Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in themodel answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may tryto assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given moreImportance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in thefigure. 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 constantvalues may vary and there may be some difference in the candidate's answers and modelanswer.
6) In case of some questions credit may be given by judgement on part of examiner of relevantanswer based on candidate's understanding.
7) For programming language papers, credit may be given to any other
program based on equivalent concept.

Q.1) A) Attempt any THREE: **12M**

a. State the significance of buses in power system.

(Each point 1M)

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.
- Any other point

b. Why the utilities want to maintain constant frequency?
(Any four points, 1M for each)

Ans:

The frequency of a power system is dependent entirely upon the speed at which the generators are rotated by their prime movers. Therefore frequency is a matter of speed control of the machines in the generating stations. If the frequency is not maintained constant following are effects on power system:

Utilities want to maintain constant frequency supply because

1) The steam turbines or rotating machines undergo exercise vibration resulting in metal fatigue and blade failures.
2) Decreasing the efficiency of auxiliary equipments connected in the plants.
3) Drop in generated output and loss of power giving prolonged outage
4) Loss of generator exciter speed and voltage in power system will drop.
5) The maintenance cost of equipment will increase due to continues problem
6) Malfunction of the equipment operation due to variation frequency and speed.
7) Life of the equipment will be reduced which affects the quality of products of manufacturers.
8) The extension use of synchronous clocks requires maintaining accurate synchronous time which necessitates regulation of frequency.
9) Due to further effects it is necessary to maintain constant supply frequency.

c. List out the information that can be collected from load flow analysis.
(4M for any four)

Ans: **Information collected from the load flow analysis -**

(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 (increase or decrease) 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 voltage level on power flow.

d. Define steady state stability, transient stability and dynamic state stability.
(4M)

Ans: **Define**

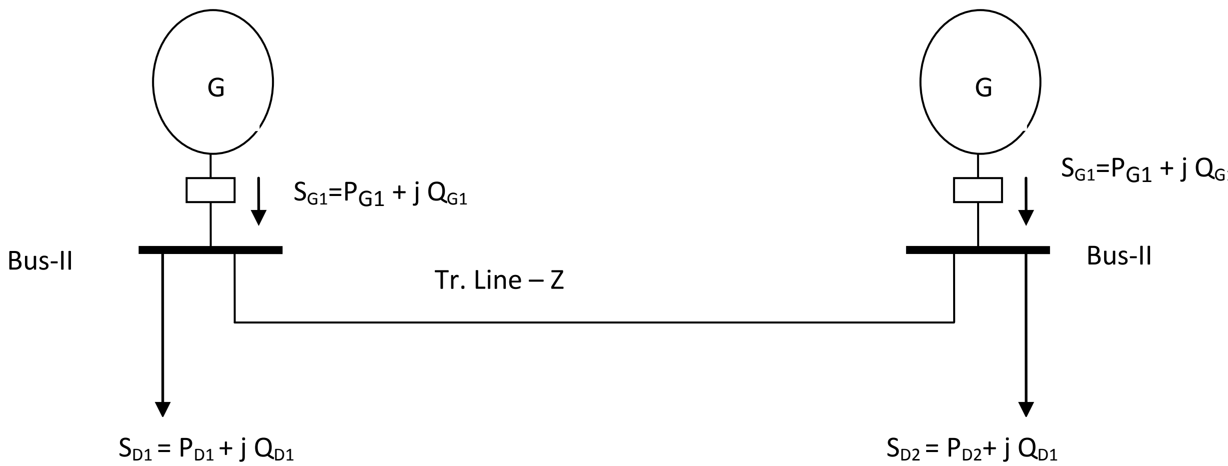
- **Steady State Stability:** It is the ability of the power system to regain its normal operating condition even after experiencing small disturbance in the system.

- **Transient state stability:** It is the ability of the power system to regain its original or new operating condition even after experiencing a large disturbance in the system.
- **Dynamic state stability:** It is the condition of the power system which lies between the study state stability and transient state stability.

Q. 1) B) Attempt any ONE: **06M**

a. Considering a simple two bus system derive $I_{bus} = V_{bus} Y_{bus}$.
(Each step 1M)

Ans: Consider a simple two bus power system as shown in the fig.



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 ∏ 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,

$$S_1 = S_{G1} - S_{D1}$$
$$= (P_{G1} - P_{D1}) + j\,(Q_{G1} - Q_{D1})$$
$$= P_1 + j\,Q_1$$

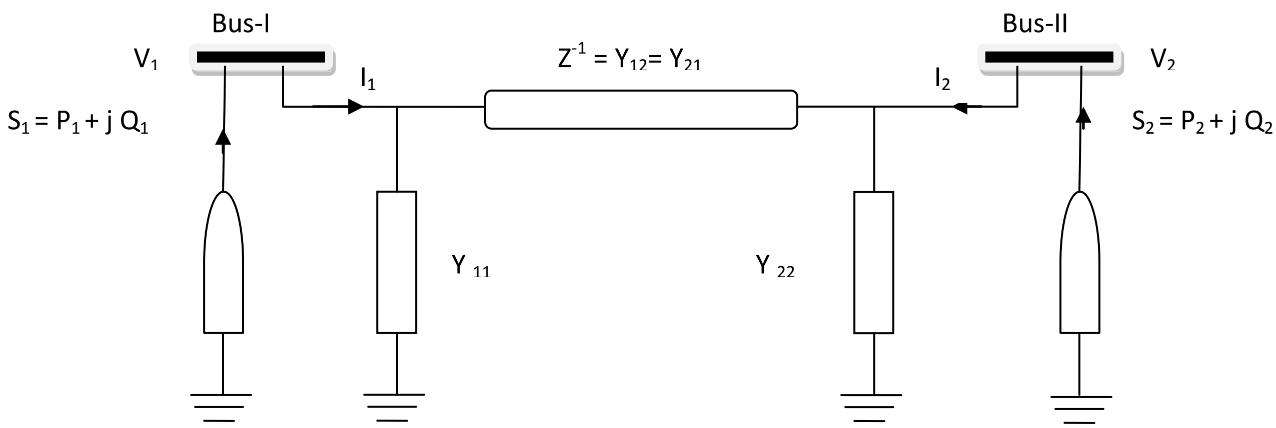
And

$$S_2 = S_{G2} - S_{D2}$$
$$= (P_{G2} - P_{D2}) + j\,(Q_{G2} - Q_{D2})$$
$$= P_2 + j\,Q_2$$

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 i.e. bus current of bus - II



Bus power S_1 can also be written as,

$S_1 = V_{1\,/}\, I^*_1$ $I_1^* = S_1/V_1$ $I_1 = S_1^*/V_1^*$

Where I_1 enters 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

$I_1 = S_1^*/V_1^* = V_1\, Y + (V_1 - V_2)\, Y'$ ----------------- (1)

$I_2 = S_2^*/V_2^* = V_2\, Y + (V_2 - V_1)\, Y'$ ----------------- (2)

The above two = o.s. can be simplified as

$I_1 = V_1\,(Y + Y') - Y'\, V_2$------------------ (3)

$I_2 = -Y_1Y' + (Y+Y')\, V_2$ ------------------- (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)

$I_2 = Y_2 V_1 + Y_{22} V_2$ ------------------ (4)

Above eq 7 o.s. can be written in matrix form as,

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

i.e**. I bus = Y bus V bus** ---------------- (6)

I bus = bus current vector

V bus = bus voltage vector

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

b. List out data required for load flow studies.
(Any six points 1M for each)
Ans: Data required for load flow studies:

(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 bus	No of buses	Bus date
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 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.

Q.2.Attempt any FOUR: 16M

a. State and explain different types of buses in power system.
(1M each bus)

Ans: Different types of buses in power system:

In a power system each bus or node is associated with four quantities magnitude of voltage - P,Q,V and its phase angle ‘δ’,

In load flow studies two out of four quantities are specified and remaining two are required to be obtained thro 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 consumers point of view. This is also called as PQ bus. Power ejected from bus is considered as – ve

II Generator bus: - At this bus power generated is injected into the system. Hence the magnitude of voltage corresponding to its rating are specified from load flow solution and it is required to find out Q & S.This is also called as PV bus

III 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 bus is made to take additional real and reactive power to supply transmission losses. This bus is known as **Slack or Reference Bus.** As the power demand varies, variation in real power flow and reactive power flow results into variation in load angle (frequency) and bus voltage profiles. Hence it is also called as **Swing bus.**

IV voltage control bus – Voltage control equipment such as transformer, capacitor bank are connected

At this bus the magnitude of bus voltage and phase angle are specified while P & Q are obtained through the load flow solution.

Type Of Bus	Specified quantities specification	Quantities Obtained Unknown Quantities
Load bus	P,Q	V, δ
Generator bus	P, V	Q, δ
Slack bus	V, δ	P,Q
voltage control bus	V, δ	--

b. Explain briefly the relation between real power and frequency of the system. ***(4M)***

Ans: Relation of Real power with Frequency:

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.

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 , $P_g > P_d + P_L$ P_g 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, $P_g < P_d + P_L$ Pg. In this condition load tries to draw more power from the generator s than its capacity and as P_g 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.

c. List out the significant features Y_{bus} matrix.
(Any 4 1M each)
Ans: 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 IIor outage of tr. line
   $Y_{ik} = Y_{ki} = 0$ if i≠k between but I ∝bus II∝ i ∝ k are not connected.
6) $Y_{bus} = (Z_{bus})$ whereZ_{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.

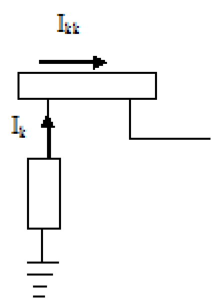
d. State and explain 'bus loading' and 'Line-flow-equation'
(Explanation of bus loading 2M, Line flow equation 2M)
Ans: <u>Bus Loading:</u>

The real of reactive power at any k^{th} bus can be written as

$S_k = P_k - jQ_k = V_k^* I_k$

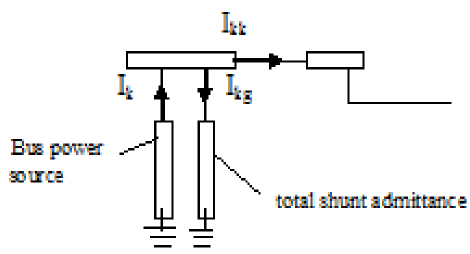
$$\therefore \text{current at Bus i } I_k = \frac{p_k - jQ_k}{V_k^*}$$

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 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.

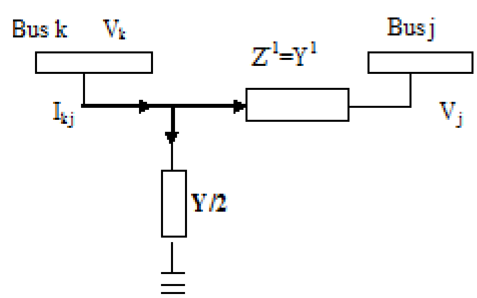


Now the net current through bus - $I_{kk} = I_k - I_{kg}$

$$= \frac{p_k - jQ_k}{V_k^*} - V_k Y_{kk}$$

When Y_{kk} – total shunt admittance

Tr. Line Flow equation:



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

$P_{jk} - jQ_{jk} = V_j^* I_{jk} = V_j^*(V_j - V_k)y^1 + V_j^* V_j \, y/2$

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

e. Write the “suing equation” and state its significance.
(Equation - 2M, significance – 2M)

Ans. Significance of Swing equation –

KE stored in the rotor of prime mover received by generator as mechanical (T_m) torque and generator generates (T_e) electromagnetic torque. Under stable conditions these two torques are equal.

But $T_m - T_e = T_a$ i.e. accelerating torque.
if $T_m > T_e$…………….. rotor accelerate
& $T_m < T_e$ ……………... rotor retards

Depending upon T_a, rotor gets angularly displaced w.r.to. axis of rotating mag. Field or synchronously rotating field. The accelerating power at the rotor of generator is given by “swing equation” which is written as

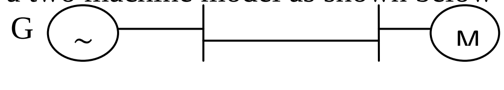
Swing Equation

$$M\frac{d^2\partial}{dt^2} = P_a = P_s - P_e \; OR \; M\frac{d^2\partial}{dt^2} = P_m - P_e$$

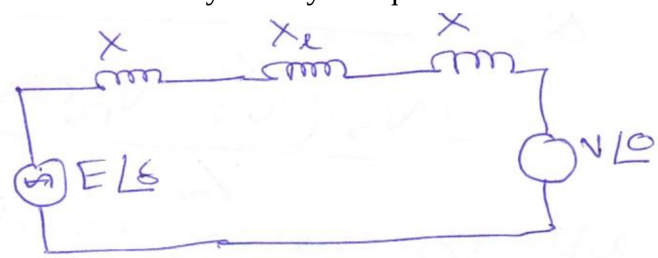
M=inertia constant
δ = rotor angular displacement=$\theta - w_s t$
P_m = mechanical power input in MW
P_e = electrical power output in MW

f. Explain the power system stability with the help of simple two machine model.
Ans:

Consider a two machine model as shown below



A synchronous generator is feeding power to syn. Motor through a short tr. Line.
Assume the losses in the line are negligible i.e. R =0.
Let represent the above system by its equivalent reactance diagram.



→ (2 M)

Let v = v =$\angle 0$ voltage across the motor E = E $\angle \delta$ emf generated by generator.
X – syn. reactance of the generator / ph
X - syn. reactance of the motor / ph
X_l – reactance of the tr. Line /ph

The complex power delivered by the generator to the motor is

$P = \frac{VE \sin\delta}{X}$

For maintaining voltage constants by controlling excitation, for the given system 'x' also Remains constant.

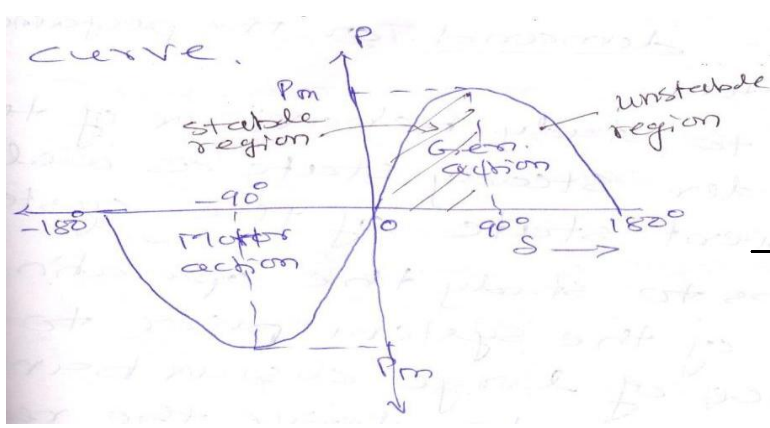
Then $P \propto \sin\delta$

For $\delta = 90^0$ $P = P_{max} = \frac{VE}{X}$

$$\therefore P = P_{max} . \sin\delta$$

When δ is the P is +ve∝ vicecersa.

The Graphical representation of power 'P' and the load angle 'δ' is called the power angle Diagram or power angle curve.



→ (2M)

When δ is +ve the power flows from generator to load. When δ is –ve the power flows from motor to generator.

Q.3. Attempt any FOUR: **16M**

a. State the difference between "shunt compensation" and "synchronous compensation".
(Any 4 – 1M each)

Ans:

Sr. No.	Synchronous compensation	Shunt compensation
1	Synchronous condenser Can supply lagging as well as leading VARs	Capacitor Bank Can supply only leading VARs
2	The control of synchronous condenser is fast and continuous	The control of Capacitor Bank is slow
3	The failure of synchronous condenser means loss of complete unit	The failure of one unit of capacitor bank affects that unit only.
4	Synchronous condenser can be overloaded for short periods	Capacitor bank cannot be overloaded.
5	No switching problems present in synchronous condenser	Due to switching problems present in Capacitor Bank harmonics are produced.
6	For large VAR requirement synchronous condenser is economical	For small VAR requirement capacitor banks are economical.

b. State the need of reactive power compensation and state its classification.
(Need of reactive power compensating equipments 1/2 mark each, Classification 2M)

Ans: Need of Reactive power compensating Equipments:

- Most of the equipments especially at 400KV and above are operated close to the present limits of design and are operated with a voltage profile of ±5%
- Most of the loads absorb lagging VARs to supply magnetizing current of x'mers, induction motors etc. At the time of peak load, vars demanded by loads greatly exceed vars which can be transmitted over the lines therefore additional equipment is necessary to generate lagging VARs
- Shunt capacitance of the line absorbs loading vars. At the time of lighter loads lagging vars. produced by lines are much larger than required by consumer loads. This surplus lagging vars. are absorbed by additional equipment to keep voltage profile within limits.
- Therefore it is necessary to provide additional equipment to generate or absorb vars. Shunt connected inductances absorbs lagging vars. and shunt capacitor generates lagging vars.

OR

Need 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.

Classification of Reactive power compensation:

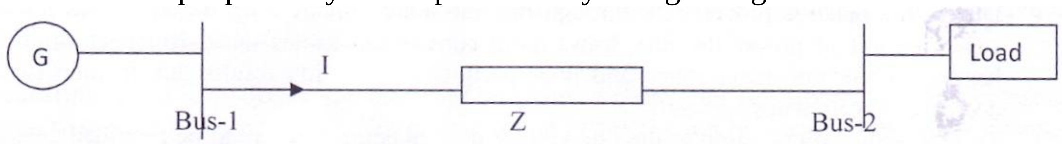
1. Shunt compensation
   - Shunt reactors
   - Shunt capacitors
2. Synchronous compensation
   - Synchronous phase modifiers
3. Series compensation
   - Series capacitors
4. Static VAR system (SVS)

c. Derive the equation to prove that voltage drop across the tr. line is mainly due to reactive power flow

Ans: Relation between reactive power and voltage drop:

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.

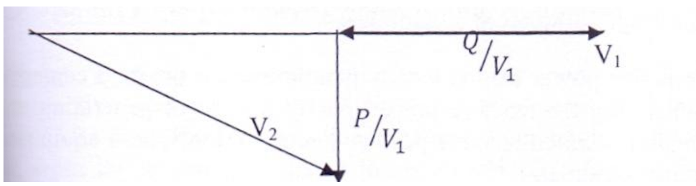


Let V_1 be Bus voltage at bus 1
Let V_2 be bus voltage at bus 2
Two buses are interconnected by a short transmission line with zero line losses (i.e. R=0)
$\therefore Z = jX$
Maintain the voltage at bus 1 by regulating output voltage of generator
Now = $V_2 = V_1 - IZ$
Complex power at bus 1 is
$S = V_1 I_1^* = P + j\,Q$…………………… assuming inductive

$$\therefore I = \frac{p - jQ}{V_1} X$$

$$V_2 = V_1 - \left(\frac{p-jQ}{V_1}\right) jX = \left(V_1 \frac{Q}{V_1} X\right) - J\frac{P}{V_1} X \longrightarrow \textit{(2M)}$$

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.

Assuming the voltage drop due to real power negligible, the voltage drop is directly proportional to the reactive power Q.

$$V_2 = V_1 - \frac{Q}{V_1} X$$

$$V_1 - V_2 = +\frac{Q}{V_1} X$$

In order to keep the receiving end voltage V_2 fixed the drop $\left(\frac{Q}{V} X\right)$ must remain constant this shows that V_1-V_2 α 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. ⟶ *(2M)*

d. Write SLFE for two bus power system and define each parameters.
(SLFE 3M, Define each parameter 1M)

Ans: SLFE equation:

$S_1^* = V_1^2 Y_{11}$ Lœ$_{11}$ $+ Y_{12} V_2 V_1$L$(\delta_2 - \delta_1) = P_1 - j Q_1$ $P_1 = V_1^2 Y_{11}$ Cos œ$_{11}$ $+ Y_{12} V_2 V_1$ Cos $(\delta_2 - \delta_1)$ $Q_1 = (V_1^2 Y_{11}$ Sin œ$_{11}$ $+ Y_{12} V_2 V_1$ Sin $(\delta_2 - \delta_1)$	$S_2^* = V_2^2 Y_{22}$ Lœ$_{22}$ $+ Y_{21} V_2 V_1 (\delta_1 - \delta_2) = P_2 - j Q_2$ $P_2 = V_2^2 Y_{21}$ Cos œ$_{22}$ $+ Y_{21} V_2 V_1$ Cos $(\delta_1 - \delta_2)$ $Q_2 = (V_2^2 Y_{22}$ Sin œ$_{11}$ $+ Y_{12} V_2 V_1$ Sin $(\delta_1 - \delta_2)$

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

$P_1 = V_1{}^2 Y_{11} \text{Cos } œ_{11} + Y_{12} V_2 V_1 \text{Cos } (\delta_2 - \delta_1) = (P_{G1} - P_{D1})$

$Q_1 = -- [(V_1{}^2 Y_{11} \text{Sin } œ_{11} + Y_{12} V_2 V_1 \text{Sin } (\delta_2 - \delta_1) = - (Q_{G1} - Q_{D1})$

$V1\angle\delta_1$, $v2\angle \delta_2$ – bus voltages

P1 , Q1 Power at bus 1

P2 , Q2 Power at bus 2

PG1, QG1 generated power

e. List out the factors that governs load shedding.
(1M per point Any 4 with brief explanation)

Ans: 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

f. With reference to Indian Power System, state the types of LDC and their locations.
(1M for each type)

Ans:

For the efficient, economical and integrated transmission of electrical supply, the Central Government has made region wise demarcation of the country and has established Load Dispatch Centers. And these LDS facilitate voluntary interconnections and co-ordination of the inter-State, regional and interregional generation and transmission of electricity.

Hence Government has identified different types of LDC depending on their locations.

I. **National Load Dispatch Centre (NLDS) –**

II. **In India NLDS is located at Delhi**

III. **Regional Load Dispatch Centre(RLDS)**

IV. **State level Load Dispatch Centre(SLDC)**

V. **Sub-state Load Dispatch Center(SSLDC)**

VI. **Local Area LDC**

India, there is one NRLDC located at Delhi. State wise 33 SLDCs including DVC and BBMB Control centers controlled by state government. There are region wise 5 RLDCS and regions are …..

Name of the Region	States included	Name of RLDC	Located
NORTHERN Region	Jammu and Kashmir, Uttar Pradesh, Punjab, Hariyana	NRLDC	Delhi
EASTERN Region	Bengal, Bihar, Orissa	ERLDC	Kolkata)
SOUTHERN Region	Karnataka, Goa, Kerala,Tamilnadu	SRLDC	Banglore
WESTERN Region	Mharastra, Gujarat, Madhya Pradesh,Chattis gad	WRLDC	Mumbai
NORTH-EASTERN Region	Assam, Sikim, Nagaland	NERLDC	Shillong)

In Western Region in Maharashtra SLDS is located in Nagpur. **SSLDC is located at Mumbai. And LLDC at TROMBAY.**

Or

Type of LDC		Locations
NLDC- National Load Dispatch Centre		Delhi
RLDC –Regional Load Dispatch Centre	ERLDC- Eastern Region	Kolkata
	SRLDC-Southern Region	Banglore
	WRLDC-Western Region	Mumbai(Kalwa)
	NERLDC- North East Region	Shillong
	NRLDC- Northern Region	Delhi
SLDC- State Load Dispatch Centre	**Eg.**Maharashtra State LDC	Nagpur (Ambazari)
SSLDC-Sub State Load Dispatch	**eg** Maharashtra State LDC	Mumbai(Andheri)
LLDC- Local Load Dispatch centre	**Eg.** Tata Power Company Ltd.	Mumbai(Trombe)

Q.4 (A) Attempt any THREE: **12M**

a. Determine the self-admittances of 3-bus system with the following data:

Bus Code i – k	Line Impedance z_{ik}	Line charging admittance y_{ii}
1 – 2	0.02 + j0.06	j0.03
1 – 3	0.08 + j0.04	j0.025
2 – 3	0.06 + j0.018	j0.020

Ans:

Solution: Bus Code	Impedence(z)	Admittance(1/z)	Line Charging
1-2	0.02+j0.06	5-j15=y12	Y11=j0.03
1-3	0.08+j0.24	1.25-j3=y13	Y22=j0.025
2-3	0.06+0.18	1.66-j5=y23	Y33=j0.02

(1Marks)

Now, calculating self admittance of all buses,

- $y_{11} = y_{11} + y_{12} + y_{13}$
$= (j0.03) + (5 - j15) + (1.25 - j3.75) ----------- \textbf{1 marks}$
$y_{11} = 6.25 - j18.72$
- $y_{22} = y_{21} + y_{22} + y_{23}$
$= (5 - j15) + (j0.025) + (1.66 - j5) ------------- \textbf{1 marks}$
$y_{22} = 6.66 - j19.97$
- $y_{33} = y_{31} + y_{32} + y_{33}$
$= (1.25 - j3.75) + (1.66 - j5) + (j0.02) --------- \textbf{1 marks}$
$y_{33} = 2.91 - j8.73$

b. List out the advantages Y_{bus}.
(1M for each point)

Ans: Advantages of Y-Bus

i. Y-Bus is a sparse matrix.
ii. It is simple in preparing data.
iii. It can be modified b for changes in N/W.
iv. It reduces computer memory and time requirement.

c. List out the various methods of voltage control and their field of applications.
(Any 4 – 1M each)

Ans: Methods of voltage control:

i) Excitation control
a – Tirrid regulator
b – Brown – boveri regulator
} at generating station
ii) Shunt capacitors
iii) Series capacitors
iv) Auto transformers
v) Tap-changing transformers
a – on line tap changing
b – off line tap changing
vi) Boosters
} at transformer substations
vii) Synchronous condenser – at Loud end.

d. Explain the working of turbine speed governing system with the help of block diagram.
(Speed governing system of turbine 2M, Diagram 2M)

Ans:

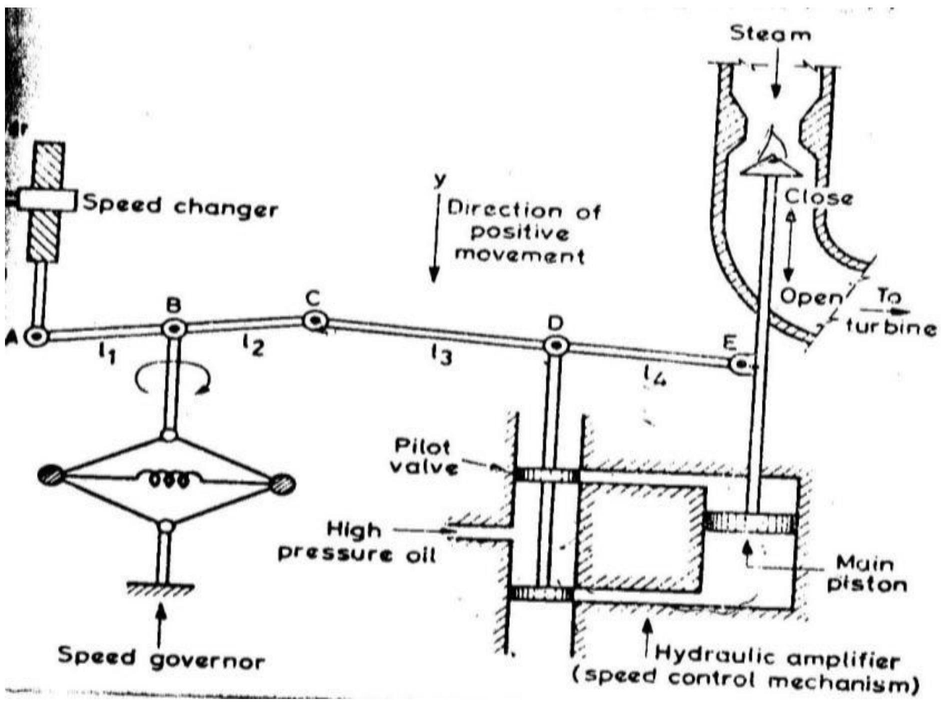
Components in speed governing system of turbine:

i. Fly ball speed governor: it is sensing the change in speed (frequency). As speed increases fly ball more outwards and linkage mechanism moves downwards.

ii. Hydraulic amplifier: here 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.

iii. Linkage mechanism: linkage between different links provides a movement to control valve in proportion to change in speed. It also provides feedback from stream valve moment.

iv. Speed changer: it provides a steady state power output setting for the turbine. Its downward movement opens the upper pilot valve so that more steam is admitted to the turbine under steady conditions and vice versa



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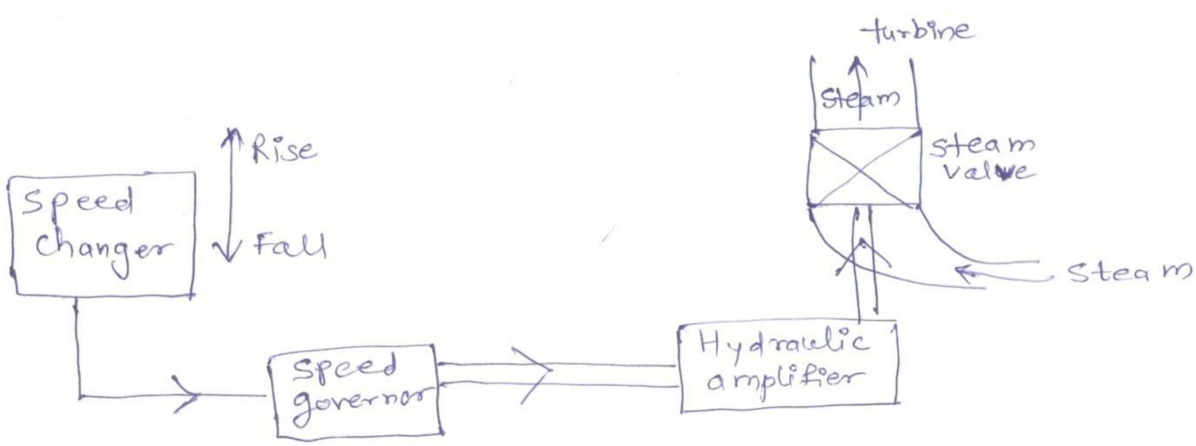
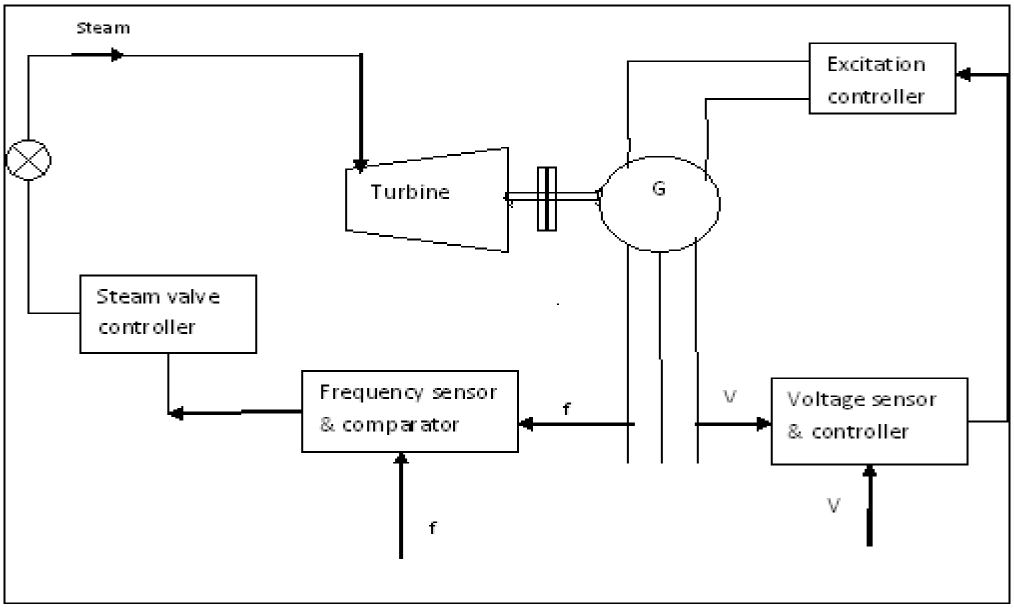


Q.4 (B) Attempt any ONE: **06**

a. Explain with the help of block diagram working of Automatic load frequency and voltage control loops of a synchronous generator.
(Explanation 3M, Diagram 3M)

Ans:

Automatic load frequency & voltage control loop of synchronous generator.



- Power demand is never steady and it is continually changing with rising or falling trend, Therefore steam input to turbo-generators or water input to hydro generator must be continuously regulated to match the active power demand. If it fails to meet the demand. Then difference the active power is reflected in variation of generator speed which results in variation in frequency and this is undesirable. Max permissible variation in frequency is ±0.5 Hz
- Also to meet the reactive power demand with reactive power generation, excitation of generators must be continuously regulated. If it fails then voltages at various system buses may vary beyond the prescribed limit
- In modern power system, automatic generation OR voltage regulation equipment is installed in each generating stations. In this system, controllers are set for a particular operating condition and they take care of small changes in load demand without frequency and voltage exceeding the prescribed limits. For large variation in demand, the controllers must be reset manually or automatically.
- Variation in real power is reflected/depend on internal machine angle or load angle ‘δ’ and is independent of bus voltage where as bus voltage depends on machine excitation and is of load angle ‘δ’.
- Momentary variation in δ is caused by momentary variation in generator speed. Therefore, load frequency and excitation voltage controls are non-interactive for small changes and can be modeled and analyzed independently. Excitation control is fast acting

and depends on generator field whereas power frequency control is slow acting and depends on generator and turbines moment of inertia. Hence transient in excitation voltage control vanish, much faster than and do not affect the dynamics of power frequency controller.

b. State and explain the various planning tools used for load forecasting.
(2M each)

Ans.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.

i. Stimulation Tool:

This tool help stimulate the behavior 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. 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.

Q.5 Attempt any FOUR: 16M

a. State and explain conventional methods of improving transient stability. (any two)
(Any two 2M each)

Ans:

a) **Effects of Generator Design:** A heavy machine hasgreaterinertia 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.

b) **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.

c) **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.

d) When two lines are connected in paralleland 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.

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

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

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

h) **Rapid fault clearing:** By decreasing the fault cleaning angle (by using high speed breakers) stability can be improved.

i) **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.

b. State the adverse effects powers system instability.
(Each effect 1M)

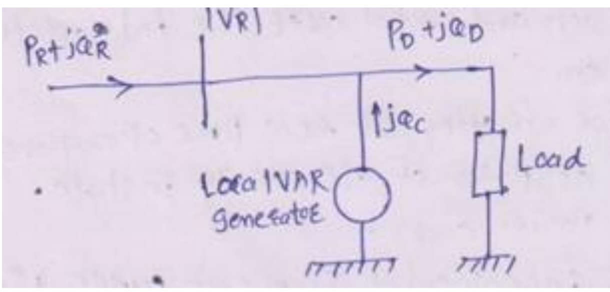
Ans:

Due to instability of power system following effects can be observed:

1) As the P_d>> P_g, 'freq' of system varies over a wider range / beyond the limits. Hence protective scheme of generator ∝transformer come into action ∝ trips them.
2) Due to fluctuation of V, F, P, Q performance of grid network reduces and consumers receive poor quality of supply.
3) If the system parameters are not controlled one by one generators will trip off and it leadsmajor failure sometimes to collapsing of whole system.
4) As consumer receives poor quality supply the performance of their machines reduces, production rate decreases, quality of product reduces and overall there is financial loss.

c. With the help of diagram, explain the reactive power injection method used for voltage control.
(Each point 1M, Any other relevant explanation should be considered)

Ans.



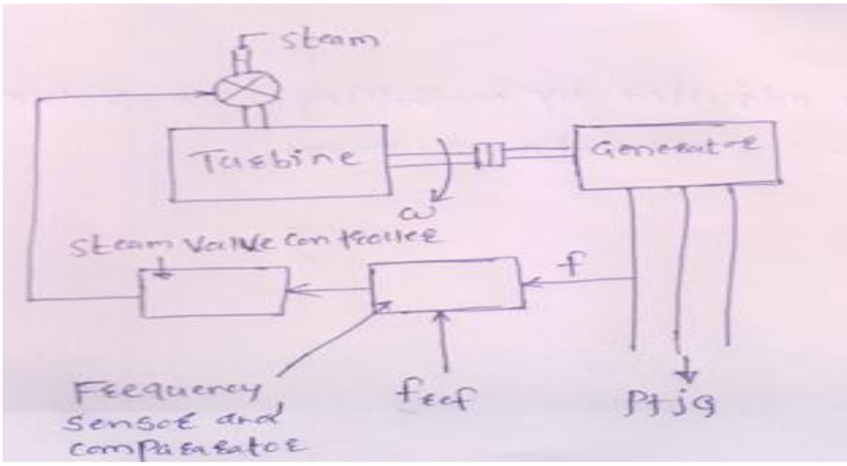
- To keep the receiving end voltage at a specified value $|V_{SR}|$a fixed amount of VARS $|Q_R^S|$must be drawn from the line.
- To accomplish this under conditions of a varying VAR demand Q_D, a local VAR generator must be used as shown in fig.
- The VAR balance equation at the receiving end is now.

$$Q_R^S + Q_c = Q_D$$

- Fluctuations is a_D are absorbed by the local VAR generator a_c such that the VARS drawn from the line remain fixed at a_R^S
- The receiving end voltage would thus remain fixed at$|V_R^S|$. Local VAR compensation can, in fact be made automatic by using the signal from the VAR meter installed at the receiving end of the line.

d. With the help of block diagram, explain load-frequency control using single area case.
(Definition 2M, explanation 2M)

Ans. 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:



- 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 $N = \frac{120\,f}{P}$
  Hence the frequency adjusted by controlling steam valve.

e. List out the functions of state load dispatch centre.
(Any four 1M each)
Ans.

In accordance with section 32 of Electricity Act, 2003 roles and functions of SLDCs are as under:

For Transmission of power within a State, the State Government has established State Load Dispatch Stations.

1. SLDS 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 ways.

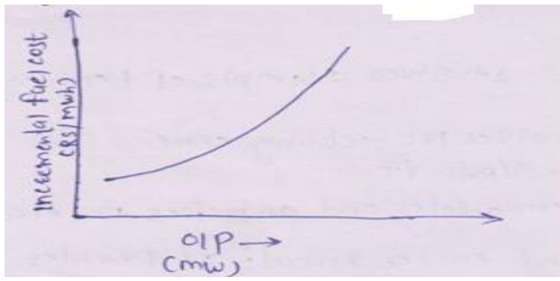
2. The State Load Dispatch Centre shall be operated by a Government company or any authority or corporation established or constituted Government Company or any authority or corporation established or constituted by or under any State Act, as may be notified by the State Government.
3. No State Load Dispatch Centre shall engage in the business of trading in electricity.

a) The State Load Dispatch Centre shall be the apex body to ensure integrated operation of the power system in a State.
b) The State Load Dispatch Centre shall – be responsible for optimum scheduling and dispatch of electricity within a State, in accordance with the contracts entered into with the licensees or the generating companies operating in that State;
c) It should monitor grid operations within the state.
d) It has to keep the accounts of the quantity of electricity transmitted through the State grid.
e) It has to exercise supervision and control over the intra-state transmission system.
f) SLDC are responsible for carrying out real time operations for grid control and dispatch of electricity within the State through secure and economic operation of the State grid in accordance with the Grid Standards and the State Grid Code.
g) The State Load Dispatch Centre may collect such fee and charges from the generating companies and licensees engaged in intra-State transmission of electricity as may be specified by the State Commission.
h) 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.
i) Optimum scheduling and dispatch of electricity within the State. For this SLDCs estimate the demand of the State / DISCOMS, as may be the case, availability of power in the State/DISCOMS from State generators and other sources like Central Generating stations, bilateral contracts etc, conveys the final requisition to RLDCs on the State's entitlement from the Central Generating Stations and bilateral transactions under open access, if any, and issues final dispatch schedule to the State Generators and drawl schedule to the DISCOMS.

f. With the help of incremental fuel cost curve explain the economic load dispatch.
(Curve 2M, explanation 2M)

Ans:

- The incremental fuel cost curve in a curve drawn between power o/p (mw) to incremental fuel cost (Rs/mwh).
- The incremental fuel cost is given by the slope of the input-output curve. The unit of incremental fual cost is Rs/mw-hr.



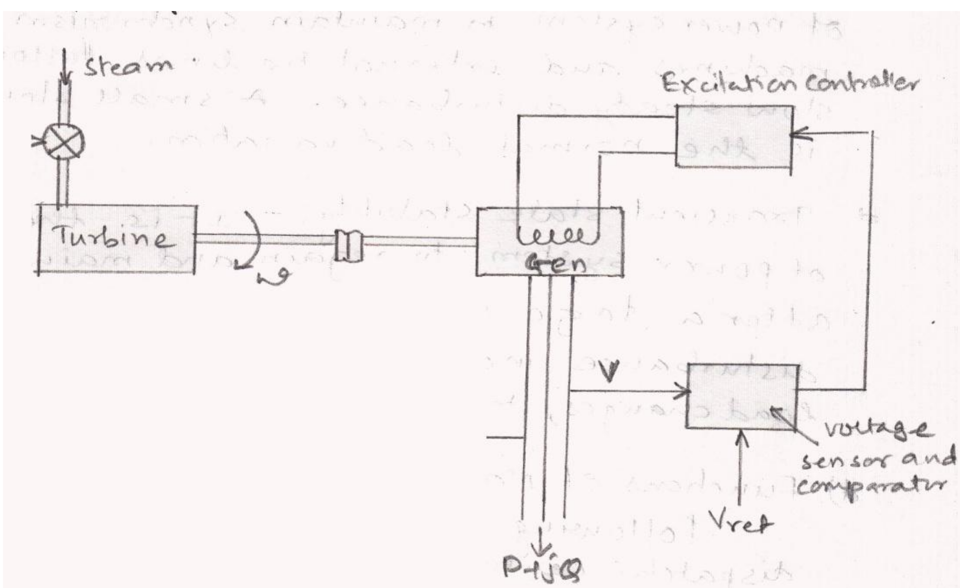
- This incremental cost is made up of incremental fuel cost plus incremental cost of other items like water, supplies wages etc. Since it is quite difficult to express cost of water, supplies wages etc. directly as a function of o/p.
- Mostly incremental fuel cost is taken as the incremental cost and forms the basis of load division.

Q.6 Attempt any FOUR: 16M

a. With the help of labeled diagram explain the functioning of Automatic Voltage Control System.

(Diagram 2M, function 2M, any other diagram shall be considered)

Ans.



The above fig shows the schematic diagram of an AVC system. It basically consists of a main exciter which exists the alternator field to control the output voltage. The exciter field is automatically controlled through error, e= V_{ref}. V_T .Suitably amplified through voltage and power amplifier function.

i. Potential Transformer: It gives a sample of terminal voltage V_T

ii. Differencing device: It gives the actuating error

iii. Error amplifier: It demodulates and amplifies the error signal.

iv. SCR power amplifier and exciter field: It provides the necessary power amplification to the signal for controlling the exciter field.

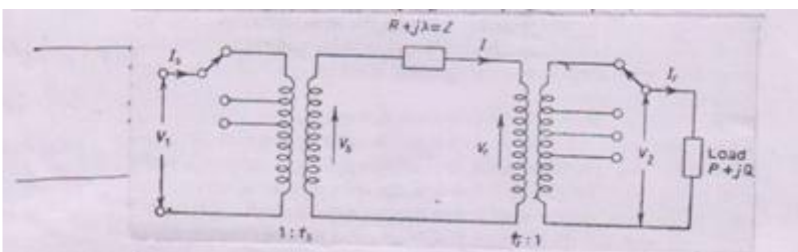
v. Alternator: Its field is excited by the main exciter voltage V_E

vi. Stabilizing transformer: It is well known that the dynamic response of a control system can be improved by the internal derivative feedback lop.

b. How voltage can be controlled in power system with the help of transformer?
(2M each method)

Ans. Method of voltage control:

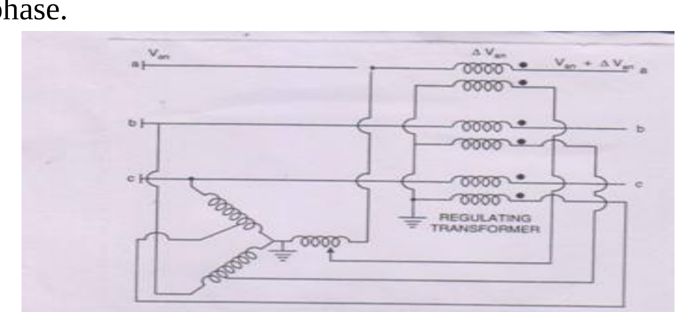
i) Online tapchanging transformer:



All transformers are provided with taps on the winding foradjusting the ratio of transformation. Taps are usually provided on the high voltage winding to enable afine control of voltage. Generally the tap changing can be be done any when the transformer is in de-energised state. However in some cases tapchanging is also possible when the transformer is energized. These tranformers make it possible to maintain a constant voltage level on important buses in the system.

ii) Regulating transformer:

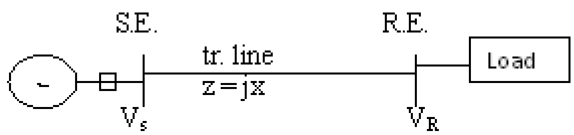
A special type of transformer designed for small adjustments of voltage is known regulating transformer. The fig. shows a typical arrangement to use a regulating transformer for voltage mag control in a 3 phase ckt. A 3 phase transformer provides on adjustable voltage to the primary ωdgof the regulating transformer. The secondary ωdgof the regulating transformer are connected in series with the lines. Thus a voltage magnitude|ov| to the voltage of each phase.



c. Derive the expression for max. power flow under steady state condition.
Ans.

Definition: It is the locus of power transmitted from generating station to the load centre w.r.to power angle.

Consider a simple power system with loss less transmission line as shown in figure



Power transmitted from S.E. to R.E. is $s = V_s I^*$

where $I = \frac{V_s - V_R}{jx}$

$= V_s \left(\frac{Vs^* - VR^*}{-jx}\right)$

Now $V_R = V_R \angle 0^0$…………………………………………reference rector

$V_s = |V_s| \angle \delta$ ⟶ *(1M)*

∴substituting in above equation

$S_s = P_s + jQ_s$

$S_s = \frac{Vs^2 - V_s V_R \angle\delta}{-jx} \times \frac{i}{j}$

$= \frac{Vs^2 - V_S V_R (\cos\delta + j\sin\delta)}{x} x\, j$

$= \frac{V_S V_R}{x} \sin\delta + j\left(\frac{Vs^2}{x} - \frac{V_S V_R \cos\delta}{x}\right)$

$$\therefore\ P_s = \frac{V_S V_R}{X} \quad Q_S = \frac{Vs^2 - V_S V_{R\cos\delta}}{X}$$

$= \frac{Vs - (V_S V_R \cos\delta)}{x}$ ⟶ *(1M)*

Similarly at Receiving end, power will be

$S_R = V_R I_R^* = V_R = \left(\frac{V_R - V_S}{jx}\right)^*$

$= V_s V_R \sin\delta + j\left(\frac{V_S V_R}{x}\cos\delta - \frac{VR^2}{x}\right)$

i.e. $P_R = \frac{V_S V_R}{X} \sin\delta$ $\quad Q_R = \frac{V_R (V_S \cos\delta - V_R)}{X}$

This shows that, $P_S = P_R = \frac{V_S V_R}{X} \sin\delta$ ⟶ *(1M)*

For constant values of $V_S\ V_R \propto X$

$P \propto \sin\delta$

When $0 < \delta < 180^0$………… P is +ve

$180^0 < \delta < 360^0$ i.e. δ is –ve P is also –ve

That means when 'δ' is +ve, P shows generator action and when 'δ' is –ve it shows motor action.

When δ is 90^0

$\therefore P_{max} = \frac{V_S V_R}{X}$ ⟶ *(1M)*

d. What is "stability limit"? State the difference between "steady state stability limit" and "transient state stability limit".

(Define 2M, difference 2M)

Ans.

Stability limit: The maximum feasible power flow through some point in the power system. When the entire system or port there of under investigation is operating with stability

Steady state stability limit	Transient state stability limit
Maximum possible flow of power without loss of stability when power is changed slowly	Maximum possible flow of power without loss of stability when large sudden disturbance occurs
Under small disturbances	Large disturbances
Steady state stability limit	Transient state stability limit is less

e. How environmental and social factors affect the load forecasting in power system?

(2M environmental, 2M social)

Ans."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. **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.

2. **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 on power assumption.

Temperature & wind speed/direction affects the heating /air conditioning loads.

Cloud, humidity, fog affects lighting load as they affect the day-light illumination.

Temperature & load has non-linear relationship. In a typical season changes in temp is 1^0C, then change in load demand will be by 1%.

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 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, Marashtra 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 in load forecasting.

f. The incremental fuel curve of two units of a generating station are
$dF/dP_1 = 0.4P_1 + 40$ Rs/MWh
$dF/dP_2 = 0.4P_2 + 35$ Rs/MWh
Determine load distribution between the two units under economical load dispatch, if the total load on generating station is 500 MW.

Ans.

$dF/dP_1 = 0.4P_1 + 40$ Rs/MWh

$dF/dP_2 = 0.4P_2 + 35$ Rs/MWh

Total Load = 500 mw

$P_1 + P_2 = 500$………………..(i)…………………………(1M)

For economical load dispatch $dF/dP_1 = dF/dP_2$

$0.4P_1 + 40 = 0.5P_2 + 35$

$0.4P_1 – 0.5P_2 = 35-40 = -5$

$0.4P_1 – 0.5P_2 = -5$……..(ii)………………………..(1M)

Solve equation (i) & (ii)

$0.5 (P_1 + P_2 = 500)$

$0.4P_1 - 0.5P_2 = -5$

$0.5P_1 + 0.5P_2 = 250$

$0.4P_1 - 0.5P_2 = -5$

$0.9P_1 = 245$

$P_1 = \frac{245}{0.9} = 272.22$ MW……………………………..(1M)

Put P_1 in equation (i)

$P_1 + P_2 = 500$

$272.22 + P_2 = 500$

$P_2 = 227.78$MW…………………………………….(1M)

Thus the load distribution is $P_1 = 272.22$MW, $P_2 = 227.78$MW