Q_1 - Q_2 = 82.954 \text{ MVAR}$$

27. **(b)**

$$\text{Let base impedance} = Z_B$$

$$X_{(\Omega)} = 0.025\, Z_B$$

$$Y_{(\mho)} = \frac{1.4}{Z_B}$$

Assuming inductance of line, L H/km and capacitance as C F/km.

$$X = \omega l L$$

$$Y = \omega l C$$

$$L = \frac{X}{\omega l} = \frac{0.025 Z_B}{\omega l}; \qquad C = \frac{Y}{\omega l} = \frac{1.4}{\omega l Z_B}$$

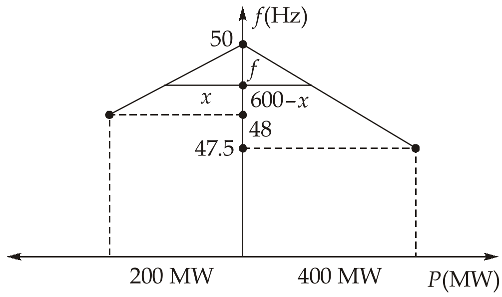
Velocity of propagation is,

$$v = \frac{1}{\sqrt{LC}}$$

$$3 \times 10^5 = \frac{1}{\sqrt{\frac{0.025 Z_B}{\omega l} \times \frac{1.4}{\omega l Z_B}}}$$

$$\text{Length of the line, } l = \frac{\sqrt{0.025 \times 1.4} \times 3 \times 10^5}{2\pi \times 50} = 178.65 \text{ km}$$

28. **47.69 (47.00 to 48.00)**



$$\frac{50-f}{x} = \frac{50-48}{200}$$

$$0.01\,x + f = 50 \quad \text{...(i)}$$

and $$\frac{50-f}{600-x} = \frac{50-47.5}{400}$$

$$50 - f = 3.75 - 6.25 \times 10^{-3}\,x$$

$$6.25 \times 10^{-3}\,x - f = -46.25 \quad \text{...(ii)}$$

$$x = 230.77 \text{ MW}$$

From equation (i),

$$(0.01 \times 230.77) + f = 50$$

$$f = 47.69 \text{ Hz}$$

29. **(4)**

The relay current setting = 25%

∴ The relay operates at a current of

$$= 0.25 \times 5 = 1.25 \text{ A}$$

The VA burden on the relay is,

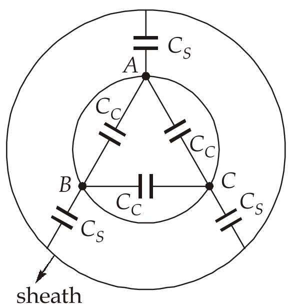
$$VA = 5$$

$$5 = V \times 1.25$$

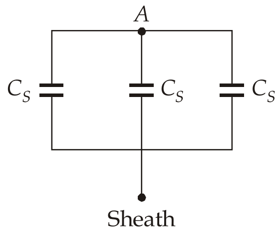
∴ $$V = 4 \text{ V.}$$

30. **(c)**

When all conductors are shorted,



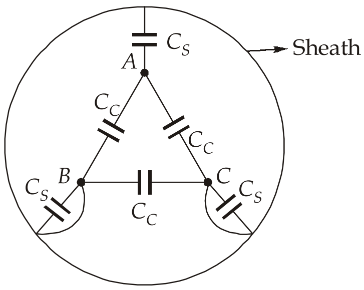
Capacitance between shorted conductors and sheath is $3C_s$.



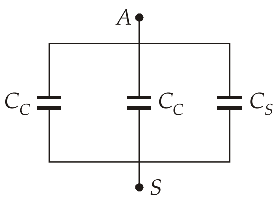
$\therefore \quad 3C_s = 0.8\ \mu F$

$$C_s = \frac{0.8\mu F}{3} = 0.2667\ \mu F$$

When two conductors shorted with sheath



$\therefore$



$$C_{AS} = 2C_C + C_S$$

$\therefore$ Capacitance between two conductors shorted with sheath and the third conductor is $2C_C + C_S$.

$\therefore \quad 2\,C_C + C_S = 0.4$

$$2C_C + 0.2667 = 0.4$$
$$2C_C = 0.1333$$
$$C_C = 0.0666\ \mu F$$

31. (b)

Capacitance of the cable, $C = \dfrac{2\pi \in_r \in_0}{\ln\left(\dfrac{R}{r}\right)} F/m = \dfrac{2\pi \times 4 \times 8.854 \times 10^{-12}}{\ln\left(\dfrac{1.6}{0.4}\right)} = 0.16\ \mu F/km$

Power factor on open circuit,

$$\cos\phi = 0.08$$
$$\phi = \cos^{-1}(0.08) = 85.41°$$

$\therefore$ Dielectric loss anlge, $\delta = 90° - 85.41° = 4.59°$

$\therefore$ Dielectric loss $= \omega CV^2 \tan\delta$

$$= 2\pi \times 50 \times 0.16 \times 10^{-6} \times (11 \times 10^3)^2 \times \tan 4.59° = 488.28\ W$$

32. (a)

$$\vec{I_R} = 100\angle 0°\text{A} \quad ; \quad \vec{I_Y} = 100\angle{-120°}\text{A} \quad ; \quad \vec{I_B} = 100\angle{-240°}\text{A}$$

$$I_{R0} = \frac{1}{3}\left(\vec{I}_R + \vec{I}_Y + \vec{I}_B\right)$$

$$\vec{I}_{Ro} = \frac{1}{3}[100\angle 0° + 100\angle 240° + 100\angle 120°] = 0 \text{ A}$$

$$\vec{I}_{R1} = \frac{1}{3}\left[\vec{I}_R + a\vec{I}_Y + a^2\vec{I}_B\right]$$

$$= \frac{1}{3}(100\angle 0° + (1\angle 120°)(100\angle -120°) + (1\angle 240°)(100\angle -240°))$$

$$= 100 \text{ A}$$

$$\vec{I}_{R2} = \frac{1}{3}\left[\vec{I}_R + a^2\vec{I}_Y + a\vec{I}_B\right]$$

$$= \frac{1}{3}(100\angle 0° + (1\angle 240°)(100\angle{-120°}) + (1\angle 120°)(100\angle -240°)) = 0 \text{ A}$$

33. 4.2 (4.1 to 4.3)

In order to circulating currents in the relay are in the phase opposition. The CTs on the star connected low voltage side of the transformer should be connected in delta and CTs on the delta connected HV side of the transformer should be connected in star.

Let the currents on the primary and secondary sides of the transformers be I_{L1} and I_{L2} respectively. Then, $\sqrt{3} \times 400 \times I_{L1} = \sqrt{3} \times 11000 \times I_{L2}$

$$I_{L2} = \frac{4}{110} I_{L1}$$

For, $I_{L1} = 1000$

$$I_{L2} = \frac{4}{110} \times 1000 = \frac{400}{11} \text{ Amp}$$

Since the CTs on the low side are connected in delta, the current through the secondary of the CT is 5 A (in phase) and the current through the pilot wire will be $5\sqrt{3}$ A.

Hence, the CT ratio on HV side $= \dfrac{400}{11\left(5\sqrt{3}\right)} = 4.2$

34. 82.0 (81.5 to 82.5)

Number of units, $n = 3$

Ratio of shunt capacitance to mutual capacitance,

$$K = \frac{0.15C}{C} = 0.15$$

Voltage across bottom most unit,

$$V_3 = \text{safe working voltage of the unit} = 20 \text{ kV}$$

So voltage across top most unit,

$$V_1 = \frac{V_3}{1+3K+K^2} = \frac{20}{1+3(0.15)+(0.15)^2} = \frac{20}{1.4725}$$

$$V_1 = 13.58 \text{ kV}$$

Voltage across middle unit, $V_2 = V_1(1 + K)$

$$= (13.58 \text{ kV})\ (1 + 0.15)$$

$$= 15.617 \text{ kV}$$

Maximum safe working voltage of the string,

$$V = V_1 + V_2 + V_3$$

$$= 13.58 + 15.617 + 20$$

$$V = 49.197 \text{ kV}$$

$$\text{String efficiency} = \frac{V}{nV_n}\times 100 = \frac{49.197}{3\times 20}\times 100 = 81.995 \approx 82\%$$

35. 0.268 (0.200 to 0.300)

Since active power demand at bus-2 is 1 p.u. only S_{G1} can supply real power to the load at bus-2. So this real power should flow in the transmission line from bus-1 to bus-2 complex power flowing from bus-1 to bus-2, S_{12}

$$S_{12} = V_1 I_{12}^*$$

V_1 = voltage at bus-1

I_{12} = current through transmission line from bus-1 to bus-2

$$S_{12} = V_1 I_{12}^*$$

$$= 1\angle 0°\left[\frac{1\angle 0° - 1\angle -\delta}{j0.5}\right]^* = 2[1\angle -90° - 1\angle(-\delta - 90°)]^*$$

$$S_{12} = 2[1\angle 90° - 1\angle 90° + \delta]$$

$$S_{12} = 2\angle 90° - 2\angle 90° + \delta$$

The real power flow from bus-1 to bus-2 is,

$$P_{12} = 2\cos 90° - 2\cos(90° + \delta)$$

Given that, $P_{12} = 1$ [Real power flow from bus-1 to bus-2 to supply S_{D2}]

Therefore, $1 = -2\cos(90° + \delta)$

$$1 = 2\sin\delta$$

$\therefore$ $\delta = 30°$

$\therefore$ Voltage at bus-2, $V_2 = 1\angle -30°$ V

Complex power flow from bus-2 to bus-1,

$$S_{21} = V_2 I_{21}^*$$

I_{21} = Current flowing through transmission line from bus-2 to bus-1

$$S_{21} = 1\angle -30°\left[\frac{1\angle -30° - 1\angle 0°}{j0.5}\right]^*$$

$$= 2\angle -30°\ [1\angle -120° - 1\angle -90]^*$$

$$= 2\angle -30°\ [1\angle 120° - 1\angle 90°]$$

$$S_{21} = 2\angle 90° - 2\angle 60°$$

The reactive power supplied by capacitor,

$$Q_{G2} = 2[\sin 90°] - 2 \sin 60°$$
$$= 2 - \sqrt{3} = 0.268 \text{ p.u.}$$

36. (d)

We know that, $(Z_{p.u.})_{new} = (Z_{p.u.})_{old} \times \frac{(MVA)_{new}}{(MVA)_{old}} \times \frac{(kV)^2_{old}}{(kV)^2_{new}}$

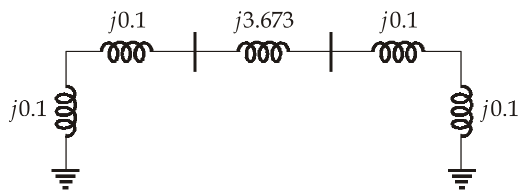
For G_1 and M_1:

$$(X_{p.u.})_{new} = 0.05 \times \frac{80}{40} \times \left(\frac{11}{11}\right)^2 = j\,0.1 \text{ p.u.}$$

For line:

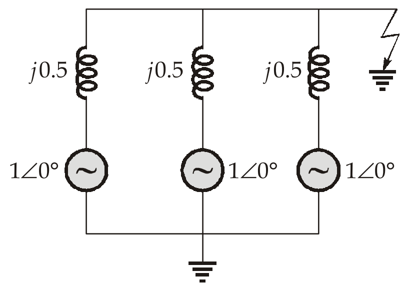
$$(X_{\Omega})_{base} = \frac{(kV)^2}{MVA} = \frac{33^2}{80} = 13.6125\ \Omega$$

$$(X_{p.u.})_{line} = \frac{\text{Actual value}}{\text{Base value}} = \frac{50}{13.6125}$$
$$= j\,3.673 \text{ p.u.}$$



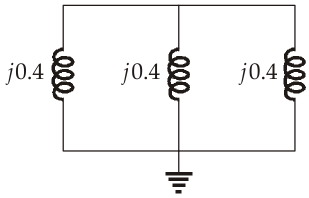
37. 7.058 (7.043 to 7.061)

Positive sequence reactance diagram:



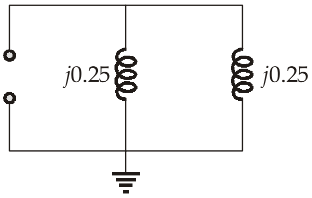
$\Rightarrow$ $$Z_{01} = j\frac{0.5}{3}$$

Negative sequence reactance diagram:



$$\Rightarrow \quad Z_{02} = j\frac{0.4}{3}$$

Zero sequence reactance diagram:



$$\Rightarrow \quad Z_{00} = j\frac{0.25}{2}$$

$$I_f = 3\left(\frac{E}{Z_{01}+Z_{02}+Z_{00}}\right) = 3\left(\frac{1}{j0.425}\right)$$

$$I_f = -j7.058 \text{ p.u.}$$

$$\Rightarrow \quad |I_f| = 7.058 \text{ p.u.}$$

38. 1.53 (1.25 to 1.75)

Natural frequency of oscillations is,

$$f_n = \sqrt{\frac{\left.\left(\frac{\partial P_e}{\partial \delta}\right)\right|_{\delta_0}}{M}}$$

$$GH = \frac{1}{2}M\omega$$

$$M = \frac{GH}{\pi f} = \frac{1\times 3}{\pi \times 50} = 0.019$$

$$P_e = \frac{|E||V|}{X}\sin\delta_0$$

$$0.6\ P_{max} = P_{max}\sin\delta_0$$

$$\delta_0 = \sin^{-1}(0.6) = 36.87°$$

$$\left.\frac{\partial P_e}{\partial \delta}\right|_{\delta_0} = P_e\cos\delta_0 = \frac{1.1}{0.5}\cos(36.87°) = 1.76 \text{ p.u.}$$

$$f_n = \sqrt{\frac{1.76}{0.019}} = 9.62 \text{ rad/sec}$$

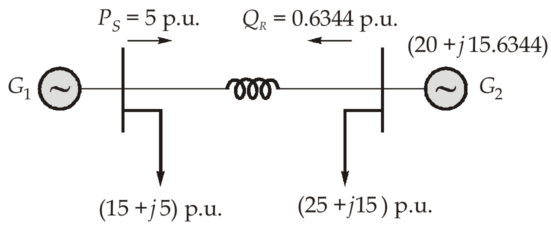
$$f_n = \frac{9.62}{2\pi} = 1.53 \text{ Hz}$$

39. 0.78 (0.75 to 0.80)

By equalizing the station,

$$P_{G_1} = P_{G_2} = 20 \text{ p.u.}$$

Now,
$$5 = \frac{|E||V|}{|X|}\sin\delta = \frac{1\times 1}{0.05}\sin\delta$$
$$\delta = 14.47°$$



$$Q_R = \frac{|V_1||V_2|}{X}\cos\delta - \frac{|V_1|^2}{X} = -0.6344 \text{ p.u.}$$

Total load on station 2 $= (25 + j15) + (-5 + j0.6344)$
$= (20 + j15.6344)$

Power factor of station 2 $= \cos\left(\tan^{-1}\left(\frac{15.6344}{20}\right)\right)$
$= 0.78$ lagging

40. (c)

Minimum number of equations $= 2n - m - 2$
$= 2(112) - 20 - 2$
$= 202$

41. 0.134 (0.12 to 0.14)

Line to line fault current, $|I_f| = \frac{\sqrt{3}\cdot E_a}{X_1 + X_2}$

$$|I_f| = \frac{\sqrt{3}}{X_1 + X_2}$$

$$2 = \frac{\sqrt{3}}{X_1 + X_2}$$

$$X_1 + X_2 = \frac{\sqrt{3}}{2} \text{ p.u.}$$

Line to ground fault current $= \frac{3\cdot E_a}{X_1 + X_2 + X_0}$

$$3 = \frac{3}{X_1 + X_2 + X_0}$$

$\therefore$ $X_1 + X_2 + X_0 = 1$
$X_0 = 1 - (X_1 + X_2)$

$$X_0 = 1 - \frac{\sqrt{3}}{2}$$

Zero sequence reactance, X_0 = 0.134 p.u.

42. **1.0 (0.95 to 1.05)**

The rating of the machine,

$$G = 100 \text{ MVA}$$

$$\text{Inertia constant, } H = 5 \text{ kW-s/kVA} = 5 \text{ KJ/KVA} = 5 \text{ MJ/MVA}$$

Kinetic energy stored in the rotating parts of generator and turbine at synchronous speed (f = 50 Hz) $= HG = 5 \times 100 = 500$ MJ

Excess power input to the generator shaft before the steam valve begins to close,

$$= 100 - 60 = 40 \text{ MW}$$

Excess energy transferred to rotating parts in 0.5 sec

$$= 40 \times 0.5 = 20 \text{ MJ}$$

Since, Kinetic energy, $K.E. \propto (\text{speed})^2 \propto f^2$

So, frequency at the end of 0.5 sec

$$f_2 = f_1\sqrt{\frac{\text{Total energy stored in 0.5 sec}}{\text{Energy stored at synchronous speed}}}$$

$$f_2 = 50\sqrt{\frac{500+20}{500}} = 50 \times 1.02 \approx 51 \text{ Hz}$$

$$\text{Change in frequency} = f_2 - f_1 = 51 - 50 \approx 1 \text{ Hz}$$

43. **(c)**

Only Y_{22}, Y_{24}, Y_{42}, Y_{44} will change because transmission line is connected between 2^{nd} and 4^{th} buses.

$$Y_{22} = -j60 + \frac{1}{Z_{se}} + \frac{Y_{sh}}{2}$$

$$= -j60 + \frac{1}{j0.1} + j20 = -j60 - j10 + j20 = -j50$$

$$Y_{24} = Y_{42} = 0 - \frac{Y_{sh}}{2} = -j20$$

$$Y_{44} = -j25 + \frac{1}{Z_{se}} + \frac{Y_{sh}}{2} = -j25 + \frac{1}{j0.1} + j20 = -j25 - j10 + j20$$

$$Y_{44} = -j15$$

44. **(b)**

Given, before fault,

$$0.6\, P_{m1} = P_{m1} \sin\delta_0$$

$$\therefore \quad \delta_0 = 36.86° \text{ (or) } 0.643 \text{ radian}$$

During fault,

$$P_{m2} = 0.25\, P_{m1} \text{ as } X_2 = 4X_1$$

After fualt,

$$P_{m\,3} = 0.75\ P_{m\,1} \text{ (given)}$$

$$\therefore \quad \delta_{max} = 180 - \sin^{-1}\left(\frac{0.6P_{m1}}{0.75P_{m1}}\right)$$

$$= 126.86° \text{ (or) } 2.214 \text{ radian}$$

Since,

$$\cos\delta_{cr} = \frac{P_s(\delta_{max} - \delta_0) + P_{m3}\cos\delta_m - P_{m2}\cos\delta_0}{P_{m3} - P_{m2}}$$

$$\cos\delta_{cr} = \frac{0.6P_{m1}[2.214 - 0.643] + 0.75P_{m1}\cos(126.86) - 0.25P_{m1}\cos(36.86)}{0.75P_{m1} - 0.25P_{m1}}$$

$$= \frac{0.6(2.214 - 0.643) + 0.75\cos(126.86) - 0.25\cos(36.86)}{0.75 - 0.25}$$

$$\cos\delta_{cr} = 0.585$$

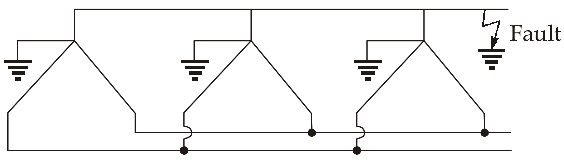
$$\delta_{cr} = 54.2°$$

45. 6.512 (6.40 to 6.60)

Let base MVA be 10 MVA and base kV be 6.6 kV

$$\therefore \quad \text{Base current} = \frac{10 \times 10^3}{\sqrt{3} \times 6.6} = 874.77 \text{ Amp}$$

when all the 3 alternators are solidly grounded,



Since all the alternators are operating in parallel, the resultant reactance will be one-third i.e.,

$$Z_1 = \frac{j0.15}{3} = j0.05 \text{ p.u.}$$

$$Z_2 = \frac{j0.1}{3} = j0.0333 \text{ p.u.}$$

$$Z_0 = \frac{j0.05}{3} = j0.0166 \text{ p.u.}$$

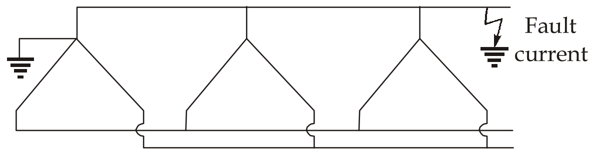
$$\text{Fault current, } I_f = \frac{3}{Z_1 + Z_2 + Z_0}$$

$$= \frac{3}{j0.05 + j0.0333 + j0.0166} = -j30 \text{ p.u.}$$

$$I_f = -j30 \times 874.77$$

$$= -j26243.1 \text{ Amp}$$

when only one alternator neutral is solidly grounded and the others are isolated.



$$Z_1 = \frac{j0.15}{3} \text{ p.u.}$$

$$Z_2 = \frac{j0.1}{3} \text{ p.u.}$$

$$Z_3 = j0.05 \text{ p.u.}$$

$$\therefore \quad \text{Fault current, } I_f' = \frac{3}{Z_1 + Z_2 + Z_0}$$

$$= \frac{3}{j0.05 + j0.033 + j0.05} = -j22.55 \text{ p.u.}$$

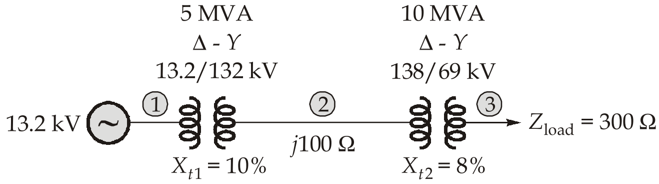
$$= -j22.55 \times 874.77$$

$$I_f' = -j19731.65 \text{ Amp}$$

$$\therefore \quad |I_f - I_f'| = |-j26.243 + j19.731|$$

$$= 6.512 \text{ kA}$$

46. 58.93 (58.0 to 60.0)



Let, $S_{base} = 10 \text{ MVA}$

$V_{base} = 13.8 \text{ kV}$

Base impedance at section-3,

$$Z_{3\text{ base}} = \frac{(69 \times 10^3)^2}{10 \times 10^6} = 476.1\,\Omega$$

$$Z_{load} = \frac{300}{476.1} = 0.63 \text{ p.u.}$$

Base impedance at section-2,

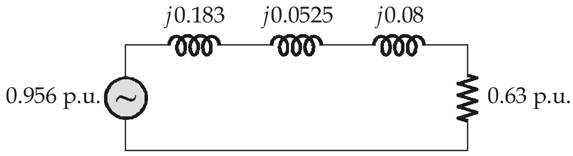
$$Z_{2\text{ base}} = \frac{(138 \times 10^3)^2}{10 \times 10^6} = 1904.4\ \Omega$$

$$Z_{line} = \frac{j100}{1904.4} = j0.0525 \text{ p.u.}$$

$$X_{t1\text{ (new)}} = 0.1 \times \left(\frac{132}{138}\right)^2 \times \frac{10}{5} = 0.183 \text{ p.u.}$$

$$X_{t2} = 0.08 \text{ p.u.}$$

$$E_s = \frac{13.2}{13.8} = 0.956 \text{ p.u.}$$



$$V_L = 0.956 \times \frac{0.63}{j(0.183 + 0.0525 + 0.08) + 0.63}$$

$$V_{L\text{ (p.u.)}} = 0.956 \times \frac{0.63}{\sqrt{(0.3155)^2 + (0.63)^2}} = 0.854$$

$$\text{Voltage at load} = V_{L\text{ (p.u.)}} \times V_{L\text{ (base)}}$$
$$= 0.854 \times 69 \text{ kV}$$
$$= 58.926 \text{ kV}$$

47. (d)

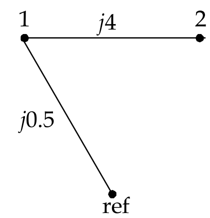
To have a shunt element i.e. $y_{10}, y_{20}, y_{30},$ or y_{40}

$$Y_{11} = y_{10} + y_{12} + y_{13} + y_{14} = 0$$
$$y_{10} = Y_{11} - y_{12} - y_{13} - y_{14}$$
$$y_{10} = -5 + 2.5 + 2 + 0 = -0.5 \neq 0$$
$$y_{10} = -0.5 \quad \therefore \text{ shunt element is present}$$
$$y_{20} = Y_{22} - y_{12} - y_{23} - y_{24}$$
$$= -9 + 2.5 + 1 + 5 = -0.5$$
$$y_{20} = -0.5$$
$$y_{30} = Y_{33} - y_{13} - y_{23} - y_{43}$$
$$= -9 + 2 + 1 + 4 = -2$$
$$y_{30} = -2$$
$$y_{40} = Y_{44} - y_{14} - y_{24} - y_{34}$$
$$= -9 + 0 + 5 + 4$$
$$y_{40} = 0$$

$\therefore$ Only bus 4 is not having shunt element.

48. (d)

Existing system and bus matrix is



$$Z_{Bus} = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 \end{bmatrix}$$

Modifying line with reactance $j2$ is equivalent to adding a line in parallel with impedance $j4$. Thus it is type-4 modification.

$$[Z_{new}] = [Z_{old}] - \frac{1}{Z_{11} + Z_{22} - 2Z_{12} + Z_s}\begin{bmatrix}\text{subtract} \\ 2^{old}\text{ column} \\ \text{from first column}\end{bmatrix}[\text{Transpose}]$$

$$[Z_{Bus}]_{new} = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 \end{bmatrix} - \frac{1}{j0.5 + j4.5 - 2(j0.5) + j4}\begin{bmatrix} j0 \\ -j4 \end{bmatrix}\begin{bmatrix} j0 & -j4 \end{bmatrix}$$

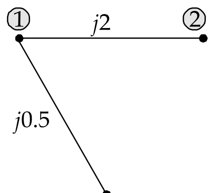
$$= \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 \end{bmatrix} - \frac{1}{j8}\begin{bmatrix} 0 & 0 \\ 0 & -16 \end{bmatrix}$$

$$= \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 \end{bmatrix} - \begin{bmatrix} 0 & 0 \\ 0 & -\frac{16}{j8} \end{bmatrix}$$

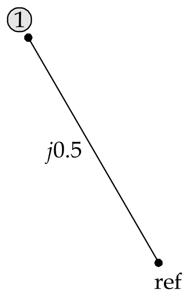
$$= \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 - \frac{j16}{8} \end{bmatrix} = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j2.5 \end{bmatrix}$$

Alternative :

New system will

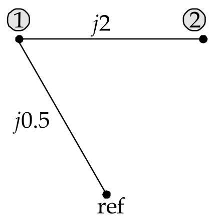


First branch :



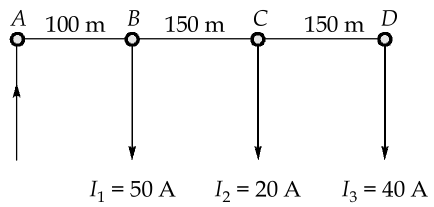
$$Z = [\ j0.5]$$

Type – 2 modification



$$Z = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j0.5 + j2 \end{bmatrix} = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j2.5 \end{bmatrix}$$

49. **(a)**



The resistance of line = 0.25 Ω per 1,000 meters.

Resistance of section *AB*,

$$R_{AB} = 0.25 \times \frac{100}{1000} = 0.025\ \Omega$$

Resistance of section *BC* = Resistance of section *CD*

$$R_{BC} = R_{CD} = 0.25 \times \frac{150}{1000} = 0.0375\ \Omega$$

Given, $I_1 = 50\text{A}, I_2 = 20\text{ A and } I_3 = 40\text{ A}$

Voltage at *D*, $V_D = 400\text{ V}$

Voltage at *C*, $V_C = V_D + I_3R_{CD}$

$= 500 + 40(0.0375) = 501.5\text{ V}$

Voltage at *B*, $V_B = V_C + (I_2 + I_3)R_{BC}$

$= 501.5 + 60 \times 0.0375$

$= 503.75$

Voltage at A, $V_A = V_3 + (I_1 + I_2 + I_3)R_{AB}$

$= 503.75 + (40 + 20 + 50) \times 0.025 = 506.5\text{ V}$

50. **(b, c, d)**

Before fault :

$$X_1 = 0.25 + \frac{0.5 \times 0.4}{0.5 + 0.4} + 0.05$$

$$X_1 = 0.522\text{ pu}$$

$$P_{eI} = \frac{|E'||V|}{X_1}\sin\delta$$

$$1 = \frac{1.2 \times 1}{0.522}\sin\delta = 2.3\sin\delta$$

$$\delta_o = 25.8°$$

During fault : No power is transferred.

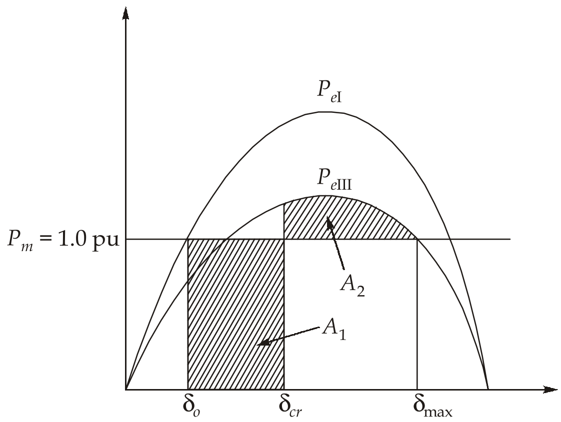
$$P_{eII} = 0$$

Post fault :

$$X_{III} = 0.25 + 0.05 + 0.5 = 0.8$$

$$P_{eIII} = \frac{1.2 \times 1.0}{0.8}\sin\delta$$

$$= 1.5\sin\delta$$



The maximum permissible angle

$$\delta_{max} = \pi - \sin^{-1}\left(\frac{1}{1.5}\right) = 2.41 \text{ rad}$$

$$\delta_o = 25.8° = 0.45 \text{ rad}$$

Equal area criterion :

$$A_1 = P_m(\delta_{cr} - \delta_o)$$

$$= 1 \times (\delta_{cr} - 0.45) = \delta_{cr} - 0.45$$

$$A_2 = \int_{\delta_{cr}}^{\delta_{max}} (P_{eIII} - P_m) d\delta$$

$$= \int_{\delta_{cr}}^{2.41} (1.5 \sin\delta - 1) d\delta$$

$$= [-1.5\cos\delta - \delta]_{\delta_{cr}}^{2.41}$$

$$= 1.5 \cos \delta_{cr} + \delta_{cr} - 1.293$$

Setting $A_1 = A_2$

$$\delta_{cr} - 0.45 = 1.5 \cos \delta_{cr} + \delta_{cr} - 1.293$$

$$\cos \delta_{cr} = \frac{0.843}{1.5} = 0.562$$

$$\delta_{cr} = 55.8°$$

■■■■