MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

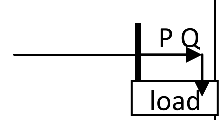
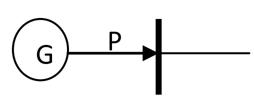
MODEL ANSWER

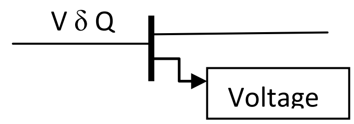
SUMMER – 2018 EXAMINATION

Subject: Power System Operation & Control **Subject Code: 17643**

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q.N.	Answer	Marking Scheme
1.	**(A)** **(a)** **Ans.**	**Attempt any THREE:** **State and explain different types of bases with reference to power system.** In load flow studies refer to power system, two out of four quantities are specified and remaining two are required to be obtained through load flow solutions. Depending upon which quantities have been specified, the buses are classified as follows. **I. Load Bus**: - At this bus power is injected or delivered to load. Hence real & reactive component of power is specified. At this bus voltage is allowed to vary within the permissible limit and phase angle 'δ' is not important from consumer's point of view. This is also called as PQ bus. Power injected from bus is considered positive.  **II. Generator bus**: - At this bus power generated is injected into the system. Hence the magnitude of voltage corresponding to its  	**12** **4M** ***1M for each***

		rating are specified from load flow solution and it is required to find out Q & S. This is also called as PV bus. **III. Voltage Control bus**: This bus generally considered as PV bus, but there is physical difference. Voltage control bus has voltage control  capabilities and uses tap-changing transformer & static VAR compensators whereas generator bus has generator. Here $P_G = 0$ & $Q_G = 0$, hence $P_i = -P_D$, $Q_i = -Q_D$. V_i are known and δ_i is unknown. **IV Slack Or Swing Or Reference Bus**: - In power system power is injected by generator bus and power is delivered or ejected at Load bus. So whatever losses takes place in the system remains unknown, until the load flow solution is complete. Hence one of the generator buses is made to take additional real and reactive power to supply transmission losses. This bus is known as slack or swing bus. At this bus the magnitude of bus voltage and phase angle are specified while P & Q are obtained through the load flow solution.	
	(b) **Ans.**	**State the reason for consumers demand for constant frequency supply.** **Consumers demand constant frequency supply because** i. In most of the industries, Induction motor is used as common drive, which runs at speed that is directly related with frequency. (N= 120f/p) variation in frequency affects the quality of the product and rate of production. ii. Induction motor used as common A.C. drives though has rigid construction but due to variation in supply frequency, life of induction motor reduces by 500 Hrs. They are not sensitive for small variation in the supply frequency. i.e. of the order of 50 $\pm$ 2 Hz. iii. In railway stations, the electric chokes are driven by single-phase synchronous motor, the speed of the synchronous motor depends on supply frequency directly. Hence it needs constant frequency supply for all 24 Hrs. of the day. If frequency falls by 1 hr , then clock falls back by 15 min. & it takes no. of hours to reduce the error to zero. iv. In some industries such as the textiles rubber, plastic & paper	**4M** ***Any 4 1M each***

<table>
<tr><td></td><td></td><td>require frequency constant or to a tolerance of $\pm$ 0.25 per min.
v. Electric gear systems used in industries requires the frequency 49.5 Hz to 50.5 Hz range.</td><td></td></tr>
<tr><td></td><td>(c)
Ans.</td><td>Define the ‘driving point admittance’ and ‘transfer admittance’.
In power engineering, nodal admittance matrix or admittance matrix or Y Matrix or Y_{bus} is an n x n matrix describing a power system with n buses.Nodal equation for system is given by……
$\mathbf{I_{bus} = Y_{bus}\ V_{bus}}$
Where , I_{bus} = bus current vector and V_{bus} = bus voltage vector
Y bus – bus admittance matrix = $\begin{vmatrix} Y_{11}Y_{12} \\ Y_{21}Y_{22} \end{vmatrix}$

For a two bus system these nodal equations can be written as…….
$I_1 = Y_{11} V_1 + Y_{12} V_2$
$I_2 = Y_2 V_1 + Y_{22} V_2$

Here, $Y_{11} = \frac{I1}{V1}$when $\Big|$ V_2 =0
It is the self admittance of bus-1 as the ratio of curent at bus -1 (I_1) to voltage at bus-1(V_1) , when bus-2 is short circuited with the grounds. It is known as Driving point admittance.
$\mathbf{Y_{12}} = \frac{I1}{V2}$ whenV_1=0
It is the admittance impressed at bus -1as the ratio of of curent at bus -1 (I_1)to voltage at bus-2(V_2) when bus-1 is shorted with grounds. It isknown asTransfer admittance
OR
Driving point admittance: All diagonal elements of Y_{bus} admittance matrix is called as short circuit self-admittance or driving point admittance. It is equal to sum of all line admittances and line charging admittance connected to the bus.
For a three bus system,
$Y_{11} = y_{11} + y_{12} + y_{13}$

Where y_{11} – line charging admittance

y_{12} – line admittance between bus1 & bus2

y_{13}- line admittance between bus2 & bus3</td><td>4M

Driving point admittance 2M</td></tr>
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		Transfer admittance: All off diagonal elements of Y_{bus} admittance matrix is called as short circuit transfer admittance or mutual admittance. It is equal to negative of line admittance connected between reference buses. $Y_{12} = -y_{12}$ and $Y_{12} = Y_{21}$	***Transfer admittance 2M***
	(d) **Ans.**	**Explain with example 'large disturbances' and 'small disturbances' referred to power system stability.** **Large disturbances:** The disturbance in power system which cannot be represented by linear or algebraic equations ***Example:*** • Sudden rise/fall in power demand by large value. • Failure of major equipment such as transformer, generator. • Switching off major transmission lines EHV line, HVDC lines. • Occurrence of fault, loss of synchronism **Small disturbances:** The disturbance in power system which can be represented by linear equations or algebraic equations for the purpose of analysis. ***Example:*** • Small rise/fall in power demand • Charging setting points of voltage control equipment • Charging the settings of excitation system • Changing settings of relays/ switch gears in protection systems.	**4M** ***Definition 1M each*** ***Example 1M each***
1.	**(B)** **(a)** **Ans.**	**Attempt any ONE:** **State data required for Load flow studies.** Following Data are required for load flow analysis: 1. **System data**: It includes: Single line diagram system of a power, number of buses-*n*, number of PV buses, number of loads, number of transmission lines, number of transformers, number of shunt elements, the slack bus number, voltage magnitude of slack bus (angle is generally taken as 0o), tolerance limit, base MVA, and maximum permissible number of iterations. 2. **Generator data:** No. of generating stations connected in the systemready to generate the required amount of power and their	**06** **6M** ***Any 6 1M each***

time duration should be available. Each generators rating, maximum& minimum limits of generation, their characteristics, and excitation control details are made available.

3. **Transmission line data -** For every transmission line connected between buses I and k the data includes the starting bus number i, ending bus number *k*,
   - Line parameters – .*r*esistance of the line, reactance of the line and the half line charging admittance. Series impedance (z) in per unit, shunt admittance (Y) in per units,
   - Thermal limits of the line.
   - Length of the line.
   - Identification of each line and its '∏' equivalent circuit.
4. **Transformer data:**Type of transformer such as distribution transformer / power transformer, auto-transformer, tap-changing transformer (on-line or ff-line). Also ratings, % impedance and tap setting points, tap setting on HV /LV /both sides are required. (Quite often it may be necessary to adjust voltages on one or both sides of the transformers to maintain the potential levels at the neighboring buses within specified limits. For achieving this, auto and double winding transformers with provision for tap changing on H. V. side or used so as to facilitate smoother control. For every transformer connected between buses *i*and *k* the data to be given includes: the starting bus number *i*, ending bus number *k*, resistance of the transformer,reactance of the transformer, and the off nominal turns-ratio.
5. **Bus data:** Depending upon no. of buses in the system, bus data should be made available.

Type of bus	**Bus data**	**No of buses**	**For each Bus**
Generator bus	P, (V)		PGi, V_i, , minimum and maximum reactive power limit (Qi,min, Qi,max).
Load bus	P, Q		active power demand PDi, and the reactive power demand QDi.
Slack bus	V, δ		Generator ratings which is assume to be connected to slack bus

Voltage control bus	P Q V		Voltage control equipment used and its rating, max. & min. limits

6.Some of lines may be tuned with reactive compensating equipment, for stabilizing the voltage level. Their ratings and setting values should be made available.

7. If the load flows study is to be carried out for a specific load demand, then the most effective manner in which generation can be scheduled at the various buses by ensuring the desired voltage profile. A no. of load flow solutions is possible for different sets of control parameters. It is therefore necessary to define and objective of load flow analysis.

(b) **Define 'Steady state stability' 'Transient state stability' and 'Overall stability' of power system.** **6M**

Ans.

1. Steady state stability is the ability of the power system to regain and maintain equilibrium condition (synchronous speed) after experiencing a small/ slow disturbance such as small load variation or changes in load condition occurs, then the phenomenon is known as steady state stability.

2M for each

OR

Steady state stability is the stability the power system attains after small disturbance. Suppose a small amount of load is disconnected. Then there is a mismatch in the power system so power flow will fluctuate, voltage in diff part will rise suddenly & for small duration frequency mismatch will be there. But after a very short duration again the power system will regain its steady state.

2. Transient stability is the ability of the power system to regain or maintain equilibrium conditions after experiencing a large & sudden disturbance.

OR

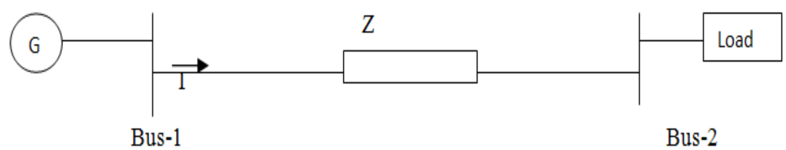
Transient stability corresponds to the stability attained after a large disturbance. Suppose somewhere a fault occurs & suddenly a large part of load is bypassed. Then there is a large unbalance in the system. Then also gradually the system attains the stability.

3. Over all stability: It is the stability of a power system when synchronism of one of working generator has been lost. The normal operating condition can be reestablished without disconnection of major elements. Modern power system uses automatic control devices and therefore it is to be tested for its ability to remain in synchronism under steady state as well as transient conditions. Both prior to and after the disturbance. Such operating condition of system is called as Overall stability.

2. **Attempt any FOUR:** **16**

(a) **Derive the relation between real power and frequency in a single two bus power system.** **4M**

Ans. Consider a simple two bus system in which power is transmitted from bus-1 to bus-2 through a short transmission line.



1M

Let $V_1 L\delta_1$ - the voltage at bus-1 $V_2 L\delta_2$ - the voltage at bus-2

Z – total series impedance of the trans. Line per phase $= R + j X$

Since $R <<<< X$, $Z = jX$

Let I – current through the line per phase

$$= \frac{V1L\delta1 - v2L\delta2}{z} = \frac{v1L\delta1 - v2L\delta2}{jX}$$

S_{12} - complex power transferred from bus-1 to bus-2 = $V_1 I_1^*$

$$= \frac{V_1^2 - V_1 V_2 L(\delta_1 - \delta_2)}{-j X} \times \frac{j X}{j X} = \frac{jXV_1^2 - j X V_1 V_2 L(\delta_1 - \delta_2)}{X^2}$$

$$= \frac{jV_1^2 - j V_1 V_2 \ L(\delta_1 - \delta_2)}{X}$$

1M

$$= \frac{jV_1^2 - j V_1 V_2 (\cos\delta - j \sin\delta)}{X} \quad \text{where } \delta_1 - \delta_2 = \delta$$

$$= \frac{V_1 V_2 \sin\delta}{X} + \frac{j (V_1^2 - V_1 V_2 \cos\delta)}{X} = P_1 + j Q_1$$

		So now, $P_1 = \frac{V_1V_2 \text{ Sin } \delta}{X}$ ----1 $Q_1 = \frac{(V_1^2 - V_1V_2 \text{ Cos } \delta)}{X}$ --------2 Similarly, we can also calculate complex power S_{21} that flows from bus-2 to bus-1. We have, $S_{21} = V_2 I_2^* = V_2 \angle\delta_2 \left(\frac{V_2 \angle -\delta_2 - V_1 \angle -\delta_1}{j X} \right)$ $= \frac{V_1V_2 \text{ Sin } \delta}{X} + \frac{j (V_1V_2 \text{ Cos } \delta - V_2^2)}{X} = P_2 + j Q_2$ Therefore, $P_2 = \frac{V_1V_2 \text{ Sin } \delta}{X}$ -----------3 $Q_2 = \frac{(V_1V_2 \text{ Cos } \delta - V_1^2)}{X}$ -------------4 From equations 1 & 3, we get…… $P_1 = P_2 = \frac{V_1V_2 \text{ Sin } \delta}{X}$ Therefore, net power flow through the line is….. $P = \frac{V_1V_2 \text{ Sin } \delta}{X}$ For given system X is constant. If voltages at both ends of the line are maintained constant i.e. V_1& V_2 remains same. Then, $P \propto Sine\delta$ ……………Where $\delta = \omega t = 2\prod f t$ $\delta \propto t$ This shows that variation in real power flow results in variation of supply frequency. P is maximum when Sin δ = 1 $P = P_{max}$ when $\delta = 90^0$ But to operate the power system under stability condition the value δ is maintained between 35^0 to 45^0.	***1M*** ***1M***
	(b) **Ans.**	**State the types of reactive power compensating equipments used for 'loads' and 'transmission lines'.** **Load compensation:** Since most loads are inductive and consume lagging reactive power, the compensation required is usually supplied by leading reactive power. Shunt compensation of reactive power can	**4M**

		be employed either at load level, substation level, or at transmission level. SVC can be used to compensate the reactive power to the loads, like furnaces, roller mills. The load power factor is measured from voltage and current signals, compared with a reference signal. Error signal controls the firing angle of TCR or switching of TSC to generate the required reactive power. Unbalanced loads are created in traction loads, electric arc furnaces. The SVC regulator consists of separate reactive power measurement control and firing pulse generation circuits for each phase to enable individual phase control. The firing angle for each phase will be different depending on its load conditions thus effecting unbalanced control. **Line compensation**: Excess amount of reactive power generated in the network causes rise in voltage level, sometimes beyond control. To reduce this rise of voltage level, reactive compensating equipment's are to be connected which absorbs the reactive power from the line. This process is called line compensation. A device that is connected in parallel with a transmission line is called a shunt compensator, while a device that is connected in series with the transmission line is called a series compensator. We shall assume that the shunt compensator is always connected at the midpoint of transmission system, while the series compensator can be connected at any point in the line. It can be **capacitive** (leading) or **inductive** (lagging) reactive power, although in most cases compensation is capacitive. **OR** **Reactive power compensating equipment for loads:** 1. Shunt capacitors near the loud terminals 2. Series capacitors to feed the leading VAR to loud so that p.f. can be improve. 3. Series reactors to feed the lagging VARs to loud such as induction furnace, welding transformation. 4. Staic VAR system 5. Synchronous phase modifier – It is a synchronous motor under no. load runs in parallel with load. 6. SVR with TCR/TSC used in industries like furnaces, roller mills.	***2M for each***

For transmission lines:

1. Shunt capacitors: In receiving end substations, distribution substations and in switching substations. Connected either to the tertiary winding of power transformers or to the bus bars.
2. Shunt reactors- Used to compensate ferrenti effect, effect of capacitance parameter of HV & EHV transmission line.
3. Series reactors
4. Static VAR system – in EHV, HV tr. Lines
5. Synchronous modifiers
6. Static synchronous compensator (STATCOM)

(c) Ans. **State SLFE for simple two bus system and define it's parameters.** **4M**

For a two bus power system, Load flow equations can be written as……

$V_1\angle\delta_1$ be the voltage at bus 1, $V_2\angle\delta_2$ be the voltage at bus 2

$\mathbf{Y_{11}}$– self admittance of bus-1 $\mathbf{Y_{22}}$– self admittance of bus-2

$\mathbf{Y_{12} = Y_{21}}$– mutual admittance between bus-1&bus-2

1M for each equation

Then real power at bus -1…

$\mathbf{P_1} = PG_1 - PD_1 = \mathbf{V_{12}\,Y_{11}\,Cos\,\alpha_{11} + Y_{12}\,V_2\,V_1\,Cos\,(\delta_2 - \delta_1 + \alpha_{12})}$

Reactive power at bus -1…

$\mathbf{Q_1} = QG_1 - QD_1 = \mathbf{-\,[V_{12}\,Y_{11}\,Sin\,\alpha_{11} + Y_{12}\,V_2\,V_1\,Sin\,(\delta_2 - \delta_1 + \alpha_{12})]}$

Real power at bus -2…

$\mathbf{P_2} = PG_2 - PD_2 = \mathbf{Y_{21}\,V_2\,V_1\,Cos\,(\delta_1 - \delta_2} + \alpha_{21}\mathbf{) + V_{22}\,Y_{22}\,Cos\alpha_{22}}$

Reactive power at bus -2….

$\mathbf{Q_2} = QG_2 - QD_2 = \mathbf{-\,[\,Y_{21}\,V_2\,V_1\,Sin\,(\delta_1 - \delta_2} + \alpha_{21}\mathbf{) + V_{22}\,Y_{22}\,Sin\,\alpha_{22}]}$

OR

For a simple two bus system Load flow equations can be written as….

SLFE equation: $S_1{*} = V_{1\,2}\,Y_{11}\,Loe_{11} + Y_{12}\,V_2\,V_1 L(\delta_2 - \delta_1)$ $= P_1 - j\,Q_1$ $P_1 = V_{1\,2}\,Y_{11}\,Cos\,oe_{11} + Y_{12}\,V_2\,V_1\,Cos\,(\delta_2 - \delta_1)$ $Q_1 = (V_{1\,2}\,Y_{11}\,Sin\,oe_{11} + Y_{12}\,V_2\,V_1\,Sin\,(\delta_2 - \delta_1)$	$S_2{*} = V_{2\,2}\,Y_{22}\,Loe_{22} + Y_{21}\,V_2\,V_1\,(\delta_1 - \delta_2)$ $= P_2 - j\,Q_2$ $P_2 = V_{2\,2}\,Y_{21}\,Cos\,oe_{22} + Y_{21}\,V_2\,V_1\,Cos\,(\delta_1 - \delta_2)$ $Q_2 = (V_{2\,2}\,Y_{22}\,Sin\,oe_{11} + Y_{12}\,V_2\,V_1\,Sin\,(\delta_1 - \delta_2)$

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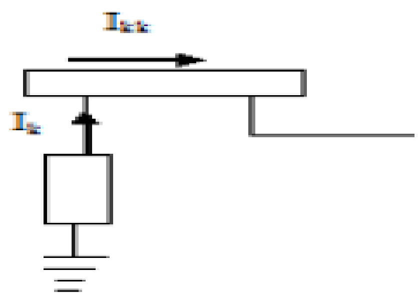
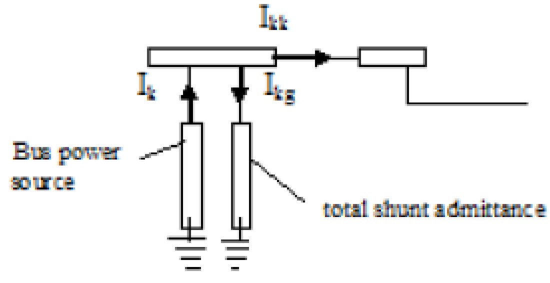
	(d) **Ans.**	**State the information that can be obtained from Load flow studies.** **The information that can be obtained from the load flow studies are:** (1) We can predetermine real power (MW), reactive power (MVAR),voltage and power angle **δ**at any point in the network. (2) Real power flow in the system provides information about real power flow balance and its effect in the on the system network. (3) Reactive power flow at various parts in the system provides information about setting points of reactive compensating equipments. (4) We can obtain information about voltages at various buses in the system and so determine the variation in bus voltages at specific buses and operation of voltage control equipments. That means, it also gives information for choice of appropriate rating and tap-setting of the power transformer in the system for maintaining voltage profile at specific buses. (5) We can obtain operational currents of all tr. lines and obtain the comparison with their thermal limits. (6) We can obtain impact of any change in generation (increase or decrease) on the system performance or stability condition. (7) We can also study influence of any modification or extension of the existing grid circuits on the system loading. (8) We can study the influence of any change in conductor size and system voltage level on power flow for adopting energy conservation technique. (9) Load flow studies provide no. of solutions and so we can obtain economic power generation and optimal l load distribution among generating units connected in the system. (10) Well in advance we can plan for generation of power to meet the power demand throughout 24 hours of the day.	**4M** ***Any 4 1M each***
	(e) **Ans.**	**State and explain base load equation and Line-flow equations.** **Bus Loading equation**: The complex power in terms of real & reactive power at any k^{th}bus can be written as $S_k = V_K I_k^* = P_k + jQ_k$	**4M** ***2M for each***



And so current $I_K = \frac{P_K - j\,Q_K}{V_{K^*}}$

Bus current I_K is positive if flows into the system.
If the shunt elements i.e. line charging element is neglected then system model can be represented as shown in above figure,
Now bus current is equal to current injected into the bus by bus power source.

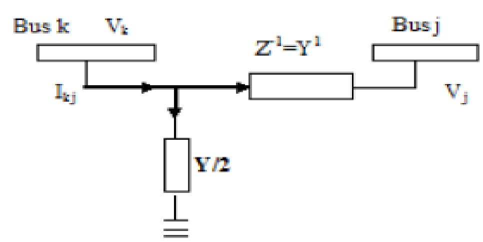


$$I_{kk} = I_k$$

If the shunt elements i.e. line charging element is considered, then system model can be represented as shown in below,
Now bus current is equal to current injected into the bus by bus power source minus the current through shunt element.

$$I_{kk} = I_k - I_{kg}$$

$$= \frac{P_K - j\,Q_K}{V_{K^*}} - V_k Y_{kk}$$

		Where Y_{kk} – total shunt admittance **<u>Transmission Line Flow equation</u>:**  The above two equations are called as Line flow equations, The algebraic sum of power expressed by above equations gives power loss in the line between bus k and bus-j. Assume that current is flowing throl tr. Line from bus k to bus j. $I_{kj} = \frac{(V_k - V_j)}{Y} Y^1 + V_k \, {}^{Y}/_{2}$ Where Y^1– line admittance Y – line changing admittance Now power flow from bus k to bus j is P_{kj}-jQ_{kj} $= V_k^* I_{kj} = V_k^*(V_k - V_j)y^1 + V_k^* V_k \, {}^{y}/_{2}$ Similarly power flow from bus j to bus k is $P_{jk} - jQ_{jk} = V_j^* I_{jk} = V_j^*(V_j - V_k)y^1 + V_j^* V_j \, {}^{y}/_{2}$	
	f) **Ans.**	**State the adverse effect of instability on power system.** **Due to instability of power system following effects can be observed:** 1) As the Pd>>Pg, frequency of system varies over a wider range/ beyond the limits. Hence protective scheme of generators, transformersmay trip them. 2) Due to fluctuation of V, F, P, Q performance of grid network reduces and power transmission capacity reduces and so consumers receive poor quality of supply. 3) If the system parameters are not controlled, than one by one generator will trip off and it leads major failure sometimes leads to collapsing of whole system. 4) As consumer receives poor quality supply the performance of their	**4M** ***Any 4 points 1M for each***

		machines reduces, production rate decreases, quality of product reduces and overall there is financial loss.	
3.	**(a)** **Ans.**	**Attempt any FOUR:** **Why do consumers demand electrical supply at constant voltage?** The consumers demand rated supply to all equipment to his premises. Due to variation in the supply voltage the current drawn by the equipment varies. 1. When supply voltage decreases beyond the limit the current drawn by equipment increases & efficiency decreases. As a result performance of the equipment also reduces its life. 2. The induction motor which is commonly used as industrial drive develops the torque which depends on supply voltage ∴T $\propto V^2$. Hence large variation in supply voltage leads to more variation in torque developed .So far small variation in supply voltage the performance of motor gets affected and as a result the quality of product & the process gets affected. 3. In the lighting system the luminous output of lamp sources depends on supply voltage. Light flux of a lamp depends on voltage, with the voltage fluctuation light flux varies strongly As supply voltage decreases the luminous output of lamp decreases with more fluctuation in supply voltage reduces life of lamp also reduces. 4. Nowadays the more sophisticated equipments are used e.g computers which are very much sensitive towards supply parameters. Fluctuation in supply voltages damages these instruments permanently.	**16** **4M** ***1M for each***
	(b) **Ans.**	**State the advantages of reactive power compensation in power system operation.** **Advantages of reactive power compensation in power system operation:** 1. Maintains flat voltage profile 2. Better voltage regulation 3. Reduction in losses 4. Improvement of P.F 5. Reduction in KVA demand charges 6. Decrease in KVA loading of generators	**4M** ***Any 4 1M each***

(c) **State the significance of study of load flow analysis.** **4M**

Ans.

Significance of study of load flow analysis:

Load flow studies gives magnitude & phase angle of the voltage at each bus, Real and reactive power flow through tr. Lines, current flow through tr. Lines.

Hence load flow Studies are essential for- - - -

Any 4 1M each

- For designing the power system.
- For operation of the system.
- For future expansion of the system to meet increase in the demand.
- For inter connecting the two systems to meet the load demand.
- For analyzing both normal and abnormal (means outage of tr. Lines or transformer or gen. units) operating conditions.
- For analyzing the initial conditions of the system when the transient behavior of the system is to be studied.
- Transmission lines can carry only certain amount of current and we must make sure that we do not operate these links too close to their stability or thermal limits so LFA helps to know the amount current flowing through various lines in the network.
- LFA also helps in maintaining the stability of the system by giving the information about real, reactive power flow in the system.

(d) **Write Y_{bus} matrix for 3-bus system and list out its characteristics.** **4M**

Ans.

The admittance matrix is $$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix}$$ *1M*

Where,

$Y_{11} = y_{11} + y_{12} + y_{13}$ &

$Y_{22} = y_{21} + y_{22} + y_{23}$ &

$Y_{33} = y_{31} + y_{32} + y_{33}$.

Also,

$Y_{12} = Y_{21} = -y_{12} = -y_{21}$ &

$Y_{13} = Y_{31} = -y_{13} = -y_{31}$ &

$Y_{23} = Y_{32} = -y_{23} = -y_{32}$.

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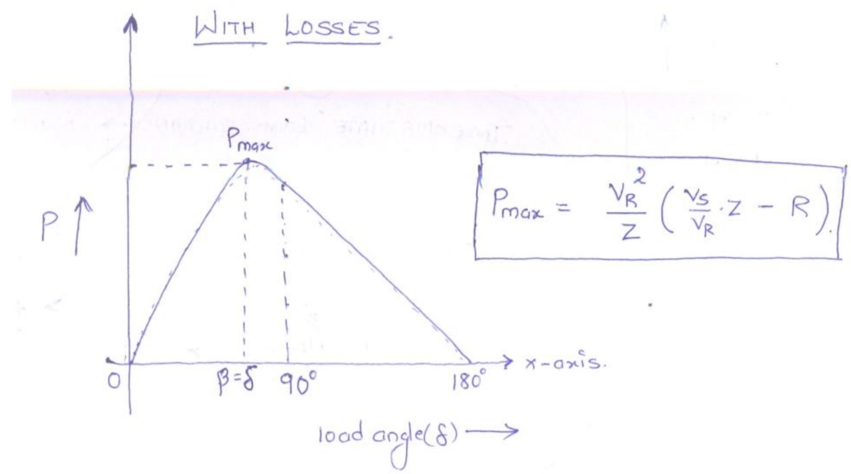
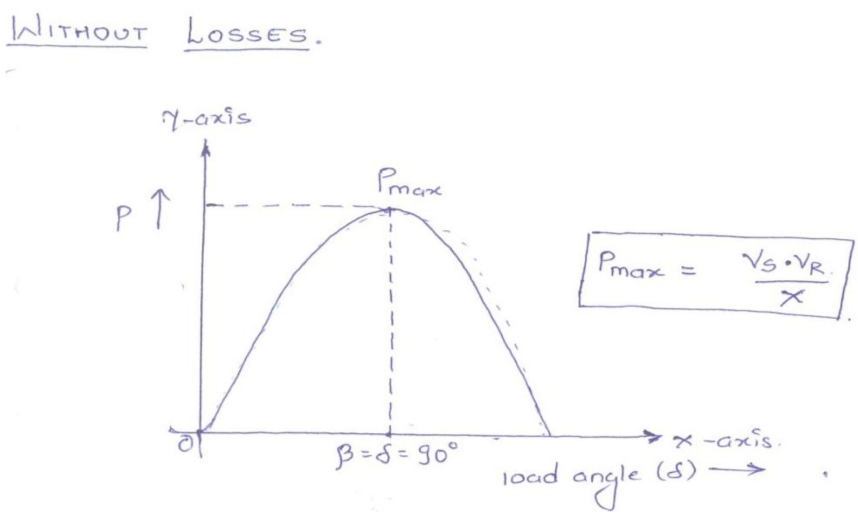
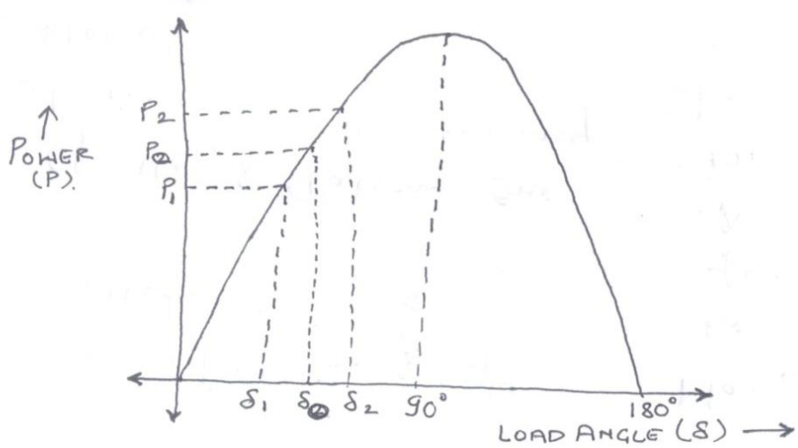
		Characteristics of Y_{bus} matrix: 1) Y_{bus} is a symmetrical matrix "n x n" matrix. 2) All diagonal elements Y_{ii} represent "self admittances" of bus "I". 3) All off diagonal elements Y_{ij} represents mutual admittance between bus "I" bus "j". 4) With reference to mutual admittance $Y_{ij}= Y_{ji}$ i.e. $Y_{12} = Y_{21}$, $Y_{13} = Y_{31}$ Hence it is a symmetrical matrix. 5) Any element in the matrix „zero" indicates that there is not to line between those buses. $Y_{21} = Y_{12} = 0$ ………… no tr. line between bus I bus IIor outage of tr. line $Y_{ik}= Y_{ki}= 0$ if i k between but I bus II i k are not connected. 6) $Y_{bus} = (Z_{bus})$ where Z_{bus}– bus impedance matrix. 7) All elements are complex numbers. 8) Self admittances are defined as $Y_{11} = Y_{11} + Y_{12}+ Y_{13}$ Where Y_{11} – line changing admittance Y_{12}, Y_{13} – line admittances Y_{11} = sum of line changing admittance and total line admittances connected to a bus. 9) Mutual admittances are defined as $Y_{12} = -Y_{12} = -Y_{21} = Y_{21}$ $Y_{13} = -Y_{13} = Y_{31}$ i.e. mutual admittance is negative of line admittance between two buses. 10) All mutual admittances are negative complex numbers.	***Any 3 characte ristics 1M each***
	(e) **Ans.**	**Draw neat & labelled power angle diagram of a power system.** **(i) Considering losses in the line.** **(ii) Neglecting losses in the line.**	**4M**

		(i) Considering losses in the line:  **(ii) Neglecting losses in the line:** 	***1½M for each Diagram and ½M for each equation***
	(f) **Ans.**	**State the factory that affect transient stability condition of power system (any four).** Transient state stability is the ability of the system to return to its normal operating condition of same equilibrium or new equilibrium position after experiencing sudden and large disturbance in the	**4M**

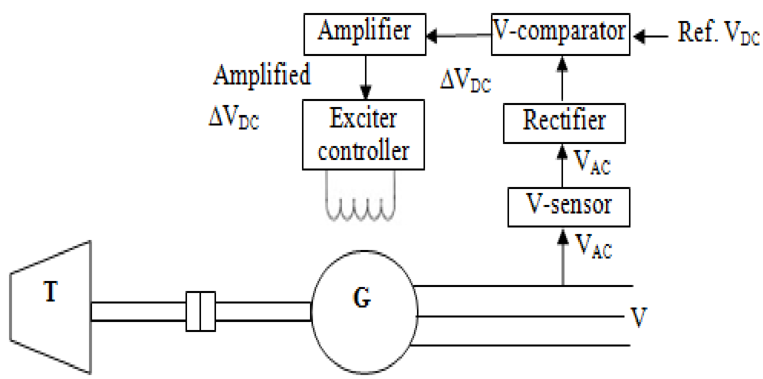
<table>
<tr><td></td><td></td><td>network.
Large disturbance means
▪ occurrence of major faults such as L-L, L-L-G, faults
▪ sudden increase in large amount of power demand
▪ faults following isolation of circuits / system
▪ Failure of major components of power system (Generators, transformer, transmission lines, circuit breakers etc).
▪ Switching off or ON of major transmission and distribution lines
▪ Transients and harmonics</td><td>Any 4 1M each</td></tr>
<tr><td>4.</td><td>(A)
(a)

Ans.</td><td>Attempt any THREE:
Explain steady state stability condition with the help of power angle diagram for power system.


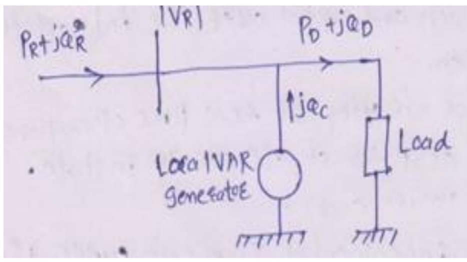
Suppose that generator is operating at steady state with load angle $\delta_0$and power flow P_0. Now Pg = Pd where Pg = power generator. And Pd= power demanded. Assume loss less system. Suppose an arbitrary change in load takes place that reduce the load angle to δ_1 and power P_1. Now the generator output is greater than load power that is at generating station generator input is greater than its output power so speed of generator accelerate and load angle also increases. Hence the system will oscillate around the load angle δ_0 and the oscillations would be damped and load angle would return to its original value δ_0.
A similar situation takes place if load angle increases to δ2. Now the generator output power is greater than input power. So generator retards, the load angle decreases and finally returns to its original value δ_0. Thus, if the system is operating at the load angle $\delta_0$is</td><td>12
4M

Diagram 2M

Explanation 2M</td></tr>
</table>

		subjected to small arbitrary disturbing forces, then regardless the direction of the force, the system returns to its original position.	
	(b) **Ans.**	**Draw neat & labeled diagram of Automatic voltage control system.** **Automatic Voltage Control/Automatic Voltage regulator (AVR):**  The automatic voltage, regulator (AVR) loop controls the magnitude of the terminal voltage V. The latter voltage is continuously sensed, rectified and smoothed. This D.C. signal, the resulting 'error voltage', after amplification and signal shaping serves as the input to the exciter which finally delivers the voltage V_f to the generator field winding.	**4M** ***Diagram 3M*** ***Labeled 1M***
	(c) **Ans.**	**List the methods of voltage control using transformers.** Following are the methods of voltage control in power system by using transformers… 1. By tap changing transformers: - Off load tap changing - On load tap changing 2. By regulating transformers 3. By Booster transformers 4. By auto transformer 5. By transformer with 1:1 ratio	**4M** ***Each method 1M***
	(d) **Ans.**	**List out the functions of National Load dispatch center.** **Functions of National Load Dispatch Centre:** 1. Supervision over the RLDCs. 2. Scheduling and dispatch of electricity over inter-regional links in	**4M**

		accordance with Grid standards specified by the Authority and Grid Code specified by the Central Commission in coordination with RLDCs. 3. Coordination with RLDCs for achieving maximum economy and efficiency in operation of National Grid. 4. Monitoring of operations and grid security of the National Grid. 5. Supervision and control over the inter regional links as may be required for ensuring stability of the power system under its control. 6. Co-ordination with Regional Power Committees for regional outage schedule in the national perspective to ensure optimum utilization of power resources. 7. Coordination with RLDCs for the energy accounting of inter-regional exchange of power. 8. Coordination for restoration of synchronous operation of National Grid with RLDCs. 9. Co-ordination for trans-national exchange of Powers. 10. Providing operational feed-back for National Grid planning to the Authority and the Central Transmission Utility. 11. Levy and collection of such fee and charges from the Generating Companies or the licensees involved in the power system as may be specified by the Central Commission. 12. Dissemination of information relating to operations of transmission system in accordance with directions or regulations issued by the Central Commission and the Central Government from time to time.	***Any 4 1M each***
4.	**(B)** **(a)** **Ans.**	**Attempt any ONE:** **Explain the method of voltage control by reactive power injection.** **Reactive power injection method for voltage control:** To keep the receiving end voltage at a specified value, a fixed amount of VARS must be drawn from the line. $Q_G = Q_D$ bus voltage is maintained at specific value. As VAR demand Q_D varies, a local VAR generator must be used as shown in fig. The VAR balance equation at the receiving end is now.	**06** **6M** ***Concept 3M***



$Q_G = Q_D + Q_C$
Any variation Q_D is are absorbed / injected by the local VAR generator and Q_G generated by the line remains fixed. This helps to keep the receiving end voltage constant.

Following are the equipment used to inject VARs in the system at different points ...

Generation system	Excitation control	Production of reactive power involves increasing the magnetic field to raise the generator's terminal voltage. To increase the magnetic field, increase the current in the field winding. Absorption of reactive power is limited by the magnetic-flux pattern in the stator, which results in excessive heating of the stator-end iron, the core-end heating limit.
Transmission system	Series reactors	Capacitors and inductors in HV and EHV trans. Line Static VAR system
Distribution system	Shunt reactors	Capacitor's bank Synchronous condenser Static VAR system

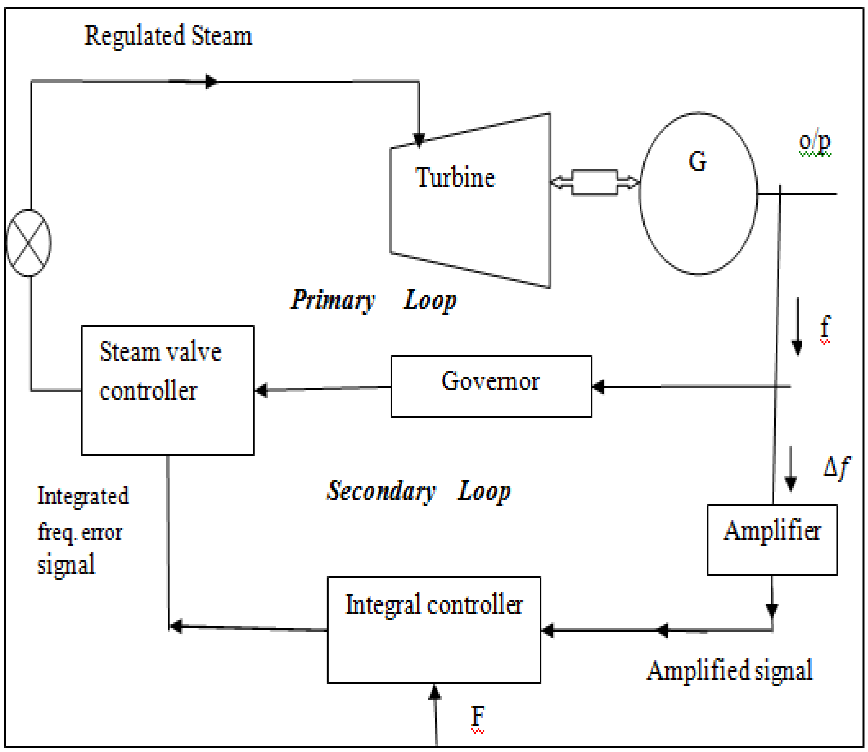
Each equipment 1M

(b) Ans. **State how social factors affect load forecasting of power system.** **6M**

Social factors affect load forecasting of power system:

Electricity consumers i.e. residential consumer, commercial consumers, industrial consumers are part of society. Hence their activities, events affect the power requirement. Following are the some of the activities that affect the load forecasting of power system. ***Each 1M***

		1) Energy consumption pattern: All 24hr,s of day load on system varies as consumer has freedom to use electricity whenever they required without any prior information. Hence daily load curves differ with the day. Also energy consumption pattern of various and type of consumer differs. To satisfy all consumers power generation must be varied with time. So during forecasting of load these factors must be considered. **2) Holidays/week ends and week days:** During power consumption pattern is nearly same but on weekends / Sundays power consumption pattern changes. Therefore their impact on load forecasting cannot be neglected. Public holidays also have considerable impact on load forecasting. Long weekend's creates more fluctuation in load demand. **3) School /college vacations:** Vacation period changes the daily routine of children and their stay at consumes power for their activities such as watching TV, playing video games, net surfing, watching films, etc. So in residential sector more power consumes by lighting and air-conditioning systems. **4) Festivals and National days:** During festivals like Diwali, Dashera, Christmas, Onam etc. more lightings are used for decoration purpose. This increases power consumption of residential as well as commercial sector. Hence they have to be considered for load forecasting. National days like Independence day, republic day, Maharashtra day etc. all government building are decorated with lights and more cultural programs were arranged. As power consumption is of considerable amount, their impact on load has to be considered in load forecasting. **5) Emergency conditions and Major accidents:** If sudden large variation power demands, failure of system components, faults (line-to-line, line-to-ground) in system, causes more imbalances in power demand and supply. It will put the system in transient stability condition. Also if major accidents takes place like sunami, wind storm, earth quack, snow storm, flood etc. may affects the infrastructure of power system. And so there may be major power failure. In such situations load forecasting becomes failure.	

		6) Special events: Labour strike in Industry, political events, VIP visits also creates large variation in power demand. These events cannot be neglected	
5.	**(a)** **Ans.**	**Attempt any FOUR:** **Draw a neat & labelled schematic diagram of 'Automatic Load Frequency Control' system.** 	**16** **4M** ***Diagram 3M*** ***Labeling 1M***
	(b) **Ans.**	**State the functions of the following in Turbine: speed governing system- Hydraulic amplifier-speed governor.** **i. Fly ball speed governor:** it senses the required change in speed by speed changer. When speed is to be increased, fly ball moves outwards and linkage mechanism moves downwards. The reverse happens when speed decreases. **ii. Hydraulic amplifier:** It comprises a pilot valve and main piston	**4M** ***Speed governo r 2M***

		arrangement. Low power level pilot valve movement is converted into high power level piston valve movement. It is necessary to open or close the steam valve against high pressure steam.	***Hydraulic amplifier 2M***
	(c) **Ans.**	**State the need of load forecasting in power system operation.** **Need of load forecasting in power system operation:** 1. Electricity is the most preferred form of energy & electrification is an ongoing process. 2. Demand for electricity tends to grow more rapidly for economic development 3. Increasing demand of electricity is due to several factors such as population growth, growth of per capital income migration to urban areas and increase in energy using products. 4. Understanding electricity demand, planning and control is critical for all countries. 5. Power system planning involves forecast of future load of both demand and energy. 6. Forecasting isuseful to determine capacity of generation transmission and distribution and decide generation facilities required. 7. Load forecasting is useful for establishing policy for procurement of capital equipment and fuel. 8. Forecasting is gaining importance due to increasing scarcity of electrical energy along with more powerful computing equipment and software.	**4M** ***Any 4 points 1M each***
	(d) **Ans.**	**State and explain the different planning tools used for power system operation.** **Types of Planning tools:** i. **Simulation Tools:** Load flow models, sc models transient stability models, production costing, adequacy calculations. ii. **Optimization tools:** Optimum power, least cost expansion planning, generating expansion planning iii. **The scenario techniques:** Sequence of events recording, possible outcomes, decisions, assumptions, computerize and automatic system.	**4M** ***Any 2 2M each***
	(e) **Ans.**	**Draw Input-Output curve of a generating unit and explain its nature.**	**4M**

MODEL ANSWER

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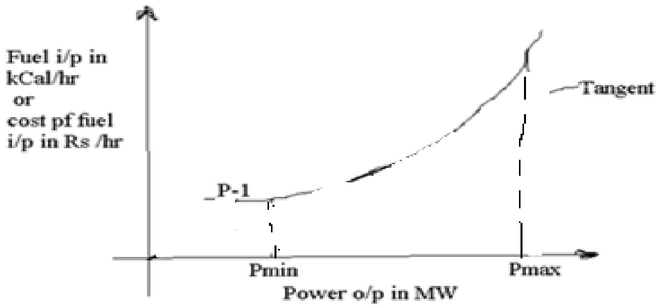
<tr><td></td><td></td><td>

It is the graphical representation of relation between input energy rate or cost of the fuel input per hour with power output in MW. It is a concave curve. Every point on the curve indicates the power output in M.W. corresponding to fuel input in kcal/hr.
The curve shows that as the load on the unit increases the rate of fuel input increases. But lower value of power output rise in the fuel input much less than that corresponding in higher range of power output. To find the fuel efficiency of the generating unit, draw a line joining point on the curve passing to the origin and now inverse of slope of this line is the fuel efficiency. To find the maximum fuel efficiency of the generating unit, draw a tangent to the curve passing through the origin. Inverse of slope this tangent is the maximum fuel efficiency of the generating unit. P_{min} & P_{max} indicates min & max limits of power generation which may be uneconomical or technically infeasible. (It depends on steam cycle, operational temp., and thermal property of fuel)</td><td>*2M for diagram*

2M for explanation</td></tr>
<tr><td></td><td>(f)

Ans.</td><td>**The incremental cost curve of two generating units are**

$$dF_1/dP_1 = 0.3\ P_1 + 50\ \text{Rs/MWh}$$

$$df_2/dP_2 = 0.4\ P_2 + 40\ \text{Rs/MWh}$$

Determine economical load distribution between the two units, if power load on power plant is 1200 MW.

$$\frac{dF_1}{dP_1} = 0.3P_1 + 50$$

$$\frac{dF_2}{dP_2} = 0.4P_2 + 40$$

For economic & load scheduling the incremental fuel cost must be same for all units. Hence we have</td><td>4M</td></tr>
</table>

$$\frac{dF_1}{dP_1} = \frac{dF_2}{dP_2}$$ *1M*

$\therefore 0.3P_1 + 50 = 0.4P_2 + 40$……….(1) *1M*

Total load on system is shared by two generating units.
Hence $P_1 + P_2 = 1200MW$ ……… .(2)

Now from equation 1 & 2,
$0.3\ P_1 + 50 = 0.4\ (1200 - P_1) + 40$

$0.3\ P_1 + 50 = 480 - 0.4P_1 + 40$ *1M*

$\therefore \mathbf{P_1 = 671.43\ MW}$ *1M*

hence $P_2 = 1200 - 671.43 = \mathbf{528.57\ MW}$

6. **Attempt any FOUR:** **16**

(a) **Determine the Y_{bus} admittance matrix for the power system with following details:** **4M**

Bus	Z_{line} in pu	Charging admittance in pu
1 – 2	0.2 + j 0.85	j 0.02
2 – 3	0.3 + j 0.88	j 0.03
1 – 3	0.25 + j 1.15	j 0.04

(Note: Charging admittance is not clearly specified so students can assume it as Y_{jj} or Y_{jk} or $Y_{jk}/2$. Solution is given assuming Y_{jj})

Ans.

Bus	Z_{line} in pu	Y_{line} in pu	Charging Admittance in pu
1 - 2	0.2 + j0.85	0.26 – j1.115	j 0.02
2 – 3	0.3 + j0.88	0.347 – j1.02	j 0.03
1 – 3	0.25 + j1.15	0.18 – j0.83	J0.04

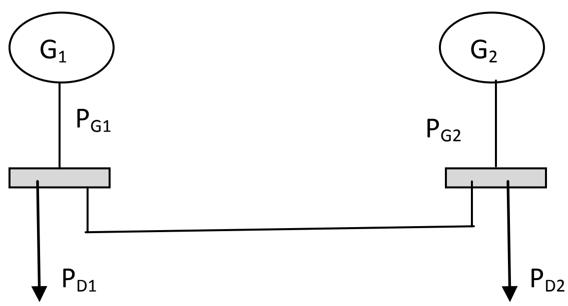
$$Y_{11} = y_{11} + y_{12} + y_{13}$$

= (j0.02) + (0.2 – j1.115) + (0.18 – j0.83)

= 0.44 – j 1.925

½ M for parameter and ½ M for Y_{bus}

		$Y_{22} = y_{21} + y_{22} + y_{23}$ $= (0.26 – j1.115) + j0.03 + (0.347 – j1.02)$ $= 0.607 – j2.105$ $Y_{33} = y_{31} + y_{32} + y_{33}$ $= (0.18 – j0.83) + (0.347 – j\,1.02) + j0.04$ $= 0.527 – j1.81$ $Y_{12} = Y_{21} - y_{12} = -y_{21}$ $= - (0.26 – j1.115)$ $Y_{13} = Y_{31} - y_{13} = -y_{31}$ $= - (0.18 – j0.83)$ $Y_{23} = Y_{32} - y_{23} = -y_{32}$ $= - (0.347 – j1.02)$ Required Y_{bus} is $\begin{vmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{vmatrix}$ $= \begin{vmatrix} (0.44 - j1.925) & (-0.26 + j1.115) & (-0.18 + j0.83) \\ (-0.26 + j1.115) & (0.607 - j2.105) & (-0.347 + j1.02) \\ (-0.18 + j0.83) & (-0.347 + j1.02) & (0.527 - j1.81) \end{vmatrix}$	
	(b) **Ans.**	**Give the advantages Y_{bus} representation in Load flow studies.** **Advantages Y_{bus} representation in Load flow studies:** i. Data preparation for LFs is simple ii. Its formation and modification is easy. iii. Y_{bus} is a sparse matrix. (i.e. most of its elements are zero). ∴ The computer memory requirements are less. For a large power system more than 90% of its off diagonal elements are zero.	**4M** ***1M for each point***

		iv. This is due to the fact that in power system network each bus is connected to not more than 3 buses in general & y_{pq} exists only if transmission line links bus p and q.	
	(c) **Ans.**	**Write swing equation and define its parameters.** $\frac{md^2\delta}{dt^2} = P_a = P_m - P_e$ $where m = angular momentum,$ $P_m = mechanical power input,$ $P_e = electrical power output,$ $P_a = accelerating power,$ $\delta = angular displacement of rotor$	**4M** ***Equation 1M*** ***Meaning of each term 3M***
	(d) **Ans.**	**Explain single area load frequency control concept.** **load-frequency control using single area case:**  In power system network single area is identified as single control area of the grid network, consisting number of generators supply power to all consumers in that area. All generators in this area are synchronized and they swing in unison to meet change in power demand of that area. i. e. they speed up or speed down simultaneously. Consider a control area consisting two generating plants connected through transmission line as shown in single line diagram. These generators are running in synchronism and their speed varies together by maintain their respective machine angels. At steady state condition, $P_{G1} + P_{G2} = P_{D1} + P_{D2}$. As load on generator G_2 increases, its output increases to meet the demand, while output of G_1 remains same. But speed of G_1 varies to maintain the synchronism and frequency. As load on generator G_2 go on increasing, its output increases up to its upper generation limit. Now to meet further increase in power demand, output of G_1 will increases and shares the power demand. If the demand is very large then both generators share the demand.	**4M** ***Diagram 1M*** ***Explanation 3M***

	(e) **Ans.**	**State the importance of ALFC and AGC in operation of power system.** **Importance of ALFC & AGC** i. The main objective of power system operation is to provide continuous reliable supply to the consumers. ii. The stability of a system depends on the balance between power generation and power demand. iii. The imbalance of real power reflected as variation of frequency which is control by ALFC. iv. The imbalance of reactive power flow reflected as variation in voltage profile is control by automatic voltage control system. v. ALFC and AGC have a feedback loop system installed at the generating station. Hence the take care off small variations in power demand without allowing the frequency or voltage to cross the limit. vi. The response time of this system is between 20 seconds to 1 minute	**4M** ***Any 4 1M each***
	(f) **Ans.**	**State the factors that govern the load shedding pattern in a power system.** **Factors that governs load shedding:** • Variations of frequency with respect to time in the event of deficit and subsequent load shedding. • Environmental impact on power system operations • Impact of public holiday s, festivals, social programs on power demand • To adapt energy conservation techniques • For optimal utilization of energy resources • To enhance use of renewable energy sources • For economical utilization of UPS, and Inverter system. • Nature of loads to be disconnected as well as their dependence on frequency and voltage • Behavior of system voltage before and after load shedding • Topographical distribution of energy reserves, load centers **OR** **Factors that governs the load shedding pattern in power system** 1) Imbalance between power demand & power generation 2) Sudden rise or fall in demand/ load 3) Major faults like 3 phase faults, L-L fault. turns into instability condition.	**4M** ***Any 4 1M each***

4) Sharing of power so to increase run time of critical loads.
5) To reduce wastage of energy & max demand
6) To adopt energy conservation objectives

OR

The factors governing load shedding duration:

- The imbalance between power demand and power generation due insufficient resources. To reduce effect of imbalance intentionally supply to some load are cut off.
- The sudden rise or fall in power demand leads to wide gap between demand and supply, and that results into instability in the system. To reduce effect of instability load shedding is carried out.
- Due to major faults like three phase short circuit fault, line to ground fault, failure of switch gears or major equipments instability condition occurs in the system. To reduce effect of instability load shedding is carried out.
- To reduce wastage of energy and to adopt energy conservation techniques supply to selective loads (mostly lighting loads) are shut off.
- To reduce the maximum demand of any industry or commercial complex local load shedding is carried out to reduce the peak demand and also to reduce energy bills.
- Refer to individual load; lighting control strategy is adopted for selectively reducing the output of light fixtures on a temporary basis so that it will reduce peak demand charges.
- Load shedding is carried out to selectively shut off a set of output receptacles so that the capacity of the UPS battery can be extended.
- To share power, the UPS switches off selected devices to increase run time of critical loads.
- The onset of summer every year brings with it the woes of load shedding. It has hit the manufacturing sector and many times forcing them to shut down operations resulting in losses worth several crore.
- Excessive drop in voltage profile in certain part of network then load shedding is carried out for compensation.