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

WINTER – 2019 EXAMINATION
MODEL ANSWER

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

Important Instructions to examiners:

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

Q. No.	Sub Q.N.	Answer	Marking Scheme
1	**(A)** **(a)** **Ans.**	**Attempt any THREE:** **State the difference between 'Load bus' and 'Generator bus'.** 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 negative. 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 **OR**	**12** **4M** ***Any four points 1M each***

Sr. No.	**Load bus**	**Generator Bus**
1	At this bus power is injected or delivered to load	At this bus power generated is injected into the system
2	at this bus real &reactive	At this bus magnitude of voltage

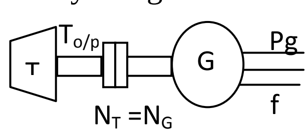
	component of power is specified. At this bus voltage is allowed to vary within the permissible limit and phase angle 'δ' is not important from consumers point of view Specified quantities/ specification- P,Q	corresponding to its rating are specified from load flow solution and it is required to find out Q & S Specified quantities /specification- P, V
3	Quantities Obtained /Unknown Quantities-- V, δ	Quantities Obtained/ Unknown Quantities—Q , δ
4	Bus voltage is variable	Bus voltage is fixed
5	This is also called as PQ bus	This is also called as PV bus

(b) **State and explain the relation between 'Real power flow' and 'frequency' in a power system.** **4M**

Ans. **Relation between real power and frequency of the system.**

Real power is generated at generating station by generators to meet the real power demand. During transmission of power from generating station to load centers some of the power in lost in the apparatus such as transmission line, transformers & generators which is also accounted as real power loss. ***1M***

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 equal to rate of power consumption. We also know that electricity is transmitted at almost velocity of light.



Considering entire power system when real power flows from generating end to load end, it can be represented in equation form as…

Real power generated = Real power demanded by load + Real power lost in the system ***1M***

		$P_g = P_d + P_L$ i.e power balance equation. 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. The losses in the system are negligible compared to P_g and P_d. Hence Pg≈Pd Sins power system is a not an ideal system, hence Pg≠ Pd. Then Pg>Pd or Pg< Pd. If Pg>Pd, then excess amount of power is at input side of generator that means at output of turbine .This shows that more KE is available in turbine so it's speed increases. Since generator is coupled to turbine, generator speed also increases. Now we know that, f= PN/120 i.e. frequency of generated e.m.f. also increases. If Pg>Pd → Pg↑ → (Gen. i/p =Turbine o/p)↑ → more KE in turbine → N_T↑↑ → N_G↑↑ → f= PN/120 hence - f↑	*1M*
		Vice-Versa ,if Pg<Pd, If Pg<Pd → Pg↓ → (Gen. i/p =Turbine o/p)↓ → more KE in turbine → N_T↓↓ → N_G↓↓ → f= PN/120 hence- f↓	*1M*
		This shows that, difference between Pg and Pd will enter into or exit from kinetic energy storage in prime mover. This kinetic energy varies the speed of the generator .Hence imbalance in real power is reflected in variation in speed i.e. variation of frequency of generated voltage. Imbalance of real power arises due to sudden drop or rise in load demand or fault occurred or failure of generator. Say suddenly all the loads connected to the system are put off or failure of transformer / tr. Line then, Pg>>>Pd, 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. 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.	

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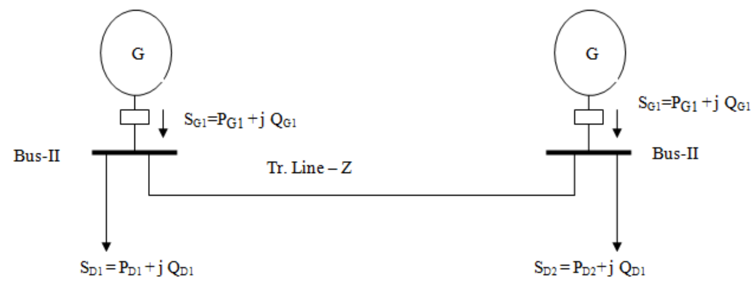
	(c) **Ans.**	**State any two voltage control methods adopted in following areas:** **(i) Generating station** **(ii) Sub-stations** **Voltage control method** **(i) Generating station :** **1.** Automatic Voltage Control/Automatic Voltage regulator (AVR) 2. Excitation control by Tirril Regulator 3. Excitation control by Brown-Boveri Regulator **(ii) Sub-stations:** 1. By regulating transformers 2. By tap changing transformers. i. Off load tap changing Location – Distribution Substations, ii. On load tap changing Location- Intermediate Distribution Substations. 3. By tap changing Auto-transformers. 4. By booster transformers 5. By shunt capacitors Location – Distribution Substations, 6. By synchronous condenser location –	**4M** ***Any 2 methods each 1M*** ***Any 2 methods each 1M***
	(d) **Ans.**	**State the necessity of voltage control in power system operation.** **Necessity of voltage control in power system operation:** 1. Maintains voltage profile 2. Better voltage regulation 3. Reduction reactive power flow 4. Reduction in losses as line current reduces 5. Improvement of P.F 6. Reduction in KVA demand charges 7. Decrease in KVA loading of generators	**4M** ***Any four necessity 1M each***
1.	**(B)** **(a)** **Ans.**	**Attempt any ONE:** **Derive $Y_{bus}V_{bus} = I_{bus}$ for a simple two-bus power system.** Consider a simple two bus power system as shown in the fig.	**06** **6M**



1M

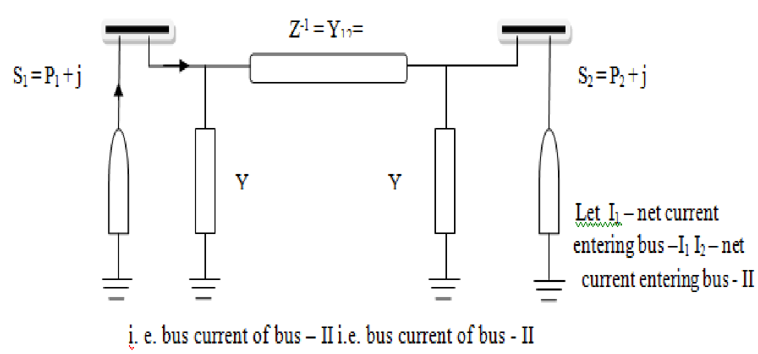
Let S_{G1}&S_{G2} be the power injected by the generators in bus – I and bus – II respectively. which was measured on the h. v. side of the transformers. Let S_{D1}&S_{D2} be the load demands on bus I & bus II respectively. Two buses are interconnected by a transmission line having ∏ equivalent ckt. Let $V_1$and V_2be the voltage at two buses I & IIrespectively.

Let S_1&S_2 be the bus power which is defined as difference between generated power and load demand.

Hence,

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

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



1M

<table>
<tr><td></td><td></td><td>
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)
$I_2 = -Y_1 Y' + (Y+Y') V_2$ ------------------- (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,
$\begin{vmatrix} I_1 \\ I_2 \end{vmatrix} = \begin{vmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{vmatrix} + \begin{vmatrix} V_1 \\ V_2 \end{vmatrix}$ ---------- **(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 = $\begin{vmatrix} Y_{11} \\ Y_{12} \\ Y_{21} \\ Y_{22} \end{vmatrix}$
</td><td>

1M

1M

1M

1M</td></tr>
<tr><td></td><td>**(b)**

Ans.</td><td>**State and explain any three methods of improving transient stability condition in a power system.**
Following are methodsthat can be adopted for the improvement of transient stability condition of a power system: These techniques are classified as Traditional Technique and New Approaches</td><td>**6M**</td></tr>
</table>

		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. 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. Some features of the power system layout and business arrangement also help in improving stability. Use of bundled conductors helps in reducing line reactance and improving line stability. The compensation of line reactance by series capacitance is another effective method of improving stability. **iv) Rapid fault clearing:** By decreasing the fault cleaning angle (by using high speed breakers) stability can be improved. **v) 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 fault and then the circuit breaker recloses, after a suitable time interval. **vi) Quick valve opening action:** During disturbance to generator more amount of power excess amount of steam is supply to turbine if turbine o/p is adjusted to get required generator o/p then system operate in equilibrium condition that means during disturbance turbine o/p has to be reduced by controlling flow of steam through valve hence now days electronic governors are used which operate valve electrically and controlled by electronics. **vii) Application of braking resistors :** whenever there is reduction sudden in load on generator without disturbing turbine i/p power then	***Any 3 methods 2M each***

		generator can artificially loaded for this breaking R are used which will substituted loss of load /demand whenever fault occurs suitable control sy. Comes into action and connected R to generator terminals. A few cycle after clearance of fault same control sy. Disconnected braking and generator will continue to feed n/w. **viii) Single pole switching:** under large disturbance most of T.R line falls that occurs are 1Ø line to ground fault if ckt- breakers and protection scheme are properly arranged then only faulty line can be de – energized . Also most of fault under large disturbance occurs in transmission sy. Are transistaly teens after clearance of fault same phase line can put into service after certain time period depends on amount of fault current ckt voltage and wind velocity . it also not visible to operate system over- long period with 1Ø open hence some arrangement have to be make for tripping the entire 3Ø line if fault fault remain for longer period. **ix) Fast acting automatic voltage regulator:** whenever fault occurs insy. Voltage at all buses in system reduces the voltage at generator bus can controlled and maintain by excitation generator sy. For this purpose automatic voltage regulators is used similarly voltage at difference buses also reduce due to sault current and drop in voltage across transmission line heance in modern power system voltage control equipment are used at specific buses in system the modern voltage regulators respond rapidly(0.5-1.5 cycle).	
2.	 **(a)** **Ans.**	**Attempt any FOUR:** **State the effect of change in frequency on various consumers and utilities.** **Effect of change in frequency on various consumers:** 1) In most of the industries, Induction motor is used as common drive, which runs at speed that is directly related with frequency. (N= 120f/p) variation in frequency affects the quality of the product and rate of production. 2) Induction motor used as common a.c. drives though has rigid construction but due to variation in supply frequency, life of induction motor reduces by 500 Hrs. They are not sensitive for small variation in the supply frequency. i.e. of the order of 50 $\pm$ 2 Hz. 3) In railway stations, the electric chokes are driven by single-phase synchronous motor, The speed of the synchronous motor depends	**16** **4M** ***Any 4 effect 1M each***

		on supply frequency directly. Hence it needs constant frequency supply for all 24 Hrs. of the day. If frequency falls by 1 hr , then clock falls back by 15 min. & it takes no. of hours to reduce the error to zero. 4) In some industries such as the textiles rubber, plastic & paper require frequency constant or to a tolerance of $\pm$ 0.25 per min. 5) Electric gear systems used in industries requires the frequency 49.5 Hz to 50.5 Hz range. 6)	
	(b) **Ans.**	**List out the advantages of reactive power compensation in power system.** **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.	**12** ***Any four advantages 1M each***
	(c) **Ans.**	**List out the data required for Load flow studies.** • Single line diagram of a power system. • 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 equ. Ckt. • 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. • At certain buses, static capacitors are used for voltage level improvement their admittance value should be clearly specified. • Some of lines may be tuned for the purpose of voltage	**4M** ***Any four points 1M each***

stabilization, by using shunt reactors or series capacitors. Their values should be made available.

- Depending upon no. 07 buses in the system bus data should be made available : -

Type of bus	No of buses	Bus date
Generator bus		P, (V)
Load bus		P, Q

- 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.
  A no. of load flow solutions is possible for different sets of control parameters.

OR

FollowingData are required for load flow analysis:

1. **System data**: It includes: Single line diagram system of a power, number of buses-*n*, number of PV buses, number of loads, number of transmission lines, number of transformers, number of shunt elements, the slack bus number, voltage magnitude of slack bus (angle is generally taken as 0o), tolerance limit, base MVA, and maximum permissible number of iterations.
2. **Generator data:** No. of generating stations connected in the system ready to generate the required amount of power and their time duration should be available. Each generators rating, maximum& minimum limits of generation, their characteristics, and excitation control details are made available.
3. **Transmission line data -** For every transmission line connected between buses I and k the data includes the starting bus number i, ending bus number *k*,
   - Line parameters – .*r*esistance of the line, reactance of the line and the half line charging admittance. Series impedance (z) in per unit, shunt admittance (Y) in per units,
   - Thermal limits of the line.
   - Length of the line.
   - Identification of each line and its '∏' equivalent circuit.
4. **Transformer data:** Type of transformer such as distribution

transformer / power transformer, auto-transformer, tap-changing transformer (on-line or ff-line). Also ratings, % impedance and tap setting points, tap setting on HV /LV /both sides are required. (Quite often it may be necessary to adjust voltages on one or both sides of the transformers to maintain the potential levels at the neighboring buses within specified limits. For achieving this, auto and double winding transformers with provision for tap changing on H. V. side or used so as to facilitate smoother control. For every transformer connected between buses *i* and *k* the data to be given includes: the starting bus number *i*, ending bus number *k*, resistance of the transformer, reactance of the transformer, and the off nominal turns-ratio.

5. **Bus data:** Depending upon no. of buses in the system, bus data should be made available.

Type of bus	Bus data	No of buses	For each Bus
Generator bus	P, (V)		P_{Gi}, V_i, , minimum and maximum reactive power limit (Q_i,min, Q_i,max).
Load bus	P, Q		active power demand P_{Di}, and the reactive power demand Q_{Di}.
Slack bus	V, δ		Generator ratings which is assume to be connected to slack bus
Voltage control bus	P Q V		Voltage control equipment used and its rating, max. & min. limits

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

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

(d) State the characteristics of Y_{bus} matrix. **4M**

Ans.

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

Where,

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

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

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

Also,

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

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

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

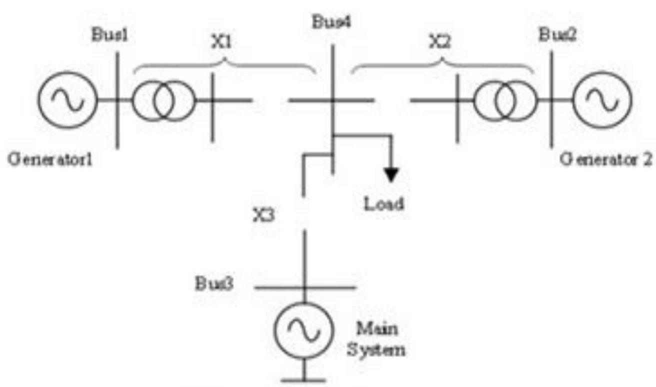
Characteristics of Y_{bus} matrix:

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

Any four characteristics 1M each

		10) All mutual admittances are negative complex numbers.	
	(e) Ans.	**With reference to power system define-** **(i) Steady state stability** **(ii) Steady state stability limit** **(iii) Transient state stability** **(iv) Transient state stability limit.** **(i) Steady state stability:** When the power system has capacity to regain and maintain equilibrium condition (synchronous speed) after a small slow disturbance such as load variation or changes in load condition occurs, then the power system is said to be in steady state stability condition. **(ii) 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. **(iii) Transient stability:** Transient stability is the ability of the power system to regain or maintain equilibrium conditions after experiencing a large sudden disturbance. **(iv) 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.	**4M** ***Each definition 1M***
	(f) Ans.	**State and explain 'dynamic state stability' and 'overall 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 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	**4M** ***Dynamic state stability 2M***

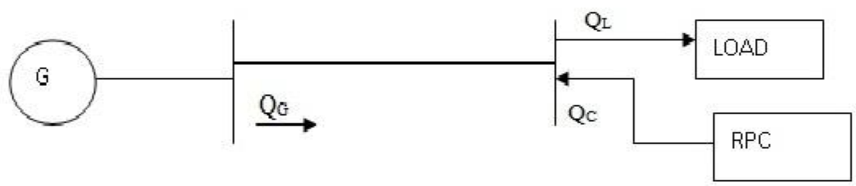
controllers and system elements on performance in terms of their influence on synchronising power and damping power. Oscillations in power (or torque) resulting from the disturbance are considered to be expressible in terms of two components. One is the component of power oscillations that is in phase 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.



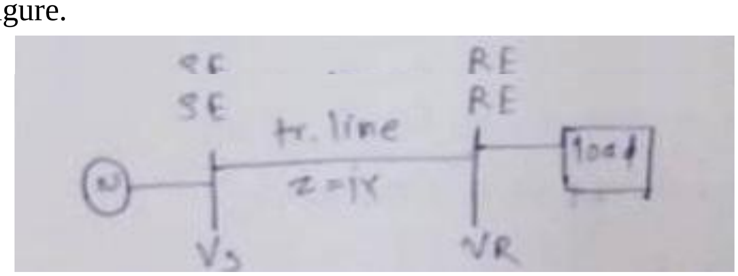
Generic network model

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.

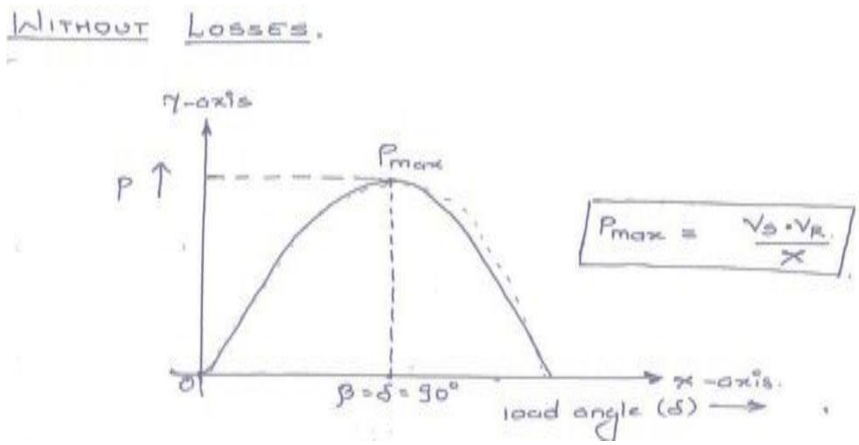
Over all stability: It is the stability of a power system when synchronism of one of working generator has been lost. The normal

		operating condition can be reestablished without disconnection of major elements. Modern power system uses automatic control devices and therefore it is to be tested for its ability to remain in synchronism under steady state as well as transient conditions. Both prior to and after the disturbance. Such operating condition of system is called as Over all stability.	***Overall stability 2M***
3.	**(a)** **Ans.**	**Attempt any FOUR:** **State and explain concept of reactive power compensation.** **State**: This method of generating the reactive power locally to meet the demand instead of generating at generating station and meeting the consumers demand is called as reactive power compensation: The main objective of the utilities is to satisfy the consumers with its power demand. To meet the consumer's reactive power demands, if the same power is generated at generating stations & feed to the consumer, it will cause voltage drop in line. This will result into reduction of transmission efficiency and the cost of power transmission increases. Instead of this is we generate power locally near the load centers& feed it to consumers to his satisfaction the performance of power system will not affect & cost of power transmission also will not increase.  Reactive power generating equipments are located near the load centers which will help to meet the reactive power demand of consumers to his satisfaction. These also help to control the voltage levels in the system. The methods used for this is also called as "Reactive Power Compensation ". And the equipment used is called as "reactive power compensating equipment". Reactive power compensating equipment can be employed either at load level, substation level, or at transmission level.	**16** **4M** ***State 1M*** ***Explana tion 3M***
	(b) **Ans.**	**State the difference between shunt compensation and series compensation refer to reactive power compensation.**	**4M**

		<table><tr><th>Shunt Compensation</th><th>Series Compensation</th></tr><tr><td>Shunt compensation is method use to reduce the rise in voltage level of transmission line by connecting reactive power compensating equipment in parallel with the line.</td><td>Series compensation is a method use to reduce the rise in voltage level of transmission line by connecting reactive power compensating equipment in series with the line.</td></tr><tr><td>Shunt compensation equipment are: Shunt reactor, shunt capacitor.</td><td>Series compensation equipment are: Series reactor, Series capacitor.</td></tr><tr><td>It cannot be overloaded</td><td>It can be overloaded for short periods</td></tr><tr><td>Located near load at the at the midpoint or receiving end of the line or substation tertiary delta winding of the auto transformer primary winding of power transformer.</td><td>Located in series with the transmission line at any point in the line.</td></tr><tr><td>Less maintenance</td><td>More maintenance</td></tr><tr><td>Failure of one unit of static capacitor bank affects that unit only, remaining unit continue to operate</td><td>Failure of compensator means loss of line or failure of line</td></tr></table>	***Any four differences 1M each***
	(c) **Ans.**	**Write SLFE of a simple two bus power system and define it'sparameters.** For a simple two bus system Load flow equations can be written as…. <table><tr><td>SLFE Equation: $S_1 * = V_{12}\, Y_{11}\, L\angle\alpha_{11} + Y_{12}\, V_2\, V_1\, (\delta_2 - \delta_1) = P_1 - j\, Q_1$</td></tr><tr><td>$P_1 = V_{12}\, Y_{11}\, Cos\angle\, \alpha_{11} + Y_{12}\, V_2\, V_1\, Cos\, (\delta_2 - \delta_1)$</td></tr><tr><td>$Q_1 = (V_{12}\, Y_{11}\, Sin\angle\, \alpha_{11} + Y_{12}\, V_2\, V_1\, Sin\, (\delta_2 - \delta_1)$</td></tr><tr><td>$S_2 * = V_{22}\, Y_{22}\, L\angle\, \alpha_{22} + Y_{21}\, V_2\, V_1$ $(\delta_1 - \delta_2) = P_2 - j\, Q_2$</td></tr><tr><td>$P_2 = V_{22}\, Y_{21}\, Cos\angle\, \alpha_{22} + Y_{21}\, V_2\, V_1\, Cos\, (\delta_1 - \delta_2)$</td></tr><tr><td>$Q_2 = (V_{22}\, Y_{22}\, Sin\angle\, \alpha_{11} + Y_{12}\, V_2\, V_1\, Sin\, (\delta_1 - \delta_2)$</td></tr></table>	**4M** ***2M***

		V_1, V_2….Vn are the bus voltages δ_1, δ_2…. are load angles with reference to bus-1, bus-2 and so on. Y_{11}, Y_{22}….. areself admittance with reference to bus-1, bus-2 and so on. Y_{12}, Y_{21}…. are Mutual admittance with reference to bus-1, bus-2 and so on S_1, S_2……complex power at bus-1, bus-2. P_1, P_2……..Real power at bus-1, bus-2. Q_1, Q_2…….Reactive power at bus-1, bus-2.	***2M***
	(d) **Ans.**	**List out the informations that can be collected 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 (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.	**4M** ***Any four points 1M each***
	(e) **Ans.**	**Derive the equation for maximum power flow under steady state condition, considering a simple two bus power system.** Consider a simple power system with less transmission line as shown in figure.  Power transmitted from S.E. to R.F. is S = VsI Where 1= $\frac{V_S - V_R}{jx}$ = V_S	**4M** ***1M***

		$\therefore V_S = \left(\frac{V_S - V_R}{-jx}\right)$	
		Now $V_R = V_R < 0$	
		$V_S = \lvert V_S \rvert < \delta$	***1M***
		$\therefore S_S = P_S + jQ_S$	
		$S_S = \frac{Vs^2 - V_s V_R < \delta}{-jx}$ X $\frac{1}{J}$	
		$= \frac{Vs^2 - V_s V_R (\cos \delta + i\sin \delta)}{x}$ j	
		$= \frac{V_S - V_R}{x} \sin \delta + i \frac{Vs^2}{x} - \frac{V_S V_R \cos \delta}{X}$	
		$\therefore P_S = \frac{V_S - V_R}{x}$ $Q_S = Vs^2 - \frac{V_S V_R \cos \delta}{X}$	***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. $= P_R = \frac{V_S V_R}{x} \sin\delta$ $Q_R = \frac{V_R (V_S \cos \delta - V_R)}{x}$	
		$\therefore P_S = P_R = \frac{V_S V_R}{x} \sin\delta$	***1M OR At the discretion of examiner***
		$\therefore$ For constant $V_S V_R$. X	
		$P \; \alpha \; sin\delta$	
		When $0 < \delta < 180$ ……………P is +ve $180 < \delta < 360$……………...P is –ve	
		$\therefore$ When δ is 90^0	

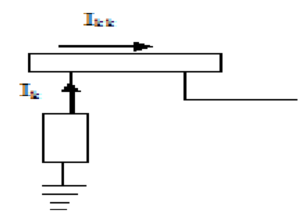
		$P_{max} = \frac{V_S V_R}{x}$ This is the maximum power flow for steady state stability.	
	(f) Ans.	**Draw and explain power angle diagram neglecting losses in the system.**  The power angle equation of a two machine system model can be written as $P = \frac{V_1 V_2}{X} \sin\delta$ Where $V_1\angle\delta$ $V_2\angle 0$ are Bus voltages δ – Loud angle X – transfer reactance of line. Now locus power 'P' with respect to loud angle 'S' is called power angle curve. For constant values of V_1 V_2 and for same transfer line x constant. Then P ∝ sin δ when δ is positive i.e. $O\angle\delta\angle 180^0$ the power P is positive. That means power flows from generator to loud. For positive values ofδ P is negative i.e. power flows from load to generator. In system power always flows from generator to load in normal operating condition. When $\delta = 0$ P = 0 i.e. power flow	**4M** ***Diagram 2M*** ***Explanation 2M***

		As δ increases power generation also increases When $\delta = 90^0$ sin $\delta = 1$ $$\therefore P = P_{max} = \frac{V_1.V_2}{X}$$ For any value of P we have 2 points on the diagram 'A' and 'B' say P is constant but rotor speed due to some reason has momentarily increased so the rotor angle δ to $(\delta + \Delta\delta)$ which corresponds to 'A'. So the corresponding output power is $(P + \Delta P)$. Now the imbalance occurs between generation α consumption and as a result rotor speed decreases and settle down to 'δ' after certain oscillations. So 'A' is stable operating power. If 'B' is stable operating point then small increase by $\Delta\delta$ 0 would shift B to B^1. Hence power output decreases and is less then P_0. Now the rotor will experience accelerating power but the rotor output decrease further and 'δ' will continue to increase few there and 'δ' will not be restored $\therefore$ B is in unstable condition. At point A ⟶ $\delta\delta \to \Delta\delta$ then P P $\to \Delta$ P As rotor output ↑⟶ rotor speed ↓⟶ δ↓ At point B ⟶ $\delta\delta \to \Delta\delta$ then P P $\to \Delta$ P Rotor output ↓⟶ rotor speed ↓↓⟶ δ↓ unstable $\therefore 0\ \delta \le 90^0$ --------stable region $90^0\ \delta \le 180^0$ -----unstable region Practically system operates for $30^0 \angle \delta \angle 45^0$.	
4.	**(A)** **(a)** **Ans.**	**Attempt any THREE:** **State and explain following equations refer to power system.** **(i) Bus loading equation** **(ii) Line flow equation**	**12** **4M**

(i) Bus Loading equation:

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

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



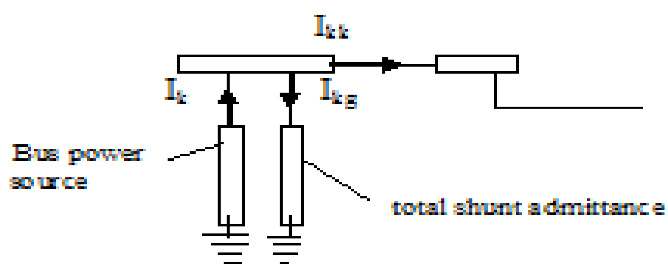
Current at bus I $I_k = \frac{P_k - Q_k}{V_k^*}$

Bus loading 2M

Bus Current $I_k$is positive when if flows into the system.

If the shunt elements are neglected or considered in Y_{bus} matrix thenabove 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

(ii) Lines Flow Equation:

Assume that current is flowingthrough tr. Line from bus k to bus j.

$$\boldsymbol{I_{kj} = \frac{V_k - V_j}{Y} Y^1 + V_k \, {}^{Y}\!/_{2}}$$

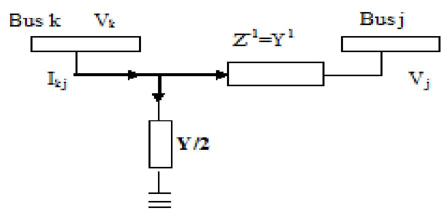
Where Y^1- line admittance

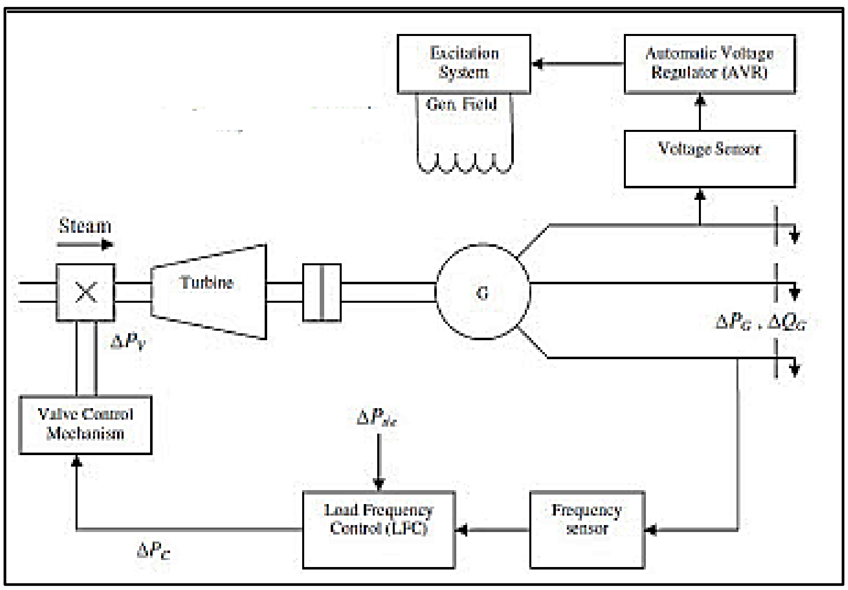
Y – line changing admittance

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

Lines flow equation 2M

		Similarly power flows from j to 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.	
	(b) **Ans.**	**State the advantages of Y_{bus} matrix in load flow studies.** ***(Note: Any other advantages shall be considered)*** 1. Data preparation for LFs is simple. 2. Its information of Y_{bus} matrix for any system. 3. Modification of Y_{bus} matrix due outage of transmission lines or transformer is easy. 4. $Y_{bus}$is a sparse matrix (i.e. most of its elements are zero). ∴the computer memory requirements are less. For a large power system more than 90% of its off. Diagonal elements are zero. This is due to the fact that in power system network each bus is connected to not more than 3 buses in general αy_{Pq} exists only if transmission line links bus p αq .	**4M** ***Any four advantages 1M each***
	(c) **Ans.**	**Write 'Swing equation'referred to power system and define it's parameters.** $$M\frac{d^2\delta}{dt^2} = P_a = P_m - P_e$$ $wherem = angularmomentum,$ $P_m = mechanicalpowerinput,$ $P_e = electricalpoweroutput,$ $P_a = acceleratingpower,$ $\delta = angulardisplacementofrotor$	**4M** ***Equation 3M*** ***Meaning of each term 1M***

	(d) **Ans.**	**List out the methods of improving transient stability in a power system.** 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	**4M** ***Any 4 methods 1M for each***
4.	**(B)** **(a)** **Ans.**	**Attempt any ONE:** **Draw neat labeled schematic diagram of turbo generator with load-frequency control and voltage control.** 	**06** **6M** ***5M for components and 1M for labeling***
	(b) **Ans.**	**List out the information of Load Dispatch Centre (LDC).** ***(Note: Functions of any type of LDC shall be considered).*** **Functions of National Load Dispatch Centre:** 1. Supervision over the RLDCs. 2. Scheduling and dispatch of electricity over inter-regional links in accordance with Grid standards specified by the Authority and Grid Code specified by the Central Commission in coordination with RLDCs.	**6M**

		3. Coordination with RLDCs for achieving maximum economy and efficiency in operation of National Grid. 4. Monitoring of operations and grid security of the National Grid. 5. Supervision and control over the inter regional links as may be required for ensuring stability of the power system under its control. 6. Co-ordination with Regional Power Committees for regional outage schedule in the national perspective to ensure optimum utilization of power resources. 7. Coordination with RLDCs for the energy accounting of inter-regional exchange of power. 8. Coordination for restoration of synchronous operation of National Grid with RLDCs. 9. Co-ordination for trans-national exchange of Powers. 10. Providing operational feed-back for National Grid planning to the Authority and the Central Transmission Utility. 11. Levy and collection of such fee and charges from the Generating Companies or the licensees involved in the power system as may be specified by the Central Commission. 12. Dissemination of information relating to operations of transmission system in accordance with directions or regulations issued by the Central Commission and the Central Government from time to time.	***Any 6 1M each***
5.	**(a)** **Ans.**	**Attempt any FOUR:** **Develop Y_{bus} matrix for a 3bus system with following details:**	**16** **4M**

Bus Code	Line impedance (Pu)	Bus Code	Line Charging admittance (Pu)
1 – 2	0.085 + j0.32	1	j0.01
2 – 3	0.045 + j0.06	2	j0.03
1 – 3	0.055 + j0.08	3	j-0.00

$Z_{12} = 0.085 + j0.32$
$Z_{23} = 0.045 + j0.06$
$Z_{13} = 0.055 + j0.08$

Calculation of mutualadmittances….

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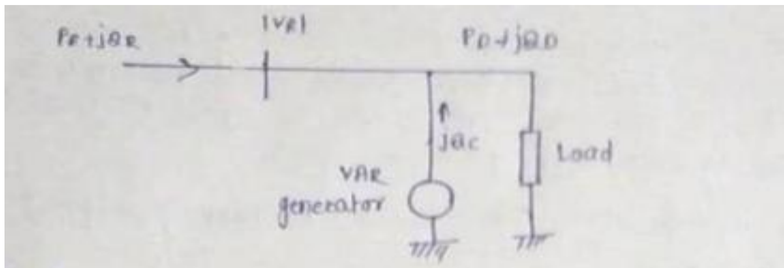
		$y_{12} = \frac{1}{z_{12}} = \frac{1}{0.085 + j0.32} = \frac{1}{0.33 < 83.47} = \frac{1}{0.33 < 75.12}$ $= 3.03 < 75.12$ y_{12} = 0.77.j2.9	***1½M***
		$y_{23} = \frac{1}{z_{23}} = \frac{1}{0.045 + j0.06} = \frac{1}{0.075 < 53.13} = 13.33 < 53.13$ $y_{23} = 7.99 - j10.66$ $y_{13} = \frac{1}{0.055 + j0.08} = \frac{1}{0.097 < 55.49} = 10.309 < -55.49$ $y_{13} = 5.840 - j8.49$	***1½M***
		$y_{12} = y_{21} - y_{12} = -y_{21}$ = - (0.77 – j0.9) $y_{13} = y_{31} - y_{13} = -y_{31}$ = - (5.840 – j8.49) $y_{23} = y_{30} - y_{23} = -y_{32}$ = - (7.88 – j10.66) Calculation of self-admittances…. $y_{11} = y_{11} + y_{12} + y_{13}$ = j0.01 + (0.77-j2.9) + (5.840 – j8.49)	

		= 6.61 – j11.38 $y_{22} = y_{21} + y_{22} + y_{23}$ = 0.77- j2.9 + j0.03 + (7.99– j10.66) = 8.76 – j13.53 $y_{33} = y_{31} + y_{32} + y_{33}$ = 5.840- j8.49 + 7.99– j10.66 + (-j0.01) = 13.83 – j19.16 ∴ Required Y_{bus} is $$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix}$$ $$= \begin{bmatrix} 6.61 - j11.38 & -(0.77 - j2.9) & -(5.840 - j8.49) \\ -(0.77 - j2.9) & (8.76 - j13.53) & -(7.99 - j10.66) \\ -(5.846 - j8.49) & -(7.99 - j10.66) & -(13.83 - j19.16) \end{bmatrix}$$ $$Y_{bus} = \begin{bmatrix} 6.61 - j11.38 & -0.77 + j2.9 & -5.840 - j8.49 \\ -0.77 - j2.9) & 8.76 - j13.53 & -7.99 + j10.66 \\ -5.846 - j8.49 & -7.99 - j10.66) & 13.83 - j19.16 \end{bmatrix}$$	*1M*
	(b) **Ans.**	**With the help of diagram explain voltage control by reactive power injection method.** Voltage control by reactive power injection method**:**	**4M**

			***Diagram 1M***
		1. To keep the receiving end voltage of specified value $\lvert V_{SR} \rvert$ a fixed amount of VARs $\lvert Q_R^S \rvert$ must be drawn from the line. 2. To accomplish this under conditions of a varying VAR demand. Q_D a local VAR generator must be used as shown in figure. 3. The VAR balance equation at the receiving end is now, $$Q_R^S + Q_C = Q_D$$ 5. Fluctuations is an are absorbed by the load VAR generator Qc such that the VARs drawn from the line remain fixed at Q_R^S 6. The receiving end voltage would thus remain fixed at $\lvert V_R^S \rvert$. 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.	***3 m for explanation***
	(c)	**State the functions of following systems referred to ALFC & AGC** - **Hydraulic amplifier.** - **Frequency integrator** - **Governor** - **Comparator**	**4M**
	Ans.	Functions of following systems referred to ALFC & AGC • **Hydraulic amplifier:** It comprises a pilot valve and main piston arrangement low power level pivot valve movement is connected into high power level piston valve movement. This is necessary in order to open or close the steam valve against high pressure stream. • **Frequency integrator:** It converts frequency signal into speed signal. • **Governor:** It raises the signal to increase or decrease the speed of turbine through link mechanism.	***Each function 1M***

		• **Comparator:** It compares the actual frequency with the reference frequency and sends the signal to Frequency integrator.	
	(d) Ans.	**State the necessity of load forecasting in power system operation.** **Necessity of Load forecasting:** Load forecasting for power system operation is required … 1. For proper planning, designing of new power system network or expansion of existing. 2. For varying generation of power with respect to time i.e. amount of growth expected in power demand. 3. For determining the capacity of power generation and power flow through transmission lines and distribution lines. 4. For proper planning of power flow through transmission & distribution network. 5. For proper operation of power system in instability condition. 6. For proper planning of resources for generation of power i.e. conventional or non-conventional resources. 7. For determining the cost of power generation, transmission and distribution. 8. For proper man power development or training of manpower for operation of power system. 9. To decide power tariff for different utilities and different consumers. 10. For proper power transaction between neighbouring grid system. 11. For proper energy sales in electrical market. 12. For finding the requirement of fuel in future.	**4M** *Any four necessity 1M each*
	(e) Ans.	**"Load shedding is adopted during the operation of power system". Give reason.** Load shedding means intentional interruption of supply to load. The reasons for adopting load shedding during power system operation are 1. To keep balance between power demand and power generation. 2. To maintain the stability condition of system due to sudden rise or fall in demand/load. 3. To overcome energy generation crises / lack of generated energy. 4. Sharing of power so to increase run time of critical loads. 5. To reduce wastage of energy and max demand. 6. To adopt energy conversation objectives. 7. To reduce peak demand charges and also to reduce energy bills.	**4M** *Any Four reasons 1M each*

	(f)	**Refer to Indian power system scenario state the types of LDC and their locations.**	4M
	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. **Indian power system** has identified different types of LDC depending on their locations. 1. National Load Dispatch Centre (NLDC) 2. In India NLDS is located at Delhi 3. Regional Load Dispatch Centre (RLDC) 4. State Level Load Dispatch Centre (SLDC) 5. Sub State Load Dispatch Centre (SSLDC) 6. Local are LDC Types of LDC:	***1M for each type with location***

Types of LDC		Locations
National Load Dispatch Centre (NLDC)		Delhi
RLDC	ERLDC – Eastern Region	Kolkata
	SRLDC – Southern Region	Bangalore
	WRLDC – Western Region	Mumbai (Kalwa)
	NELDC – North East Region	Shilong
	NRLDC – Northern Region	Delhi
SLDC -State Level Load Dispatch Centre	Maharashtra state LDC	Nagpur
SSLDC- Sub State Load Dispatch Centre	Maharashtra state LDC	Mumbai
LLDC – Local Load Dispatch Centre	Tata Power Company Ltd	Mumbai

6.		**Attempt any FOUR:**	16
	(a)	**Refer to Y_{bus} matrix, define** **- driving point admittance** **- transfer admittance**	4M
	Ans.		

$$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} \dots\dots & Y_{1n} \\ Y_{21} & Y_{22} \dots\dots & Y_{2n} \\ Y_{n1} & Y_{n2} \dots\dots & Y_{nn} \end{bmatrix}$$

Driving point admittance: The diagonal elements of Y_{bus} matrix are called **driving point admittance or self-admittance.** It is the sum of line charging admittance of a bus and line admittance between that bus other connecting buses to it.

$$\therefore y_{11} = y_{10} + y_{12} + y_{13}$$

$$y_{22} = y_{20} + y_{21} + y_{23}$$

$$y_{33} = y_{30} + y_{31} + y_{32}$$

Each definition 2M

Transfer admittance: The off diagonal elements of Y_{bus} are called as transfer admittance or mutual admittance. It is the line admittance between a bus and other bus with negative sign.

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

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

$$y_{14} = -y_{41}$$

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

OR

		Ybus matrix for a 3 bus system can be obtained from power system equations. $I_1 = Y_{11}V_1 + Y_{12}V_2 + Y_{13}V_3$ — ① $I_2 = Y_{21}V_1 + Y_{22}V_2 + Y_{23}V_3$ — ② $I_3 = Y_{31}V_1 + Y_{32}V_2 + Y_{33}V_3$ — ③ From eq. ①, we can define $Y_{11} = \frac{I_1}{V_1}\Big\|_{V_2=V_3=0}$ – It is the self-admittance of bus-1 when bus-2 & bus-3 are shorted to reference node i.e. $V_2=V_3=0$. Ill'y $Y_{22} = \frac{V_2}{I_2}\Big\|_{V_1=V_3=0}$ $Y_{33} = \frac{V_3}{I_3}\Big\|_{V_1=V_2=0}$ $Y_{12} = \frac{I_1}{V_2}\Big\|_{V_1=V_3=0}$. It is the mutual admittance between bus-1 & bus-2 and is measured by injecting current I_2 in bus-2 and shorting the bus 1 & bus-3 to reference node. Now $I_1 = 0$ but I_2 flows in opposite direction. i.e. $I_1 = -I_2$. ∴ This admittance is considered with negative sign. $Y_{21} = \frac{I_2}{V_1}\Big\|_{V_2=V_3=0}$ here. $I_2 = -I_1$ Also $Y_{12} = Y_{21}$ Ybus matrix can be written as $Y_{bus} = \begin{vmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{vmatrix}$ All diagonal elements are self-admittar and off-diagonal elements are mutual admittance. ... is useful for	

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

(b) **With the help of diagram explain voltage control by**
- tap changing transformer
- Booster transformer — **4M**

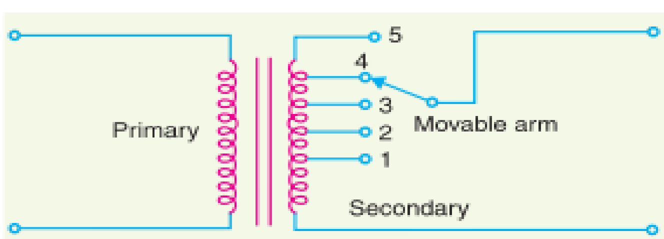
Ans. Following are the different types of transformers used for voltage contr in power system.

1) Online tap changing transformer: All transformers are provided with taps on the winding foradjusting the ratio of transformation. Taps are usually provided on the highvoltage winding to enable afine control of voltage. Generally the tap changing can be done any when the transformer is in de-energized state. However in some cases tapchanging 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.

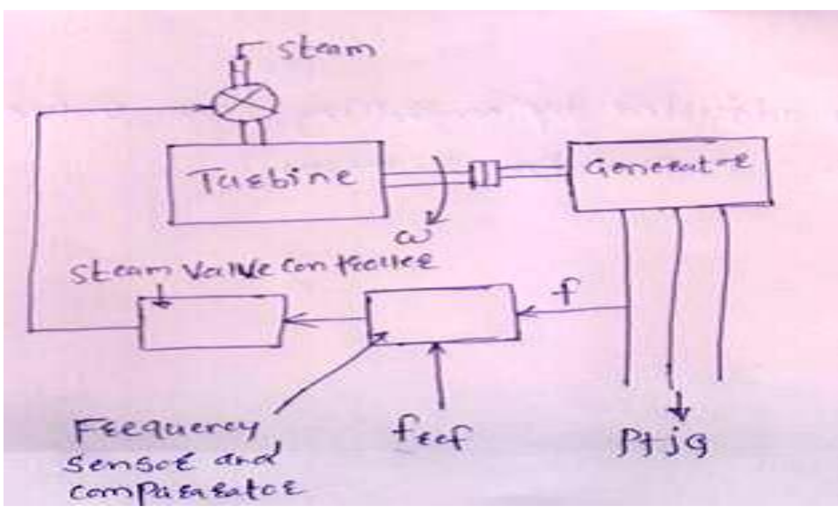
Tap changin g 2M

Location: Intermediate distribution Substation

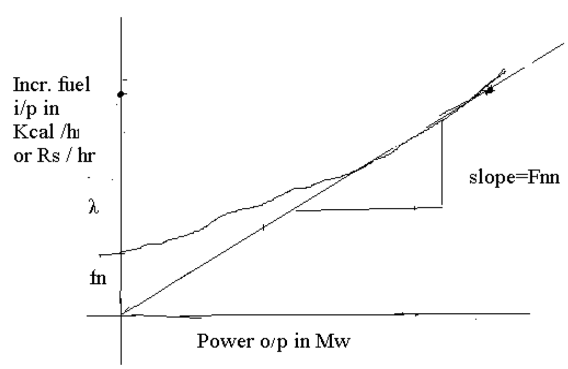
2) Off load tap-changing transformer: Figure shows the arrangement where a number of tapings have been provided on the secondary. As the position of the tap is varied, the effective number of secondary turns is varied and hence the output voltage of the secondary can be changed. Thus referring to figure when the movable arm makes contact with stud 1, the secondary voltage is minimum and when with stud 5, it is maximum. During the period of light load, the voltage across the primary is not much below the alternator voltage and the movable arm is placed on stud1. When the load increases, the voltage across the primary drops, but the secondary voltage can be kept at the previous value by placing the movable arm on to a higher stud. Whenever a tapping is to be changed in this type of transformer, the load is kept off and hence the name off load tap-changing transformer.



4) 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**	***Booster 2M***
	(c) **Ans.**	**Explain the concept of single area control referred to Load frequency control.** 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.	**4M** ***Explanation 3M*** ***Diagram 1M***

		. 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.	
	(d) **Ans.**	**List out the environmental factors that affect loud forecasting.** Following are environmental factors that affect load forecasting of power system. 1. Time dependent factor 2. Weather dependent factor [Humidity, temperature] 3. Wind – wind speed, wind direction, cloud cover, fog. 4. Random weather change [storm, sunami, heavy rain, flood]. Or 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	**4M** ***Each factor 1M***

		the correlation between weather parameters and model their influence on power assumption. 3. **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%. 4. **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.	
	(e) **Ans.**	**Draw and explain the incremental fuel cost curve.** **Definition:-**Incremental fuel cost curve is graphical representation of relation between costs of incremental fuel input with the power output in MW. Incremental production cost =Incremental cost power generation = incr. cost of fuel + incr. cost of labour + incr. cost of transportation + incr. cost of water supply+ incr. cost of taxes Practically it is difficult to develop the relation between incr. cost of labour, incr. cost of transportation, incr. cost of water supply, incr. cost of taxes with the power o/p and represent it in mathematical form.. And also they are negligible compare to incremental fuel cost. Therefore we get **Incremental production cost = Incremental fuel cost =** $\frac{dF}{dP} = \lambda$ Incremental fuel cost curve is a wide concave curve which shows that as power output is increases increment fuel cost also increases.In the lower range of power output, rise in incremental fuel cost is much smaller than that in the higher range of power output. Pmax & Pmin indicates max & min. power generation limits.  	**4M** ***1M for Diagram , 1M for equation and*** ***Explana tion 2M***

WINTER – 2019 EXAMINATION
MODEL ANSWER

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

		Now IFCC can be expressed as …. $$\frac{dF}{dP} = F_{nn} P_n + f_n = \lambda_n$$ Where f_n - intercept of the curve F_{nn} --slope of the tangent	
	(f) **Ans.**	**Incremental fuel cost curve of two generating units are as** **$dF_1/dP_1 = 0.12\ P_1 + 20$** **$dF_2/dP_2 = 0.10\ P_2 + 15$** **If the load on power plant is 410 MW, determine the most economical load sharing between two.** Given, $dF_1/dp_1 = 0.12\ P_1 + 20$ $dF_2/dp_2 = 0.10\ P_2 + 15$ Total load = 410W $\therefore\ P_1 + P_2 = 410W$……………………………(i) For economical load dispatch $dF_1/dp_1 = dF_2/dP_2$ $\therefore 0.12P_1 + 20 = 0.10P_2 + 15$ $\therefore\ 0.12P_1 - 0.10P_2 = -5$………………(ii) Solving equation (i) and (ii) $P_1 + P_2 = 410$ $0.12P_1 - 0.10P_2 = -5$ $\therefore\ 0.10\ (P_1 + P_2) = (0.4 \times 410)$ $0.10P_1 + 0.10P_2 = 41$ $0.10P_1 + 0.10P_2 = 41$ $0.12P_1 - 0.10P_2 = -5$ $0.22\ P_1 = 36$	**4M** *1M* *1M*

		$\therefore$ $P_1 = 163.63$ MW $\therefore$ From equation (i) $P_1 + P_2 = 410$ $\therefore P_2 = 410 - 163.63 = 246.37$MW $\therefore$ Load distribution is $P_1 = 163.63$MW $P_2 = 246.37$MW	***1M*** ***1M***