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

WINTER – 2016 EXAMINATION
Model Answer **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)**	**Attempt any THREE of the following:**	**12**
	(i)	**State the significance of bus in power system.**	***4M***
	Ans.	**Significance of buses –** • In a power system Bus is a node or junction where two or more than two transmission lines are connected. • Each bus or node is associated with four quantities -magnitude of voltage V, P, Q, and load angle "δ". • Bus data is required to study the performance & operation of power system network. • There are three types of buses classified in load flow analysis as ¯**Slack bus or swing bus**: In this bus voltage magnitude |Vi| and load angle δi are specified. This bus is the first to respond to changing load condition and is called as slack bus because it takes up slack in losses. ¯**Generator/ voltage control bus:** In this type of bus real power output Pgi and voltage magnitude |Vi| are specified. It means we specify the bus power Pi. The voltage of this types of bus can be controlled. ¯**Load bus:** for this type of bus we will have a prior knowledge of load power PLi and QLi. As these buses do not have any generator so PGi and QGi (generated power) are equal to zero and therefore is known as load bus.	***Each point 1M***

(ii) **State the advantage of reactive power compensation.** *4M*

Ans. **Advantage of reactive power compensation:**

1.Reduction in reactive component of circuit current
2. Maintenance of voltage profile within limits
3. Reduction of Copper losses in the system due to reduction of current.
4. Reduction in investment in the system per kw of load supplied
5. Decrease in KVA loading of generators and circuits. This decrease in KVA loading may relieve an overload condition or release capacity for additional load growth.
6. Improvement in p.f. of generators.
7. Reduction in KVA demand charges for large consumers
8. Overall improvement in system efficiency.

Each point 1M, Any 4 point

(iii) **List the data required for load flow studies with reference to transformers, transmission lines, buses and load.** *4M*

Ans. (1) Single line diagram of a power system.

(2) Transmission line data –
  (a) Line parameters – Series impedance (z) in per unit shunt admittance (y) thermal limits of the line.
  (b) Length of the line.
  (c) Identification of each line and its II equation circuit.

(3) Transformer ratings, impedance and tap setting 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.

(4) At certain buses, static capacitors are used for voltage level improvement their admittance value should be clearly specified.

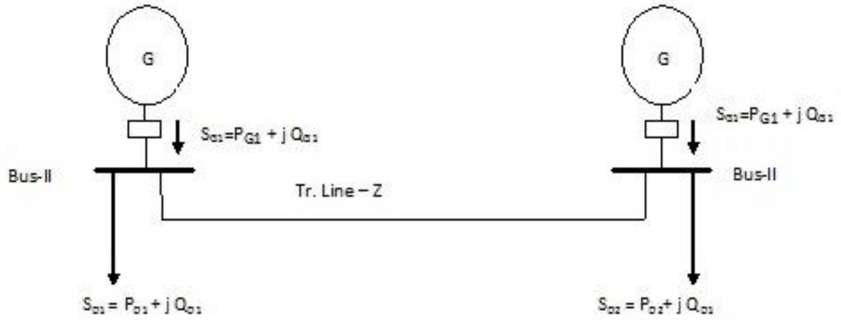
(5) Some of lines may be tuned for the purpose of voltage stabilization, by using shunt reactors or series capacitors. Their values should be made available.

(6) Depending upon no. 07 buses in they system bus data should be made available: -

Type of Buses	No. of Buses	Bus data
Generator Bus		P,(V)
Load Bus		P,Q

(7) If the load flow study is to be carried out for a specified load demand then the most effective manner in which generation can be scheduled at the various buses so as to ensure the desired voltage

Any four points 1M for each

		profile. (8) A no. of load flow solutions are possible for different sets of control parameters. It is therefore necessary to define and objective functions so as to ensure the desired voltage profile.	
	(iv) Ans.	**Define following term:** **1) Steady state stability and its limit** **2) Transient state stability and its limit** **Transient stability:** Transient stability is the ability of the power system to regain or maintain equilibrium conditions after experiencing a large sudden disturbance. **Transient state stability limit**: It refers to max possible flow of power through a point without loss of stability when system experiences a large sudden disturbance. **Steady state stability:** when the power system has capacity to regain and maintain equilibrium condition (synchronous speed) after a small slow disturbance such as road variation or changes in load condition occurs, then the phenomenon is known as steady state stability. **Steady State stability limit:** It is defined as max power which can flow through point in the system without causing loss of stability, when system experiences a small disturbance.	***4M*** ***Transient stability 1M*** ***Transient state stability limit:1M*** ***Steady state stability: 1M*** ***Steady State stability limit: 1M***
1.	**b)** **(i)** Ans.	**Attempt any <u>ONE</u> of the following:** **For a simple two bus power system derive the equation $\mathbf{I_{bus} = Y_{bus}V_{bus}}$.** Consider a simple two bus power system as shown in figure.  	**6** ***6M*** ***1M***

Let S_{G1}&S_{G2} be the power injected by the generators in bus – I and bus – II respectively which was measured on the h. v. side of the transformers. Let S_{D1}&S_{D2} be the load demands on bus I& bus II respectively. Two buses are inter connected by a transmission line having $\prod$ equivalent ckt. Let $V_1$and V_2be the voltage at two buses I & II respectively. Let S_1&S_2 be the bus power which is defined as difference between generated power and load demand.

Hence,

$S_1 = S_{G1} - S_{D1}$
$= (P_{G1} - P_{D1}) + j(Q_{G1} - Q_{D1)}$
$= P_1 + jQ_1$

And

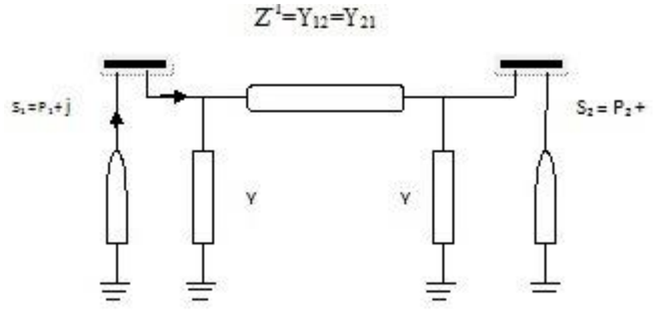
$S_2 = S_{G2} - S_{D2}$
$= (P_{G2} - P_{D2)} + j(Q_{G2} - Q_{D2})$
$= P_2 + jQ_2$

1M

This bus power can be considered as the power injected into the bus by a bus power source Hence equivalent ckt. For the given system can be drawn as follow.

Let I_1 – net current entering bus –I_1
I_2 – net current entering bus - II
i.e. bus current of bus - II

Diagram:



Bus power S_1 can also be written as,

$$S_1 = V_1/I_1^* I_1^* = S_1/V_1 I_1 = S_1^*/V_1^* S_{G1}$$

Where I_1enters tr. Line from bus – I.
By applying KCL at bus – I ,
we get

$$I_1 = V_1 Y + (V_1 - V_2)Y'$$

We get$I_1 = \frac{S_1^*}{V_1^*} = V_1 Y + (V_1 - V_2)Y'$------------------------(1)

$I_2 = \frac{S_2^*}{V_2^*} = V_2Y + (V_2 - V_1)Y'$-----------------------------------(2) **1M**

The above two equations can be simplified as

$I_1 = V_1(Y + Y') - Y'V_2$---------------------------------------(3) **1M**

$I_1 = -Y_1Y' + (Y + Y')V_2$------------------------------------(3)

Let $Y + Y' = Y_{11} = Y_{22}$

$-Y = Y_{12} = Y_{21}$

Substituting in above equn, we get

$I_1 = Y_{11}V_1 + Y_{12}V_2$--(4)

$I_2 = Y_{21}V_1 + Y_{22}V_2$---(4) **1M**

Above eq can be written in matrix form as,

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} + \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$--(5)

i.e **1M**

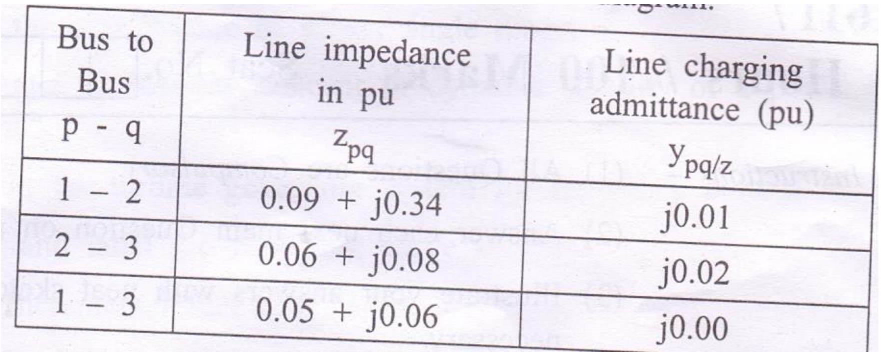
$I_{bus} = Y_{bus} + V_{bus}$---(6)

I bus = bus current vector

V bus = bus voltage vector

Y bus – bus admittance matrix = $\begin{vmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{vmatrix}$

(ii) **Draw single line diagram of a power system with the following data. Also draw admittance diagram** **6M**



Bus to Bus p - q	Line impedance in pu z_{pq}	Line charging admittance (pu) $y_{pq/z}$
1 – 2	0.09 + j0.34	j0.01
2 – 3	0.06 + j0.08	j0.02
1 – 3	0.05 + j0.06	j0.00

and calculate self- admiitances.

Ans.

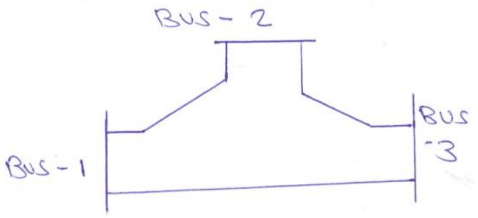
Powler system Operation 17643
And control

b) ii)

:-

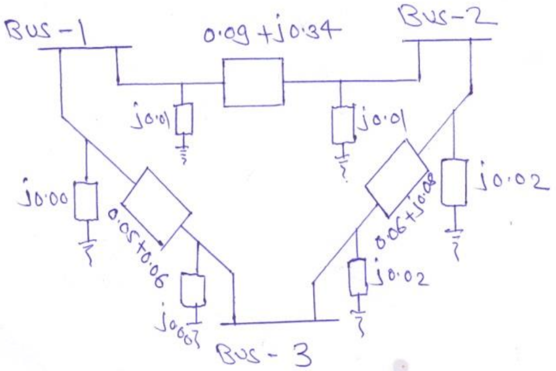
1) single line diagram of Power system - (1M)

1M



2) Admittance Diagram :- (2M)

2M



3) solution :-

Y_{11}, Y_{22} & Y_{33} are the self Admittances

$Z_{12} = 0.09 + j0.34$, $y_{12} = \frac{1}{Z_{12}} = \frac{1}{0.09 + j0.34}$

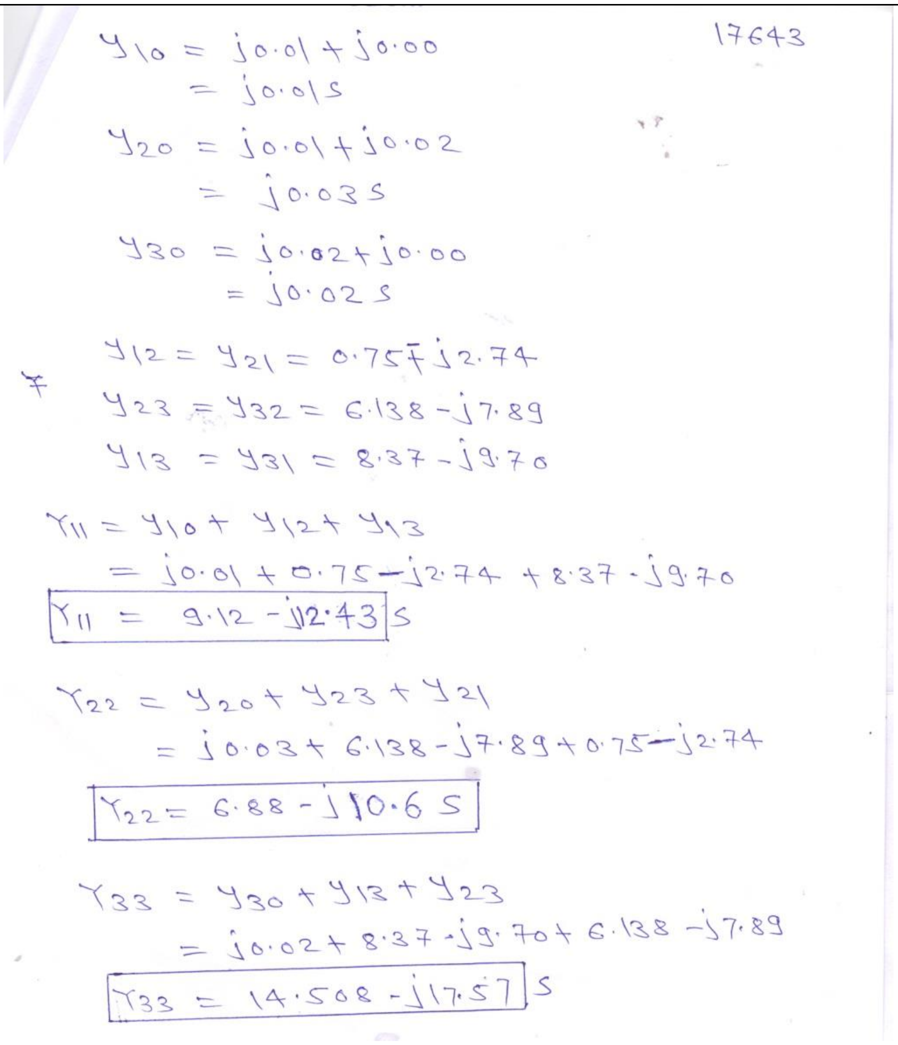
$\boxed{y_{12} = 0.75 + j2.74}$ s

$Z_{23} = 0.06 + j0.08$, $y_{23} = \frac{1}{Z_{23}} = \frac{1}{0.06 + j0.08}$

$\boxed{y_{23} = 6.138 - j7.89}$ s

$Z_{13} = 0.05 + j0.06$, $y_{13} = \frac{1}{Z_{13}} = \frac{1}{0.05 + j0.06}$

$\boxed{y_{13} = 8.37 - j9.70}$ s



17643

$y_{10} = j0.01 + j0.00$
$= j0.01\,S$

$y_{20} = j0.01 + j0.02$
$= j0.03\,S$

$y_{30} = j0.02 + j0.00$
$= j0.02\,S$

$y_{12} = y_{21} = 0.75 \mp j2.74$

$y_{23} = y_{32} = 6.138 - j7.89$

$y_{13} = y_{31} = 8.37 - j9.70$

$Y_{11} = y_{10} + y_{12} + y_{13}$
$= j0.01 + 0.75 - j2.74 + 8.37 - j9.70$
$\boxed{Y_{11} = 9.12 - j12.43}\,S$ *1M*

$Y_{22} = y_{20} + y_{23} + y_{21}$
$= j0.03 + 6.138 - j7.89 + 0.75 - j2.74$
$\boxed{Y_{22} = 6.88 - j10.6\,S}$ *1M*

$Y_{33} = y_{30} + y_{13} + y_{23}$
$= j0.02 + 8.37 - j9.70 + 6.138 - j7.89$
$\boxed{Y_{33} = 14.508 - j17.57}\,S$ *1M*

2. **Attempt any FOUR of the following:** **16**

a) **Explain relation between real power flow and frequency.** *4M*

Ans. We have studied that if there is variation in the real power flow through the system that is reflected in variation of frequency. Now the real power flow in a system include generated power, load connected the system and power demanded by the system. The system also requires some power to overcome losses in it.

Explanation 4M

Losses in the system includes:

1) Losses in the transmission lines (I^2R)
2) Losses due to corona
3) Losses in Transformer, generator etc.

We know that electrical energy cannot be stored .Whatever amount of energy is generated has to be utilized at the same moment .That means rate of energy generation must be met by rate of power consumption.

We also know that energy transmitted at almost velocity of light. Hence real power flow through the system can be written in equation form as$P_g = P_d + P_L$i.e. power balance equation.

If this equation is not satisfied then difference between generated power and used power will enter into or exit from kinetic energy storage in prime mover. This kinetic energy decides the speed of the generator .Hence imbalance in power is reflected in variation in speed i.e. variation of frequency of generated voltage.

Under normal operating condition the system generator run synchronously and generate together the power that at each moment is being drawn by all load plus the real transmission losses.

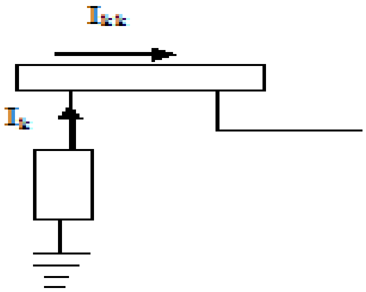
If there is sudden drop or rise in load demand or fault occurred or failure of generator then unbalanced is caused then, $P_g < P_D$ or $P_g > P_D$So this difference enters or exits in kinetic energy of prime mover, hence speed of generator i.e. frequency of generated e.m.f. varies. It is understand that variation in the power i.e due to variation in the load causes variation in frequency. Say suddenly all the loads connected to the system are put off then,$P_g \neq P_d + P_L$i.e

$P_g > P_d + P_L$i.e power balance is disturbed.

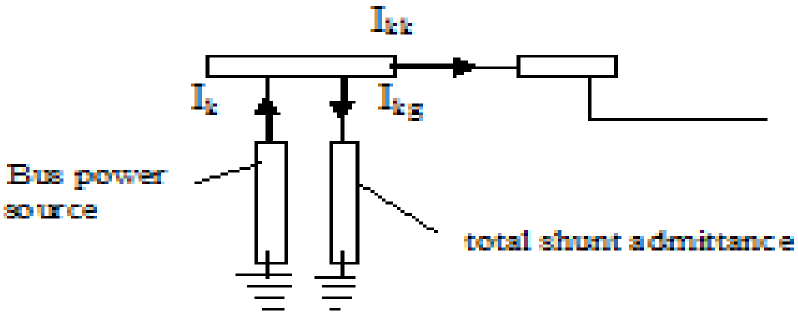
Now $P_g >>> P_L$Hence speed of the generator i.e frequency of the supply increases, But due to over speed protective system will operate and generators are trip off.

Similarly when load on the system suddenly increases then, $P_g > P_d + P_L P_g$

In this condition load tries to draw more power from the generator s

		than its capacity and as Pg is less, supply frequency reduces due to decrease in the speed of the generator and therefore of action of protective system generators will be trip off. If generators are trip off, we cannot restore the supply immediately or instantly .Generator units in hydro power station require half an hour in restart generation .Thermal power station requires more, once the generator started they have to be connected in parallel. Load on the system has to be increased in discrete steps.	
	b) Ans.	**Explain why the consumer demand constant frequency supply.** **Consumers required constant frequency supply because:** 1) In most of the industries, induction motor is use 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. 2) Induction motor used as a common ac drive, though has rigid construction but due to variation in supply frequency, life of induction motor reduces by 500Hrs. They are not sensitive for small variation in the supply frequency. 3) In railway station the electric chokes are driven by single phase synchronous motor, the speed of synchronous motor depends on supply frequency directly. Hence it need constant frequency supply 4) In some industries such as the textiles rubber, plastic & paper require frequency constant.	***4M*** ***1M each points***
	c) Ans.	**State and explain 'Bus Loading' and 'Line Flow equation'.** **Bus Loading:** The real of reactive power at any kth bus can be written as $$S_k = P_k - jQ_k = V_k^* I_K$$ Current at bus I $I_k = \frac{P_k - Q_k}{V_k^*}$ Bus Current $I_k$is positive when if flows into the system.  If the shunt elements are neglected or considered in Y_{bus}matrix then	***4M*** ***Explanation of bus loading 2M***

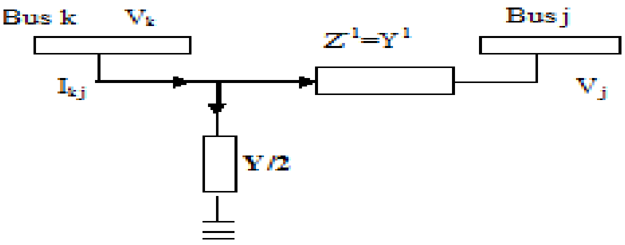
above equation represents bus current i.e. bus loading $I_k = I_{kk}$.
If the shunt elements is considered then equivalent ckt. For bus can be drawn as.



Now the net current through bus -I_{kk}=$I_k - I_{kg}$

= $\frac{P_k - Q_k}{V_k^*}$ -$V_k Y_{kk}$
When Y_{kk}=Total Shun Admittance.

Lines Flow Equation:



Explanation of Line flow equation 2M

Assume that current is flowing through 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 flows from j to k is

<table>
<tr><td></td><td></td><td>$P_{jk} - jQ_{jk} = V_j^{*} I_{jk} = V_j^{*}(V_j - V_k)y^1 + V_j^{*} V_j Y/2$

The above two equations are called as “Line flow equation”. The algebraic sum of power expressed by above equations gives power loss in the transmission line k – j.</td><td></td></tr>
<tr><td></td><td>d)
Ans.</td><td>Write SLFE for a two bus system and define its parameter.
SLFE Equation:

<table>
<tr><td>$S_1{}^{*} = V_1{}^2 Y_{11} \text{Lœ}_{11} + Y_{12} V_2 V_1 \angle(\delta_2 - \delta_1) = P_1 - j Q_1$</td><td>$S_2 {*} = V_2{}^2 Y_{22} \text{Lœ}_{22} + Y_{21} V_2 V_1 \angle(\delta_1 - \delta_2) = P_2 - j Q_2$</td></tr>
<tr><td>$P_1 = V_1{}^2 Y_{11} \text{Cosœ}_{11} + Y_{12} V_2 V_1 \text{Cos}(\delta_2 - \delta_1)$</td><td>$P_2 = V_2{}^2 Y_{21} \text{Cosœ}_{22} + Y_{21} V_2 V1 \text{Cos}(\delta1 - \delta2)$</td></tr>
<tr><td>$Q_1 = (V_1{}^2 Y_{11} \text{Sinœ}_{11} + Y_{12} V_2 V_1 \text{Sin}(\delta_2 - \delta_1)$</td><td>$Q_2 = (V_2{}^2 Y_{22} \text{Sinœ}_{11} + Y_{12} V_2 V_1 \text{Sin}(\delta_1 - \delta_2)$</td></tr>
</table>

For a simple two bus system Load flow equations can be written as….
$P_1 = V_1{}^2 Y_{11} \text{Cos œ}_{11} + Y_{12} V_2 V_1 \text{Cos}(\delta_2 - \delta_1) = (P_{G1} - P_{D1})$
$Q_1 = -[(V_1{}^2 Y_{11} \text{Sin œ}_{11} + Y_{12} V_2 V_1 \text{Sin}(\delta_2 - \delta_1) = -(Q_{G1} - Q_{D1})$

$V_1, V_2 \ldots V_n$ are the bus voltages
$\delta_1, \delta_2 \ldots$ are load angles with reference to bus-1, bus-2 and so on.
$Y_{11}, Y_{22} \ldots$ are self admittance with reference to bus-1, bus-2 and so on.
$Y_{12}, Y_{21} \ldots$ are Mutual admittance with reference to bus-1, bus-2 and so on
$S_1, S_2 \ldots$complex power at bus-1, bus-2.
$P_1, P_2 \ldots$Real power at bus-1, bus-2.
$Q_1, Q_2 \ldots$Reactive power at bus-1, bus-2.</td><td><i>4M</i>

<i>SLFE 3M, Define parameter 1M</i></td></tr>
<tr><td></td><td>e)

Ans.</td><td>State the difference between ‘Power system stability’, ‘Power system instability’, ‘Stability limit’ and ‘Overall stability’.
i) Overall stability:
It is the stability of the power system when synchronism of one of working generator has been lost the normal operating condition can be reestablished without disconnection of major elements.

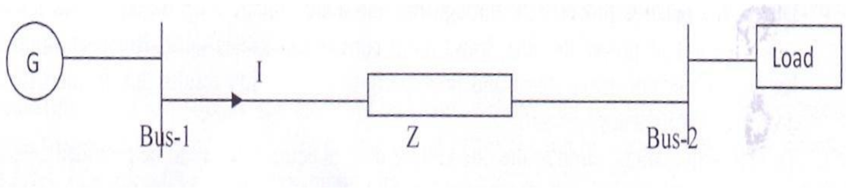
ii)Power System Stability:
It is ability to return to normal or stable operation after having been subjected to some form of disturbance.

iii)Power System instability:</td><td><i>4M</i>

<i>1M</i>

<i>1M</i>

<i>1M</i></td></tr>
</table>

		It is status of system when it looses its normal stable operating condition because of increase in power demand beyond the capacity of power generation. **iv) Stability Limit:** It is the maximum power flow possible though same particular point in the system when the entire system or part of the system to which the stability limit refers is operating with stability.	*1M*
	f) Ans.	**List out the adverse effects of power system instability.** 1) It delivers unreliable power. 2) Supply parameters fluctuate beyond the tolerance limit. 3) Non-economical power generation, transmission and distribution takes place. 4) The system experiences failure of system components which may lead to measure of power failure. 5) Operation of the system under unstable condition leads to damaging of power system components as well as loads connected to system network.	*4M* *Each point 1M*
3.	**a)** Ans.	**Attempt any FOUR of the following:** **Prove that reactive power flow through a transmission line causes voltage drop in the line.** Prove that the voltage drop in the line is mainly due to reactive power flow and not real power Consider a simple power system represented by a single diagram.  Let V_1 be Bus voltage at bus 1 Let V_2 be bus voltage at bus 2 Two buses are interconnected by a short transmission line with zero line losses (i.e. R=0) $\therefore Z = jX$ Maintain the voltage at bus 1 by regulating output voltage of generator Now = $V_2 = V_1 – IZ$ Complex power at bus 1 is	**16** *4M*

$S = V_1 I_1^* = P + j\,Q$…………………… assuming inductive

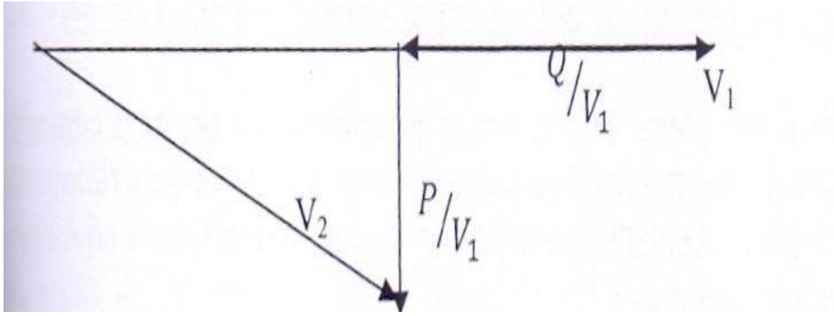
2M

$\therefore I = \text{p} - \text{jQ v1}\ X$

$$V_2 = V_1 - \left(\frac{P - jQ}{V_1}\right) jX$$

$$= \left(V_1 \frac{Q_1}{V_1}\ X\right) - j\,\frac{P}{V_1}\ X$$

The above equation can be represented in vector form as



From this vector diagram it is clear that the load voltage $V_2$is not affected much due to real component of the load P as it is normal to the vector V_1 whereas the drop due to reactive component of load is directly subtracted from the voltage V_1.

2M

Assuming the voltage drop due to real power negligible, the voltage drop is directly proportional to the reactive power Q.
$V_2 = V_1 - (Q/V_1)\ X$
$V_1 - V_2 = +\ (Q/V_1)\ X$
In order to keep the receiving end voltage V_2 fixed the drop QVX must remain constant this shows that $V_1\text{-}V_2\ \alpha\ Q$
Any variation in Q will vary the voltage drop i.e. voltage of bus 2. Hence locally Q can be supplied to the load to maintain V_2 constant.

b) **List out the various methods of reactive power compensation and state their field of application.**

4M

Ans. The equipments used for this are called reactive power compensating equipments. These equipments are classified as:

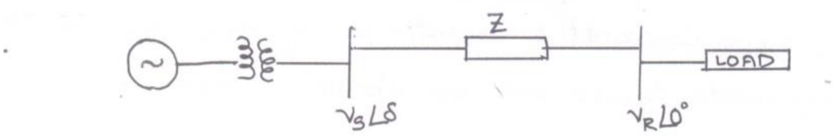
1. Shunt compensation
    - Shunt reactors
    - Shunt capacitors
    - Static VAR system (SVS)

Methods 2M

2. Synchronous compensation

		• Synchronous phase modifiers 3. Series compensation • Series capacitors **Application of compensation equipments:-** ➢ **Shunt reactors:-** • Under light load condition there causes Ferranti effect on EHV and UHV lines, so shunt reactors are used to compensate capacitive VAR of the line and to regulate the voltage within the prescribed limits. • Shunt reactors are also installed on EHV and UHV lines at an interval of 300KM in intermediate sub stations, receiving end sub-stations and sending end sub-stations to limit the voltage levels. • They are also located at tertiary windings of power transformer. ➢ **Shunt Capacitors:-** • Near the load terminals in receiving end sub-station, distribution sub-station and in switching sub- station. • In transmission lines they are connected either to the tertiary winding of the power transformer or to the bus bar ➢ **Static VAR system:-** • For continuous supply of controlled leading / lagging vars independently. ➢ **Synchronous phase modifier:-** • They are connected in parallel with the loads at the receiving end of the transmission system. ➢ **Series compensation:-** • The series compensators may be located at the sending end or receiving end or at the centre of the line. They are distributed at two or more no. of points along the line.	***Applications 2M***
	c) Ans.	**State the necessity of load flow analysis referred to power system operation.** A load flow study gives magnitude & phase angle of the voltage at each bus, real and reactive power flow through transmission. Lines, current flow through transmission lines. 1) For designing the power system. 2) For operation of the system. 3) For future expansion of the system to meet increase in the demand. 4) For inter connecting the two systems to meet the load demand.	***4M*** ***Any four 1M each***

		5) For analyzing both normal and abnormal (means outage of tr. Lines or transformer or gen. units) operating conditions. 6) For analyzing the initial conditions of the system when the transient behavior of the system is to be studied. 7) 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. 8) LFA also helps in maintaining the stability of the system by giving the information about real, reactive power flow in the system.	
	d) Ans.	**State the informations that can be obtained from load flow studies.** 1) We get MW and MVAR flow in the various parts of the system network. 2) We get information about voltages at various buses in the system 3) We get information about optional load distribution. 4) Impact of any change in generation on the system. 5) Influence of any modification or extension of the existing circuits on the system loading. 6) It also gives information for choice of appropriate rating and tap setting of the power transformer in the system. 7) Influence of any change in conductor size and system voltages level on power flow.	***4M*** ***Any Four 1M each***
	e) Ans.	**State the significant features of Y_{bus}.** **Features of Y_{bus}:** 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 II or 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 $Y_{11} = Y_{11} + Y_{12} + Y_{13}$	***4M*** ***Any 4 1M each***

		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.	
	f) Ans.	**Write swing equation and define each term in it.** $\frac{md^2\delta}{dt^2} = P_a = P_m - P_e$ $where\ m = angular\ momentum,$ $P_m = mechanical\ power\ input,$ $P_e = electrical\ power\ output,$ $P_a = accelerating\ power,$ $\delta = angular\ displacement\ of\ rotor$	***4M*** ***Equation 1M*** ***Meaning of each term 3M***
4.	**a)** **(i)** Ans.	**Attempt any THREE of the following:** **Derive the expression for maximum power limit under steady state stability condition of a power system.**  Complex power at receiving end is given by, $P_R = \frac{V_S.V_R}{B}\cos(\beta - \delta) - \frac{AV_{R^2}}{B}\cos\beta$ $- \alpha)$ Consider a transmission line whose shunt admittance are neglected, i.e. Y=0. Now, Equivalent circuit of medium & long transmission line is similar to that short transmission line having GCC as, A=1∠0°& B=Z∠B. Subtitling in above Equation we get, $P_R = \frac{V_S.V_R}{Z}\cos B - \delta) - \frac{V_{R^2}}{Z}\cos\beta$	**12** ***4M*** ***½ M*** ***1M***

$$= \frac{V_R}{Z}[V_S.\cos(B-\delta) - V_R\cos\beta]\times\frac{Z}{Z}$$

½ M

$$= \frac{V_R}{Z^2}[V_S.Z\cos(B-\delta) - V_R\,.R] \ldots..(asZ\cos\beta = R)\ldots\ldots(1)$$

1M

'P_R' will be maximum if $\frac{dP_R}{d\delta} = 0$

$$\therefore \frac{dP_R}{d\delta} = \frac{V_R}{Z}[V_S.Z\sin(B-\delta)] = 0$$

$$\therefore \sin(B-\delta) = 0$$

½ M

$\therefore \beta$-δ=0; $\therefore \beta$=δ

$\therefore$Substituting in Eq^n in (1), we get

$$P_{R_{max}} = \frac{V_R}{Z^2}[V_S.-V_R.R]$$

$$= \frac{V_R}{(R^2+X^2)}\left[V_S.\sqrt{R^2+X^2} - V_R.R\right]$$

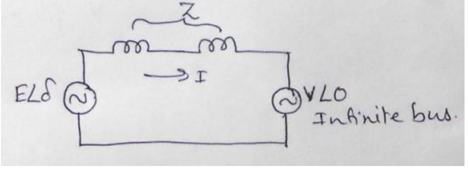
½ M

$$P_{R_{max}} = \frac{V_S.V_R}{\sqrt{R^2+X^2}} - \frac{V_{R^2}.R}{(R^2+X^2)}$$

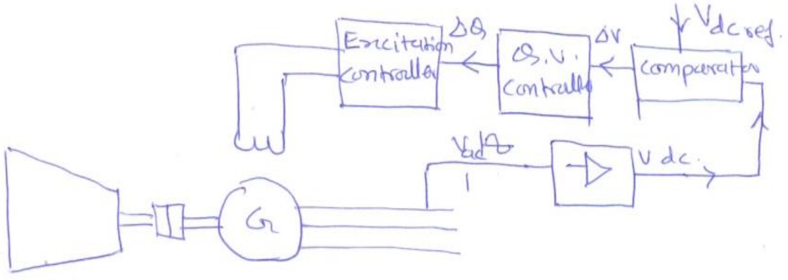
This is max steady state power

OR

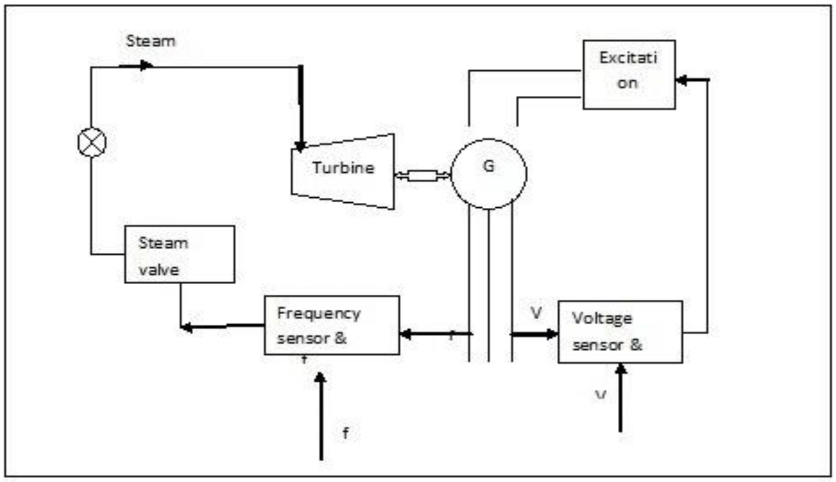
Consider equation of current through impedance Z as



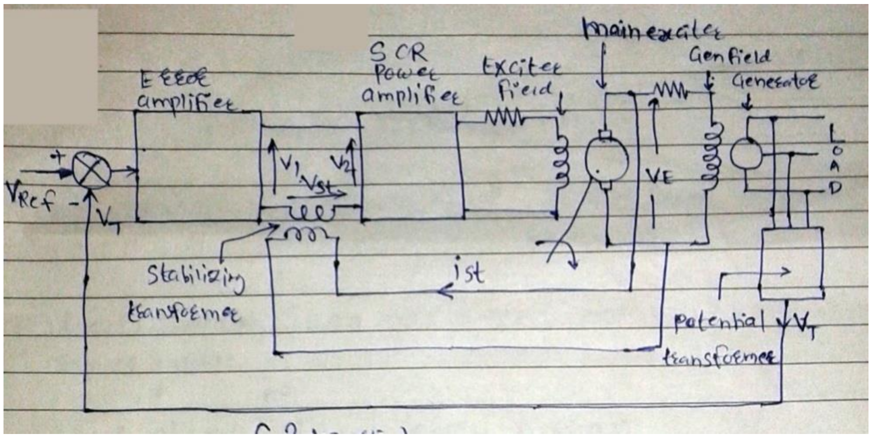
1M

		$I = \frac{\lvert E\rvert\angle\delta - \lvert V\rvert\angle 0}{z\angle\theta} = \frac{\lvert E\rvert}{\lvert Z\rvert}\angle\delta - \theta - \frac{\lvert V\rvert}{\lvert Z\rvert}\angle - \theta$ $I^* = \frac{\lvert E\rvert}{\lvert Z\rvert}\angle\theta - \delta - \frac{\lvert V\rvert}{\lvert Z\rvert}\angle\theta$ $s = VI^* = \frac{\lvert V\rvert\lvert E\rvert}{\lvert Z\rvert}\angle(\theta - \delta) - \frac{\lvert V\rvert}{\lvert Z\rvert}\angle\theta$ $P_e = R_e[S] = \frac{\lvert V\rvert\lvert E\rvert}{\lvert Z\rvert}\cos(\theta - \delta) - \frac{\lvert V\rvert^2}{\lvert Z\rvert}\cos\theta$ $z = R + JX = \sqrt{R^2 + X^2}\angle\tan^{-1}(\frac{X}{R})$ $\alpha = (90 - \theta) = \sin^{-1}\left(\frac{R}{Z}\right)$ $P_e = \frac{\lvert V\rvert\lvert E\rvert}{\lvert Z\rvert}\cos(90 - \alpha - \delta) - \frac{\lvert V\rvert^2}{\lvert Z\rvert}\cos(90 - \alpha)$ $= \frac{\lvert V\rvert\lvert E\rvert}{\lvert Z\rvert}\sin(\alpha + \delta) - \frac{\lvert V\rvert^2}{\lvert Z\rvert}\sin\alpha$ $P_e ismaximumwhen (\alpha + \delta) = \frac{\pi}{2}$ $hence, P_{emax} = \frac{\lvert V\rvert\lvert E\rvert}{\sqrt{R^2 + X^2}} - \frac{\lvert V\rvert^2}{\sqrt{R^2 + X^2}} \times \frac{\lvert R\rvert}{\sqrt{R^2 + X^2}}$ $ifE = V$ $P_{emax} = \frac{\lvert V\rvert^2}{\sqrt{R^2 + X^2}} - \frac{-\lvert V\rvert^2 R}{R^2 + X^2}$	***1M*** ***1M*** ***1M***
	(ii) Ans.	**Draw a labeled schematic diagram of 'Automatic Voltage Control' system.** 	***4M*** ***Diagram 3M label 1M***

OR



OR



(iii) **State the need of load forecasting in power system operation.** ***4M***

Ans.

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

Explanation 4M

		demand and energy. 6. Forecasting is useful 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.	
	(iv) Ans.	**List any four factors which govern the load shedding in power system.** ***(Note: Any other points)*** **Factors that affect 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	***4M*** ***Any 4 1M each***
4.	**b)** **(i)** Ans.	**Attempt any ONE of the following:** **What are the different methods of voltage control using transformer?** • Regulating Transformer: ………. Location – Distribution Substations, • Tap changing transformer (OLTC)… Location- Intermediate Distribution Substations. • Booster transformer: …. Location- HV and EHV transmission lines **1) Online tap changing transformer:** All transformers are provided with taps on the winding for adjusting the ratio of transformation. Taps are usually provided on the high voltage winding to enable a fine control of voltage. Generally the tap	**6** ***6M*** ***2M each method***

		changing can be done any when the transformer is in de-energized state. However in some cases tap changing is also possible when the transformer is energized. These transformers make it possible to maintain a constant voltage level on important buses in the system. **Location: Intermediate distribution Substation** **2) Regulating transformer:** A special type of transformer designed for small adjustments of voltage is known regulating transformer. The fig. shows a typical arrangement to use a regulating transformer for voltage mag control in a 3 phase ckt. A 3 phase transformer provides on adjustable voltage to the primary of the regulating transformer. The secondary of the regulating transformer are connected in series with the lines. Thus a voltage magnitude 0volt to the voltage of each phase. **Location: distribution Substation** **3) Booster Transformer:** Sometimes it is designed to control the voltage of transmission line at a point for away from the main transformer. This is conveniently achieved by the use of booster transformer. The secondary of booster transformer is connected in series with the line whose voltage is to be controlled. The primary of this transformer is supplied from a regulating transformer with on load tap changing gear. **Location: HV &EHV transmission Line**	
	(ii) Ans.	**State the factors that affect load forecasting.** **Factors affecting load shedding:** **Environmental factors:** Load Forecasting plays important role in power system planning & operation of system. Environmental factors also affect the load forecasting but their influence varies from area to area and country to country. Hence Environmental factors are important in load forecasting. 1. **Weather dependent factor:** Electric load has a co-relation to weather .The most important weather parameters such as dry & wet weather, dew point humidity, wind speed, wind direction, Sky cover, Sunshine responsible for load changes. We have observed that due to change in weather the domestic load, public lighting load, commercial loads etc. varies. Therefore it is necessary to determine the correlation between weather parameters and model their influence	***6M*** ***Any 6 with brief explanation each point 1M***

on power assumption.

2. **Time dependent factor:** Load demand in a power system is dependent on time and hence shows regular, irregular and random nature. Regular nature is observed during the time of day, day of week, week of the year and yearly growth. Irregular nature is observed on holidays weekends & special days. Load requirements on these days also tend to differ.

Random nature of forecast is observed when load demand does not follow any pattern because of random change in weather condition or transient faults. In random weather change (i.e. unseasonal rain, fog, and cloud cover) brings random variation in load on power system and results into occurrence of transient faults in system. Ultimately it affects the power flow through the system. Hence these factors are to be considered in load forecasting.

3. Random weather change: Storm, heavy rain, flood, sunami etc. Sudden change in weather will affect the infrastructure of the power system and there by large disturbance takes place and load demand varies. So weather forecast, are to be considered while forecasting power loads.

Social factors:

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.

1) **Energy consumption pattern:** All 24hrs 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 weekends create more fluctuation in load demand.

3) **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. 4) **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. **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 in load forecasting.	
5.	**a)** Ans.	**Attempt any FOUR of the following:** **State and explain the factors affecting the transient stability of a power system.** **Factors affecting Transient Stability:** i) Generators play a vital role in any power system. Their characteristics have a significant impact on the stability characteristics of the system. ii) Under transient conditions, the transient reactance, rotor inertia (inertia constant), excitation response and the electrical damping provided by the generator rotor and the mechanical damping by the prime mover determine the generator performance. iii) From swing equation the acceleration of the rotor ${d^2\delta}/_{dt^2}$ is inversely proportional to the moment of inertia of the machine, when accelerating power is constant, which means higher the moment of inertia, the slower will be the change in rotor angle, hence longer time for breaker operation. iv) By reducing the switching time and also the transient reactance, power limit can be substantially improved. v) Voltage regulators improve stability limits subsequent to the first	**16** ***4M*** ***1M for each***

swing oscillation, after the clearing of the faulty section.
Excitation response

b) **Sate and explain any two methods that can be adopted for the improvement of transient stability condition of power system.** *4M*

Ans. There are main two methods: Traditional Technique and New Approaches

Traditional Technique:

i) Effect of generator design.
ii) Increase of voltage
iii) Reduction in transfer reactance
iv) Rapid fault clearing
v) Automatic reclosing

New Approaches:

i) Quick valve opening action.
ii) Application of braking resistors
iii) Single pole switching
iv) Fast acting automatic voltage regulator

Any two methods from any one method or one from each methods 2M for each

Following are conventional methods:

i.) **Effects of Generator Design:** A heavy machine has greater inertia and is more stable than a light machine. Modern machines are designed to get more power from smaller machines but this is undesirable from the stability point of view. In earlier days a large number of machines were employed to generate more power and this is also not desirable from stability point of view. A salient pole alternators operate at lower load angles and hence they are more preferred than cylindrical rotor generates from considerations of stability.

ii.) **Increase of voltage:** The amplitude of the power angle curve is directly proportional to the internal voltage of the machine. An increase in voltage increases the stability limit.

iii.) **Reduction in transfer reactance:** The amplitude of the power angle curve is inversely proportional to the transfer reactance. This reactance can be reduced by connecting more line in parallel.

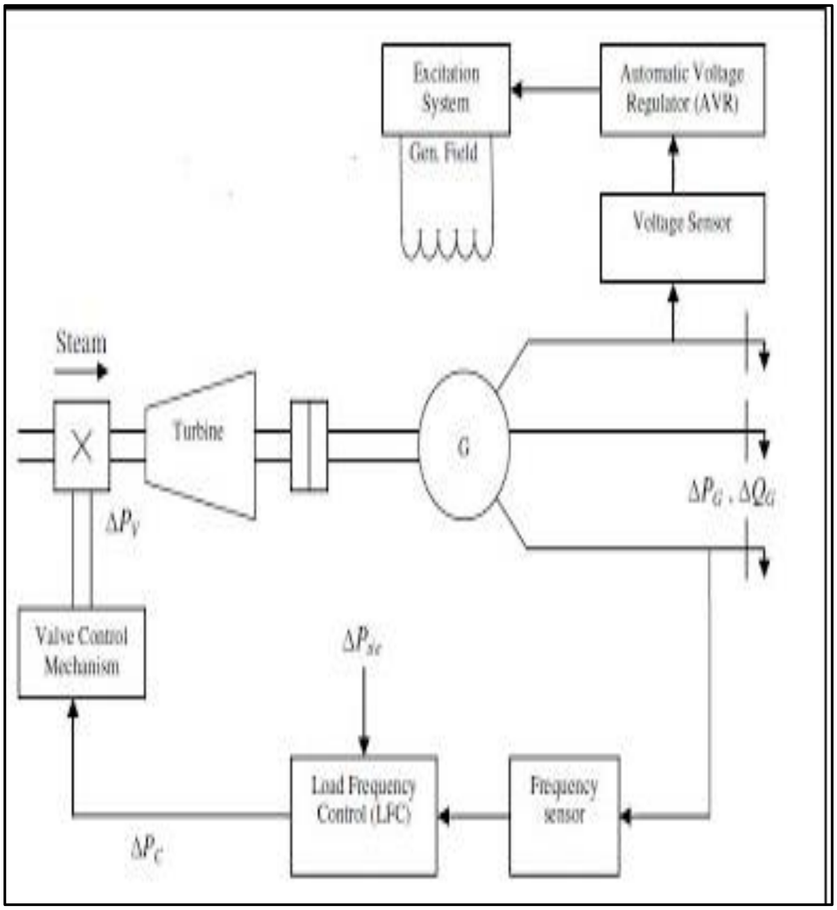
iv.) When two lines are connected in parallel and a fault occurs in one line then some power is transferred to healthy line (except when the fault is at receiving end or sending end bus). This transmission of power helps the stability of the system.

v.) Some features of the power system layout and business arrangement also help in improving stability.

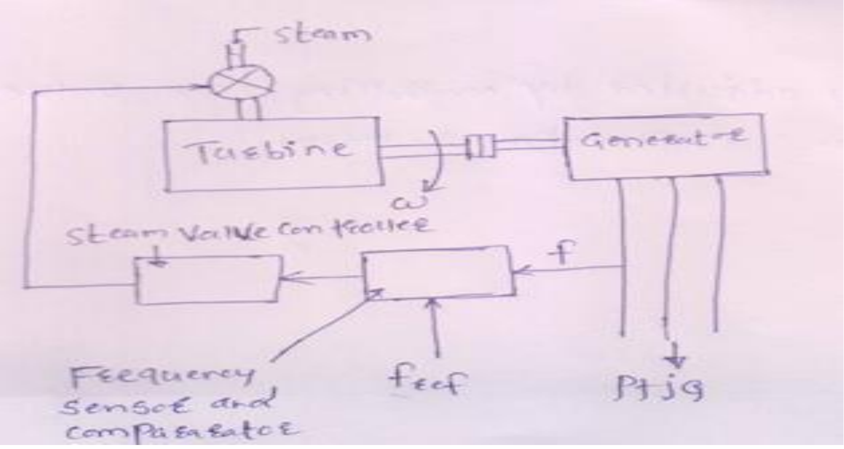
vi.) Use of bundled conductors helps in reducing line reactance and improving line stability.

vii.) The compensation of line reactance by series capacitance is another effective method of improving stability.

viii.) **Rapid fault clearing:** By decreasing the fault cleaning angle (by

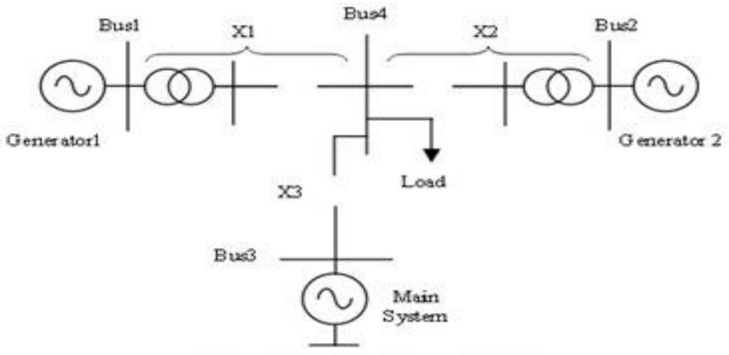
		using high speed breakers) stability can be improved. ix.) **Automatic Reclosing:** Most of the fault's on the transmission lines are of transient nature and are self-clearing. Modern circuit breakers are mostly of reclosing type. When a fault occurs, the faulted line is de-energized to suppress the are in the fault and then the circuit breaker recloses, after a suitable time interval.	
	c) Ans.	**Draw and label schematic diagram of load frequency control and excitation voltage control of a turbo generator.** 	*4M* *3M for components and 1M for labeling*
	d) Ans.	**State and explain the different planning tools used for load forecasting.** **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	*4M* *Any two methods 2M each*

		iii. The scenario techniques: Sequence of events recording, possible outcomes, decisions, assumptions, computerize and automatic system. **i. Stimulation Tool:** This tool help stimulate the behaviour of the system under certain load condition. This helps to calculate certain relevant indices. i .e cost of generation , transmission & distribution. Corporate models simulate the impact of various decision of financial performance of utilities. It requires voluminous data and required result from various models to be integrated. Eg: Load flow model, short circuit model, Transient stability model, production costing, estimation of environmental impact. Results obtained are reliable as we wouldn't experience major failure. **ii. Optimization Tools:** This tool minimizes or maximizes adequate values for decision variables. Eg: Optimum power, least cost expansion planning of generation. For example, we considered the expansion of transmission circuit and planning for electrification rural areas. Though the cost involved is very high, still we can implement it, because objective behind it is on higher side (Socio economic harnessing of ground water resource food production rural employment prevention of migration). **iii. Scenario Tool:** This tool is used to known the future in quantitative fashion. In this technique narrative description is developed which includes probable, sequential or simultaneous recorded data. This can be built up into case history. A decision points are always identified and possible outcomes are investigated. The sort of decision or assumption made by utility is noted. All these narrative descriptions are computerized and used as past data. After certain period it is also used in "automatic power management" as data. Electrical utilities should prepare integrated resource plan. This long term plan must develop the best mix of demand and supply options to meet consumers need.	
	e) Ans.	**Provide/write the major four functions of load dispatch centre.** **(*Any other point shall be considered*)** **Following are the Major functions of Load dispatch centre:** i) LDS shall facilitate wheeling and inter-connection arrangements of local grid systems within its territorial jurisdiction, for the transmission and supply of electricity by economical and efficient	***4M***

		ways. ii) The Load Dispatch Centre shall – be responsible for optimum scheduling and dispatch of electricity within a State/region, in accordance with the contracts entered into with the licensees or the generating companies operating in that State/region. iii) LDC should monitor grid operations within the State/region. iv) LDC has to keep the accounts of the quantity of electricity transmitted through the State/national /regional grid. v) LDC has to exercise supervision and control over the intra-state transmission system. vi) LDC are responsible for carrying out real time operations for grid control and dispatch of electricity within the State/region through secure and economic operation of the State/regional grid in accordance with the Grid Standards and the State/National Grid Code. vii) Overall supervision, monitoring and control of the integrated power system in the State on real time basis for ensuring stability, security and economy operation of the power system in the State/region.	***Any four points 1M each***
	f) Ans.	**With the help of block diagram explain load frequency control (single area case).** In power system network "single area" is identified as grid network consisting number of generators supply power to all consumers in that area. Stability is concerned with this area only. Power demand and supply observed for this area only. All generators are connected in parallel in synchronism and shares the load. The system can be modelled as below: 	***4M*** ***Definition 2M***

		. The above fig shows the block diagram representation of load frequency control. . Due to charge in frequency of load side the system become unstable. To make system again in to stable condition load frequency control system is adopted. . The change in frequency is sense by frequency sensor and compared it with the reference frequency. . If the frequency change occurs that signal is send to the steam valve controller. The steam value controller will adjust the opening and closing of steam. . Depending upon the frequency error the steam valve will open or close its position, which will adjust the intact to the turbine. Thus turbine speed will . Increase of decrease. . The charge in turbine speed will charge the frequency i.e N = 120f /60 . . Hence the frequency adjusted by controlling steam valve.	*Explanation 2M*
6.	**a)** Ans.	**Attempt any <u>FOUR</u> of the following:** **State the significance of power angle diagram.** **Significance of power angle diagram:** 1) To analyse the performance of power system under normal operating condition. 2) To analyze effect of rise or fall in power demand on the performance of power system. 3) To evaluate the effects of disturbance or outage system components on the power system operation. 4) To analyze the operating condition of the system before the measure power failure and to derive the reason for it.	**16** *4M* *1M Each point*
	b) Ans.	**State and explain the concept of dynamic stability of a power system.** **Dynamic state stability:** It is the condition of the power system which lies between the study state stability and transient state stability. Dynamic stability of a system denotes the artificial stability given to an inherently unstable system by automatic controlled means. It is generally concerned to small disturbances lasting for about 10 to 30 seconds. When a generator feeding power into a large network is subjected to a small disturbance, the dynamic response of the generator rotor with	*4M* *Concept 2M& 2M for explanation*

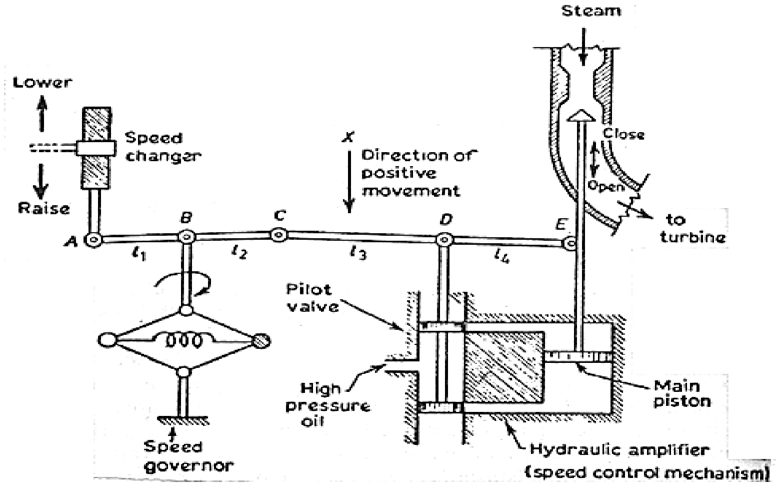
respect to the system is oscillatory with, in general, relatively light damping. This produces oscillatory variations in the magnitudes of the generator voltage, currents, power and torque. Under such circumstances it is often useful to consider the influence of controllers and system elements on performance in terms of their influence on synchronising power and damping power. Oscillations in power (or torque) resulting from the disturbance are considered to be expressible in terms of two components. One is the component of power oscillations that is in phase with rotor angle oscillations; this is termed the synchronising power component. The other is the component in phase with rotor speed oscillations; this is termed the damping power component.



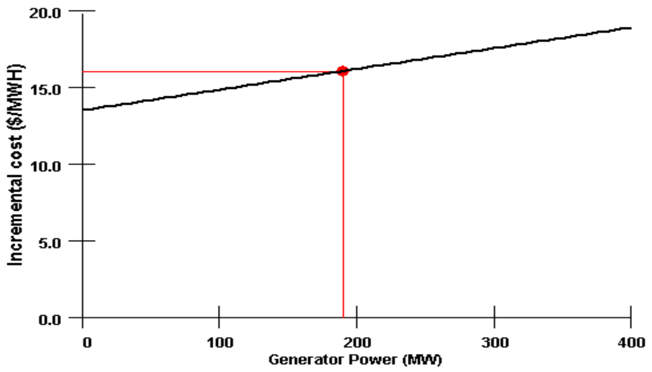
Generic network model

A controller that increases the magnitude of the power component in phase with rotor speed, i.e. the damping power, will improve the damping of the system oscillations. Any increase produced in the synchronising power component indicates that changes in rotor angle produce greater changes in the restoring torque on the generator shaft, which helps ensure that the generator remains in synchronism with the system being supplied. The term synchronising power (or torque) is, in addition, often applied to large disturbance situations, such as behaviour following three-phase system faults. Here the term simply applies to the load power (or load torque) developed, which is predominantly related to the swing in rotor angle. This load torque acts on the rotor and in such a direction as to return it to the final equilibrium value of rotor angle where the system is again in a steady condition and in synchronism with the system being supplied.

	c) Ans.	**Explain the turbine governing system for frequency control.**	***4M***

		 Turbine-Speed Governing System **Turbine Governing System:** The system consists of the following components: **i) Fly ball speed governor:** This is the heart of the system which senses the change in speed. As the speed increases the fly balls move outwards and the point B on linkage mechanism moves downwards. The reverse happens when the speed decreases. **ii) Hydraulic amplifier:** It comprises a pilot valve and main piston arrangement. Low power level pilot valve movement is converted into high power level piston valve movement. This is necessary in order to open or close the steam valve against high pressure steam. **iii) Linkage mechanism:** ABC is a rigid link pivoted at B and CDE is another rigid link pivoted at D. This link mechanism provides a movement to control valve in proportion to change in speed. It also provides a feedback from the steam valve movement (link 4) **iv) Speed Changer:** It provides a steady state power output setting for the turbine. Their downward movements open the upper pilot valve so that more steam is admitted to the turbine under steady conditions. The reverse happens for upward movement of speed changer.	*Labelled diagram 2M* *Function of 4 major part 2M*
	d)	**Draw and label the following curve-** **(i) Incremental fuel cost curve** **(ii) Fuel cost curve**	*4M*

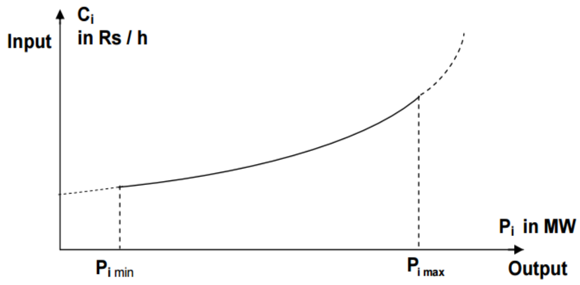
Ans. **(i) Incremental fuel cost curve:**



$$IC_i(P_{Gi}) = \frac{dC_i(P_{Gi})}{dP_{Gi}} = \beta_i + 2\gamma_i P_{Gi} \text{ Rs /MWh}$$

Incremental fuel cost curve 2M

(ii) Fuel cost curve:



Ci= ∝i + Pi + β P + γ Rs/h

Fuel cost curve 2M

e) **The cost curve of a power plant having two units are given as** *4M*

$$\frac{dF}{dP_1} = 0.45p_1 + 40 \text{ Rs/Mwh}$$

$$\frac{dF}{dP_2} = 0.5p_2 + 30 \text{ Rs/Mwh}$$

Determine the fuel cost of each unit of 4500 Mw load is equally distributed on the two units.

Ans. The incremental fuel cost curve of two units of a power plant are
$dF/dP_1 = 0.45P_1 + 40$ Rs/MWh $dF/dP_2 = 0.5P_2 + 30$ Rs/MWh
Total load on generating station = 4500 MW. Load is equally distributed on two units.

		Therefore, $P_1 = P_2 = 4500/2 = 2250MW$ Integrating the above equations we get Fuel cost curve of each unit, $C_1 = \int dF/dP1 = 0.45P1^2/2 + 40P1$ $= 0.225\ P1^2 + 40P_1$ $C_2 = \int dF/dP2_1 = 0.5P2^2/2 + 30P2$ $= 0.25\ P2^2 + 30P_2$ Substituting, $P_1 = P_2 = 500/2 = 250MW$ We get $C_1 = 0.225 \times 2250^2 + 40 \times 2250$ **= 12,29,062 Rs /hr** $C_2 = 0.25 \times 2250^2 + 30 \times 2250$ **= 13,33,125 Rs /hr**	*1M* *1M* *1M* *1M*
	f) Ans.	**Considering the cost curve of two units as given in Q. No. 6 (e), determine the fuel cost of each unit if 4500 Mw load is economically distributed.** Incremental fuel cost curve of two units are $dF/dP_1 = 0.45P_1 + 40$ Rs/MWh $dF/dP_2 = 0.5P_2 + 30$ Rs/MWh Total Load = 4500 MW $P_1 + P_2 = 4500$………………..(i) For economical load dispatch $dF/dP_1 = dF/dP_2$ $0.45P_1 + 40 = 0.5P_2 + 30$ $0.45P_1 – 0.5P_2 = 30-40 = -10$ $0.45P_1 – 0.5P_2 = -10$……..(ii) Solve equation (i) & (ii) by substitution method , we get , $0.45\ P_1 – 0.5\ (4500 - P_1) = -10$ $0.95\ P_1 = -10 + 2250 = 2240$ **$P_1 = 2357.9 = 2358$ MW** **$P_2 = 2142$ MW**	*4M* *1M* *1M* *1M* *1M*