7. SUBJECT DETAILS

7.4 POWER SYSTEM OPERATION AND CONTROL

7.4.1 OBJECTIVE AND RELEVANCE

The main objective is to provide the students with an overview of the engineering and economic matters involved in designing, operating and conrolling the power generation and transmission of a large scale, inter connected power system.

This subject is committed to the study of

i. Analytical methods of arriving at the optimal operating strategies which must meet the minimum standards of reliability i.e. continuity of supply and the problems in power systems like unit-commitment and load scheduling.
ii. Automatic control of power output of generators to maintain the scheduled frequency and automatic control of reactive power demand to maintain the desired voltage profile at the load end.

This course is introduced to enable the student master the process of simulation and modelling of the power system components and application of the simulation concepts learnt.

7.4.2 SCOPE

This subject is useful to train the under graduate in the latest techniques of analysis of large scale power systems which is a similar need exists in the industry where a practicing power system engineer is constantly faced with the challenge of the rapidly advancing field.

7.4.3 PREREQUISITES

The student is expected to have prior knowledge in circuit theory and electrical machines with special emphasis on laplace transforms, linear differential equations. Knowledge of optimization techniques, basic power systems and a first course in control theory is highly desirable.

7.4.4.1 JNTU SYLLABUS

UNIT-I

OBJECTIVE

The main objective of this unit is to study the analyitcal methods of arriving at the optimal strategies in power systems which must meet the minium standards of relaibility. It mainly focuses the attention on optimal allocation of real power at generator buses for mininizing the cost of generating real power (thermal stations).

The main objective of this unit is to focus the attention on optimal allocation of real power at generator buses including the effect of transmission line losses for mininizing the cost of generating real power (thermal stations).

SYLLABUS

ECONOMIC OPERATION OF POWER SYSTEMS: Optimal operation of generators in all thermal power stations, heat rate curve, cost curve, incremental fuel and production costs, input and output characteristics, optimum generation allocation with line losses neglected.

Optimum generation allocation including the effect of transmission line losses, loss coefficients, general transmission line loss formula.

UNITII

OBJECTIVE

This unit presents minimization of operating cost of hydrothermal system which is a dynamic optimization problem and the systematic coordination of the operation of a system of hydroelectric generation plants which is usually more complex than the scheduling of an all - thermal generation system.

SYLLABUS

HYDROTHERMAL SCHEDULING: Optimal scheduling of hydrothermal system: Hydro electric power plant models, scheduling problems, short term hydro thermal scheduling problem.

UNIT-III

OBJECTIVE

The objective of this unit is to study the modelling of synchronous generator in transient and steady state modes which are required for stability analysis of the power system and to acquire the knowledge on the modelling of prime-mover and excitation controllers which are used for the regulation of frequency and terminal voltage respectively for the purposes of stability analysis of the power systems.

SYLLABUS

MODELLING OF TURBINE, GENERATOR AND AUTOMATIC CONTROLLERS: Modelling of turbine: first order turbine model, block diagram representation of steam turbines and approximate linear models.

MODELLING OF GENERATOR (STEADY STATE AND TRANSIENT MODELS) : Description of simplified network model of a synchronous machine (classical model), description of swing equation (no derivation) and state-space ii-order mathematical model of synchronous machine.

MODELLING OF GOVERNOR: Mathematical modelling of speed governing system - derivation of small signal transfer function.

MODELLING OF EXCITATION SYSTEM : Fundamental characteristics of an excitation system, ttransfer function, block diagram representation of ieee type-1 model

UNIT-V

OBJECTIVE

The objective of this unit is to acquire the knowledge on importance of frequency control, automatic load frequency control mechanism of single area system whose role is to maintain desired megawatt output of a generator unit and assist in controlling the frequency of the larger interconnection.This unit also presents the analysis of ALFC loop in terms of static and dynamic responses.

SYLLABUS

SINGLE AREA LOAD FREQUENCY CONTROL: Necessity of keeping frequency constant.
Definition of control area, single area control, block diagram representation of an isolated power system, steady state analysis, dynamic response, uncontrolled case.

I love the challenge.

- Nancy Lopez

UNIT-VI
OBJECTIVE
The objective of this unit is to acquire the knowledge of frequency control of interconnected areas or power pools as todays power systems are tied together with neighbouring areas to gain many advantages in brief mutual assistance, which are more important than those of isolated areas.

SYLLABUS
TWO-AREA LOAD FREQUENCY CONTROL: Load frequency control of two area system, uncontrolled case and controlled case, tie line bias control.

UNIT-VII
OBJECTIVE
The objective of this unit is to acquire the knowledge on PI control for the single area system to yield zero steady state error and economic dispatch control.

SYLLABUS
LOAD FREQUENCY CONTROLLERS: Proportional plus integral control of single area and its block diagram representation, steady state response, load frequency control and economic dispatch control.

UNIT-VIII
OBJECTIVE
The objective of this unit is to study the compensation of the reactive power in powersystems, some of the characterstics of powersystems and their loads which deteriote the quality of supply and to identify those which can be corrected by compensation i.e by generation or absorption of a suitable quantity of reactive power.

SYLLABUS
REACTIVE POWER CONTROL: Overview of reactive power control, reactive power compensation in transmission systems, advantages and disadvantages of different types of compensating equipment for transmission system, load compensation, specifications of load compensator, uncompensated and compensated transmission lines, shunt and series compensation.

7.4.4.2 GATE SYLLABUS

UNIT-I
Economic operation.

UNIT-II
Economic operation.

UNIT-III
Not covered.

UNIT-IV
Swing equation.

UNIT-V
Not covered in syllabus, but asked questions from load frequency control.

UNIT-VI
Not covered in syllabus, but asked questions from tie line control.

UNIT-VII
Not covered in syllabus, but asked questions from load frequency control.

UNIT-VIII
Voltage control.

7.4.4.3 IES SYLLABUS

UNIT-I
Optimal system operation.

UNIT-II
Optimal system operation.

UNIT-III
Not covered in syllabus, but asked questions from hydro electric stations.

UNIT-IV
Swing equation.

UNIT-V
Load frequency control.

UNIT-VI
Load frequency control.

UNIT-VII
Load frequency control.

UNIT-VIII
Voltage control.

7.4.5 SUGGESTED BOOKS

TEXT BOOKS

T1 Power System Analysis, Operation and control by Abhijit Chakrabatri,Sunitha Halder.PHI 3/e,2010
T2 Modern Power System Analysis, I.J. Nagrath and D.P. Kothari, 2nd Edn., Tata Mc Graw-Hill Publishing Company Ltd.

REFERENCE BOOKS

R1 Power System Analysis and Design, J.Duncan Glover and M.S.Sarma., 3rd Edn., THOMPSON.
R2 **E**lectric Energy systems Theory, O.I. EIgerd, 2 nd Edn., Tata McGraw-Hill Publishing Company Ltd.
R3 Power system Analysis, Grainger and Stevenson,Tata Mc Graw Hill.
R4 **E**lectrical Power Systems, C.L.Wadhwa, 3rd Edn., New Age International (P) Ltd, 1998.
R5 Electric Power Systems, B.M. Weedy, B.J. Cary 4th Edn., John Wiley & Sons.

R6 Power Generation Operation and Control, A.J. Wood and B.F. Wollenberg John Wiley & Sons, 1984.
R7 Power system analaysis, Hadi Sadat, Tata Mc Graw Hill Edition.
R8 Power System Dynamics: Stability and Control, K.R. Padiyar, 2nd Edn., B.S. Publications.
R9 Computer Modelling of Electrical Power Systems, J. Arrillaga, C.P. Arnold and B.J. Harker, 2nd Edn, John Wiley & Sons Publishers.

7.4.6 WEB SITES

1. www.sonton.ac.uk (university of southampton)
2. www.berkely.edu (University of California, Berkely)
3. www.ncsu.edu (North Carolina University)
4. www.manchester.ac.uk (University of Manchester)
5. www.unb.ca (University of New Brun Swick)
6. www.umn.edu (University of Minnesota)
7. www.iitb.ac.in (IIT, Bombay)
8. www.iitk.ac.in (IIT, Kanpur)
9. www.iitm.ac.in (IIT, Madras)
10. www.iitd.ac.in (IIT, Delhi)

7.4.7 EXPERTS' DETAILS

INTERNATIONAL

1. Dr. B.F. Woolenberg,
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2. Dr. Arthur R. Bergen,
   Department of Electrical Engineering and Computer Sciences,
   University of California,
   Berkely,
   email: www.eecs.berkely.edu.

3. Dr. M.S. El - Moursi,
   Department of Electrical and Computer Engineering,
   University of New Brun Swick,
   Fredericton, NB E3B 5A3,
   Canada,
   email: m.shawky @ unb.ca.

4. Dr. B. Tyagi,
   Department of Electrical Engineering,
   Harcourt Butler Technological Institute,
   Kanpur - 208016,
   India,
   email: barjeev @ iitk.ac.in.

NATIONAL

Show me a guy who is afraid to look bad, and I'll show you a guy you can beat every time.
- Lou Brock

1. Dr. D.P. Kothari,
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2. Dr. I.J. Nagrath,
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   BITS, Pilani,
   email: www.bits-pilani.ac.in.

REGIONAL

1. Dr. A.V.R.S.Sarma,
   Associate Professor,
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2. Dr. B.V. Sankar Ram,
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   Department of Electrical and Electronics Engineering,
   JNTU, Kukatapalli, Hyderabad,
   email : bvrsram4321@yahoo.com.

7.4.8 JOURNALS

INTERNATIONAL

1. IEEE Transactions on Power Systems
2. IEEE Transactions on Power Delivery
3. IEEE Journal on Computer Application in Power
4. Power Engineering Journal, IEE
5. IEEE transactions on Power and Energy
6. IEEE transactions on Power Apparatus and Systems

NATIONAL

1. Electrical India
2. Electrical Engineering Updates

7.4.9 FINDINGS AND DEVELOPMENTS

1. "Multiple Time Resolution Unit Commitment for Short-Term Operations Scheduling Under High Renewable Penetration",Bakirtzis, E.A.; Biskas, P.N.; Labridis, D.P.; Bakirtzis, A.G., IEEE Transactions on Power Systems, Vol. 29, Issue 1, Jan 20014.
2. "Solving Multi-Objective Economic Dispatch Problem Via Semidefinite Programming",Jubril, A.M., Komolafe, O.A.,Alawode, K.O., IEEE Transactions on Power Systems, Vol. 28, Issue 3, August 20013.
3. "Dynamic Economic Dispatch Considering Transmission Losses Using Quadratically Constrained Quadratic Program Method", Zhong, H., Xia, Q., Wang, Y.; Kang, C., IEEE Transactions on Power Systems, Vol. 28, Issue 3, August 2013.
4. "A Frequency-Constrained Stochastic Economic Dispatch Model", Lee, Y.-Y., Baldick, R., IEEE Transactions on Power Systems, Vol. 28, Issue 3, August 2013.

Sl. No.	Topics in JNTU Syllabus	Modules and Sub Modules	Lecture No.	Suggested Books	Remarks
UNIT-I					
1	Optimal operation of generators in all thermal power stations	Introduction	L1	T1-Ch 11, T2-Ch7 R2-Ch8, R3-Ch 13 R4-Ch19,R5-Ch4 R6-Ch3,R7-Ch7	GATE IES
2	Heat rate curve Cost curve Incremental fuel and production costs Input and output characteristics	Heat rate curve Cost curve Incremental fuel and production costs Input and output characteristics	L2	T1-Ch 11, R3-Ch13 ,R4-Ch19,T2-Ch 7 R5-Ch4,R2-Ch8 R7-Ch7	GATE IES
3	Optimum generation allocation with line losses neglected	Lagrangian Coordination Equation	L3	T1-Ch 11, ,T2-Ch7 R3-Ch13,R4-h19 R5-Ch4,R2-Ch8 R6-h3,R7-Ch7	GATE IES
		Problems on optimum generation allocation with line losses neglected	L4	T1-Ch 11, T2-Ch7 R3-Ch13,R4-Ch19, R5-Ch4,R2-Ch8 R6-Ch3,R7-Ch7	GATE IES
		Problems on optimum generation allocation with line losses neglected	L5	T1-Ch11, T2-Ch7 R3-Ch13,R4- Ch19, R5-Ch4,R2-Ch8 R6-Ch3,R7-Ch7	GATE IES
UNIT-II					
4	Optimum generation allocation including the effect of transmission line losses	Penalty factor Incremental transmission loss Exact coordination equation	L6	T1-Ch11, T2-Ch7 R3-Ch13, R4-Ch19 R5-Ch4,R2-Ch8 R6-Ch3,R7-Ch7	GATE IES
		Problems on optimum generation allocation with line losses	L7	T1-Ch11, T2-Ch7 R3-Ch13,R4-Ch19, R5-Ch4,R2-Ch8 R6-Ch3,R7-Ch7	GATE IES
5	General transmission line loss formula Loss coefficients	Derivation of transmission loss formula assumptions	L8	T1-Ch11, T2-Ch7 R3-Ch13,R4-Ch19, R7-Ch7	
		Problems on B-Coefficients	L9	T1-Ch11, T2-Ch7 R3-Ch13,R4-Ch19, R5-Ch4,R2-Ch8 R6-Ch3,R7-Ch7	
		Exercise problems	L10	T1-Ch11, T2-Ch7 R3-Ch13,R4-Ch19 R5-Ch4,R2-Ch8 R6-Ch3,R7-Ch7	
		Exercise problems	L11	T1-Ch11, T2-Ch7 R3-Ch13,R4-Ch19 R5-Ch4,R2-Ch8 R6-Ch3,R7-Ch7	

A true friend is one soul in two bodies.

- Aristotle

Sl. No.	Topics in JNTU Syllabus	Modules and Sub Modules	Lecture No.	Suggested Books	Remarks
UNIT-III					
6	Optimal scheduling of hydrothermal system: Hydroelectric power plant models	Introduction Long range hydro scheduling Short range hydro scheduling Incremental water rate versus power output.	L12	T1-Ch11,R6-Ch7	
7	Scheduling problems	Types of scheduling problems Scheduling energy Problems	L13	T1-Ch11,R6-Ch7	IES
8	Short term hydro-thermal scheduling problem	Fundamental system Mathematical formulation	L14	T1-Ch11,T2-Ch7, R6-Ch7	
		Solution technique Algorithm Hydro thermal system with hydraulic constraints	L15	T1-Ch11,T2-Ch7, R6-Ch7	
		Problem on hydro thermal scheduling	L16	T1-Ch11,T2-Ch7, R6-Ch7	
UNIT-IV					
9	Modeling of turbine: First order turbine model Block diagram representation of steam turbines	Small signal transfer function	L17	T1-Ch14, T2-Ch8 R8-Ch4, R9-Ch7	
10	Approximate linear models	Tandem compound single and double reheat turbines Cross compound single and double reheat turbines Block diagram representations	L18	T1-Ch14,R8-Ch4, R9-Ch7	
11	Modeling generator: Description of simplified network model of synchronous machine	Introduction Modelling of synchronous machine	L19	T1-Ch14,T2-Ch4 R8-Ch7 R9-Ch7	
12	Description of swing equation	Description of swing equation, swing equation for multi-machine system, for machines swinging coherently, for non coherent machines, problems on swing equation	L20	T1-Ch14,T2-Ch12 R8-Ch2	GATE IES

Sl. No.	Topics in JNTU Syllabus	Modules and Sub Modules	Lecture No.	Suggested Books	Remarks
13	States space II-order mathematical model of synchronous machine	Generator load model, derivation and block diagram representation	L21	T1-Ch14,T2-Ch12 R8-Ch2	GATE IES
14	Modeling governor	Block diagram representation of automatic load frequency and voltage control loops of synchronous generator Small signal analysis	L22	T1-Ch14,T2-Ch8 R8-Ch4 R9-Ch7	GATE IES
15	Mathematical modeling of speed governing system Derivation of small signal transfer function	Functional diagram Block diagram representation of speed governor system	L23	T1-Ch14,T2-Ch8 R8-Ch4 R9-Ch7	GATE IES
16	Excitation system modeling : Fundamental characteristics of excitation system	Objective of excitation system Some definitions Functioning of the exciter Exciter ceiling voltage Exciter response DC, AC and static excitation systems Functional block diagram of excitation control system	L24	T1-Ch14,R8-Ch4	
17	Transfer function	Terminal voltage transducer and load compensator Exciters and voltage regulators Excitation system stabilizer and transient gain reduction Power system stabilizer	L25	T1-Ch14,R8-Ch4	
		Excitation system standard block diagram DC excitation system, derivation of transfer function AC excitation system, saturation characteristics	L26	T1-Ch14,R8-Ch4	
		Static excitation system Brushless excitation	L27	T1-Ch14,R8-Ch4, R9-Ch7	
18	Block diagram representation of IEEE type-1 model	Mathematical model of the system	L28	T1-Ch14,R8-Ch4 ,R9-Ch7	

Without friends, no one would want to live, even if he had all other goods.

- Aristotle

Sl. No.	Topics in JNTU Syllabus	Modules and Sub Modules	Lecture No.	Suggested Books	Remarks
		UNIT-V			
19	Necessity of keeping frequency constant	Introduction Governor characteristics Load frequency problem Schematic diagram of L-F and Q-V regulators of turbo generator Cross coupling between control loops	L29	T1-Ch14, T2-Ch8 R4-Ch20, R5-Ch4, R2-Ch9 R6-Ch9, R7-Ch12	IES
20	Definition of control area, single area control Block diagram representation of isolated power system	Reasons for limits on frequency Turbine speed governing system Block diagram model of load frequency control	L30	T1-Ch14, ,T2-Ch8 R4-Ch20 R5-Ch4, R2-Ch9,R6-Ch9, R7-Ch12	IES
21	Steady state analysis	Steady state analysis	L31	T1-Ch14,T 2-Ch8, R2-Ch9 R6-Ch9,R7 -Ch12	IES
		Problems on load frequency control	L32	T1-Ch14, ,T2-Ch8 R4-Ch20 R2-Ch9, R6-Ch9 R7-Ch12	GATE IES
22	Dynamic response Uncontrolled case	Problems on dynamic response	L33	T1-Ch14,T 2-Ch8, R2-Ch9	IES
		UNIT-VI			
23	Load frequency control of two area system Uncontrolled case and controlled case	Mathematical modeling of load frequency control of two area system Synchronizing coefficient Static response (Uncontrolled case)	L34	T1-Ch14,T 2-Ch8, R5-Ch4,R2 -Ch9 R6-Ch9,R7 -Ch12	GATE IES
		Dynamic response (Uncontrolled case) The Controlled case Area control error Change in tie line power due to step load change in area -1	L35	T1-Ch14,T 2-Ch8, R2-Ch9, R6-Ch9, R7-Ch12	GATE IES
		Composite block diagram representation of two area load frequency control Problems on two area load frequency control	L36	T1-Ch14,T 2-Ch8 R5-Ch4,R2 -Ch9 R6-Ch9,R7 -Ch12	GATE IES

Sl. No.	Topics in JNTU Syllabus	Modules and Sub Modules	Lecture No.	Suggested Books	Remarks
24	Tie line bias control	Tie line loading frequency characteristics Tie line bias control of two area and multi area systems Summary of tie line frequency control	L37	T1-Ch14,R4-Ch20 R5-Ch4,R2-Ch9 R6-Ch9,R7-Ch12	GATE IES
		UNIT-VII			
25	Proportional plus integral control of single area and its block diagram representation, steady state response	Control area concept Area control error Dynamic response of load frequency controller with and without integral control action.	L38	T1-Ch14,T2-Ch8, R2-Ch9	IES
26	Load frequency control and economic dispatch control	Load frequency control and economic dispatch control	L39	T1-Ch14,T2-Ch8, R2-Ch9	IES
		Problems on load frequency control	L40	T1-Ch14,T2-Ch8, T2-Ch20 R2-Ch9	GATE IES
		Problems on load frequency control	L41	T1-Ch14,T2-Ch8, T2-Ch20 R2-Ch9	GATE IES
		UNIT-VIII			
27	Overview of reactive power control	Overview of reactive power control	L42	T1-Ch19, ,T2-Ch5 R4-10,21R5-Ch5	
28	Reactive power compensation in transmission systems Advantages and disadvantages of different types of compensating equipment for transmission systems	Generation and absorption of reactive power Types of compensators Reactive power injection Static VAR generator Rotating VAR generator Observations Shunt capacitors and reactors	L43	T1-Ch19,T2-Ch5, R5-Ch5R2-Ch4	GATE IES
		Series capacitors Comparison between series and shunt capacitors Transmission lines Cables Transformers	L44	T1-Ch19,R4-Ch10, R5-Ch5	GATE IES
		Tap changing transformers Problem	L45	T1-Ch19, T2-Ch5 R4-Ch10 R5-Ch5	GATE IES
		Combined use of tap-changing transformers and reactive power injection Problem	L46	T1-Ch19,R5-Ch5	GATE IES

Keep a fair-sized cemetery in your back yard, in which to bury the faults of your friends.

- Henry Ward Beecher

Sl. No.	Topics in JNTU Syllabus	Modules and Sub Modules	Lecture No.	Suggested Books	Remarks
		Booster transformers Phase shift transformers Problem Over all view on advantages and disadvantages of different types of compensating equipment for transmission system	L47	T1-Ch19,R4-Ch10 R5-Ch5	GATE IES
		Problems on reactive power generation and absorption	L48	T1-Ch19, T2-Ch5 R4-Ch10	GATE IES
29	Load compensation Specifications of load compensator	Power factor correction Improvement of voltage regulation Load balancing	L49	T1-Ch19,R4-Ch21	
		Study of voltage regulation using short circuit capacity Problem	L50	T1-Ch19,R4-Ch21	
30	Uncompensated transmission lines	Uncompensated transmission lines	L51	T1-Ch19,R4-Ch21	
		Symmetrical Line Radial line with asynchronous load	L52	T1-Ch19,R4-Ch21	
31	Compensated transmission lines Shunt compensation	Compensation of lines Surge impedance compensation Compensation by sectioning Line length compensation	L53	T1-Ch19,R4-Ch21	IES
32	Series compensation	Effect of series compensation on surge impedance loading Comparison between shunt and series compensation	L54	T1-Ch19,R4-Ch21	IES
		Active shunt compensator V-curves for the condenser Condenser out put Use of condenser for HVDC line Static compensators	L55	T1-Ch19,R4-Ch21	IES
		Thyristor controlled reactor Basic circuits Control of Basic TCR 3-Phase arrangement of TCR Steady state performance	L56	T1-Ch20,R4-Ch21, R5-Ch9	IES
		Thyristor switched capacitors Saturated reactors FACTS Static condenser Advanced thyristor controlled series compensation Thyristor controlled phase shifting transformer	L57	T1-Ch20,R4-Ch21, R5-Ch9	IES
		Problems on reactive power control	L58	T1-Ch19, T2-Ch5 R4-Ch10,21	GATE IES

What three things do you want to accomplish this year? Write them down and place them on your refrigerator for inspiration all year long. - Source Unknown

ii. TUTORIAL PLAN

S. No	Topics scheduled	Salient topics to be discussed
1	Optimal operation of generators in all thermal power stations Heat rate curve Cost curve Incremental fuel and production costs Input and output characteristics Optimum generation allocation with line losses neglected	Problems on optimum generation allocation with line losses neglected
2	Optimum generation allocation including the effect of transmission line losses	Problems on optimum generation allocation with line losses
3	General transmission line loss formula Loss coefficients	Problems on loss loss coefficients
4	Optimal scheduling of hydrothermal system: Hydroelectric power plant models Scheduling problems Short term hydro-thermal scheduling problem	Problem on hydro thermal scheduling
5	Modeling of turbine: First order turbine model Block diagram representation of steam turbines Approximate linear models	Review on various turbine models
6	Modeling generator: Description of simplified network model of synchronous machine Description of swing equation States space II-order mathematical model of synchronous machine	Review on modeling of synchronous generators
7	Modeling governor Mathematical modeling of speed governing system Derivation of small signal transfer function	Discussion of mathematical modeling of speed governing system
8	Excitation system modeling, Fundamental characteristics of excitation system Transfer function, Transfer function	Review on excitation system modeling
9	Block diagram representation of: IEEE type-1 model Necessity of keeping frequency constant Definition of control area, single area control Block diagram representation of isolated power system	Review on IEEE type-1 model
10	Steady state analysis Dynamic response Uncontrolled case	Problems on load frequency control of single area system
11	Load frequency control of two area system Uncontrolled and Controlled case Tie line bias control	Problems on Load frequency control of two area system
12	Proportional plus integral control of single area and its block diagram representation, steady state response Load frequency control and economic dispatch control	Problems on Load frequency control

Always have some project underway… an ongoing project that goes over from day to day and thus makes each day a small unit of time. - Lillian Troll

S. No	Topics scheduled	Salient topics to be discussed
13	Overview of reactive power control Reactive power compensation in transmission system Advantages and disadvantages of different types of compensating equipment in transmission system	Overview of reactive power control
14	Load compensation Specifications of load compensator Uncompensated transmission lines	Problems on reactive power control
15	Compensated transmission lines	Problems on reactive power control
16	Shunt compensation Series compensation	Problems on reactive power control

7.4.11 STUDENT SEMINAR TOPICS

1. "Studies on Economic Feasibility of an Autonomous Power Delivery System Utilizing Alternative Hybrid Distributed Energy Resources",Som, T., Chakraborty, N., IEEE Transactions on Power Systems,Volume 29 , Issue 1 , Jan 2014.
2. "Performance-Based Pricing of Frequency Regulation in Electricity Markets", Papalexopoulos, A.D.Andrianesis, P.E., IEEE Transactions on Power systems, Volume 29, Issue 1, Jan 2014.
3. “Smart Grid-Indian perspective”, Kamal Kant Sharma, Balwinder Singh, Trends in Electrical Engineering, Sept-dec 2013.
4. “ Some efficient Optimization methods for solving the security-constrained optimal power flow problem”, D. Phan and J. Kalagnanam, IEEE Transactions on Power systems, Volume 29, March 2014.
5. Electrical systems in large thermal power plants, PC Tripati, Vol. 48, No. 5, Electrical India, May 08..
6. Power quality and reliability cost using demand side management M.S. Shashikala and M.S. Balasundaram, Vol. 48, No. 5, Electrical India, May 08.

7.4.12 QUESTION BANK

UNIT-I

1 a) Explain the following terms with respect to thermal power plants.

i) Heat rate curve ii) Incremental production cost curve

iii) Incremental fuel rate curve iv) Input output curve

b) The incremental fuel costs for the two plants are given by

$$\frac{dc_1}{dp_1} = 0.2p_1 + 45$$

$$\frac{dc_2}{dp_2} = 0.25p_2 + 34$$

(Dec 14)

Where c is in RS/HR and p is in MW. If both units operate at all times and maximum and minimum loads on each are 100MV and 20MV respectively, determine the economic load schedule of the plants for the loads of 80 MV and 180 MV. Neglect line losses.

1. i. Explain the following terms with reference to hydro plants.
   a) Input-output curve
   b) Incremental water rate curve
   c) Incremental production cost curve.

   ii. How is generation scheduled among various generators when transmission losses are neglected in a thermal system? Explain. **(Nov 13)**

2. A system consists of two generators with the following characteristics:

   F_1=($7P_1$+0.03P_1^2+70) 10^5

   F_2=($5P_2$+0.05P_2^2+100) 10^6

   Where F and P are fuel input in K-cal/hr and unit output in MW respectively. The dailyloadcycleisgivenasfollows:

Time	Load
12 midnight 6 am	50 MW
6 am to 6 pm	150MW
6 pm to 12 midnight	50 MW

   Give the economic schedule for the three periods of the day. **(Nov 13)**

3. i. Explain heat rate curve and cost curve. Bring out the differences between them.

   ii. Determine the economic operating point of three units supplying a load of 800 MW. The incremental fuel costs of the three units are:

   dF_1 / dP_1 =6.48+0.00256P Rs/MWh ,

   dF_2 / dP_2 = 7.85 + 0.00388P Rs/MWh

   dF_3 / dP_3 =7.97+0.00964P Rs/MWh **(Nov 13)**

4. Explain how the incremental production cost of a thermal power station can be determined. **(Nov 13)**

5. i. Explain the about the constraints used in economic operation of power system. **(Nov-2012)**

   ii. The incremental fuel cost of a thermal power plant having two units are given by

$$\frac{dF_1}{dP_1} = 0.02P_1 + 4$$

$$\frac{dF_1}{dP_2} = 0.024P_2 + 3.2$$

   For load demand of 180MW. What is the total saving realized against equal distribution of power? **(Nov 12)**

6. What is your analyzation by considering the optimization problem with and without transmission loss consideration. **(May 11)**

7. i. Derive equation for penalty factor.
   ii. Derive equation for optimal operation of thermal power plants. **(May 11)**

8. The fuel cost functions in Rs./hr. for three thermal plants are given by
   $C_1 = 400+8.4P_1+0.006P_1^2$, $100 \leq P1 \leq 600$
   $C_2 = 600+8.93P_2+0.006P_2^2$, $60 \leq P2 \leq 300$
   Where P_1, P_2, are in MW. Neglecting line losses and including generator limits, determine the optimal

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"A little kindness from person to person is better than a vast love for all humankind."

- Author:Richard Dehmel

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generation scheduling where P_D = 820MW. **(May 11)**

9. Draw the flow chart for obtaining optimal scheduling of generating units by neglecting the transmission losses. **(May 11, 09)**

10. i. What is Production cost of power generated and incremental fuel rate?
    ii. Write the expression for hourly loss of economy resulting from error in Incremental cost representation. **(May 11)**

11. A power System consists of two, 125 MW units whose input cost data are represented by the equations :
    $C_1 = 0.04\,P_1^2 + 22\,P_1 + 800$ Rupees/hour
    $C_2 = 0.045\,P_2^2 + 15\,P_2 + 1000$ Rupees/hour
    If the total received power P_R = 200 MW. Determine the load sharing between units for most economic operation. **(May 11, Nov 10)**

12. Two substation are connected by two lines in parallel with negligible impedance, but each containing a tap changing transformer of reactance 0.18 pu on the basis of its rating of 200 MVA. Find the net absorption of reactive power when the transformer taps are set to 1:1.1 and 1:0.9 respectively. Assume p.u., voltages to be equal at the two ends and at substation. **(Nov 10)**

13. Discuss in detail about incremental heat rate curve and cost curve? **(Nov 10)**

14. What is load factor and loss factor and state the criterion for economic operation of power system? **(Nov 10)**

15. i. Define in detail the following:
    a. Control variables
    b. Disturbance variables
    c. State variables.
    ii. Draw incremental fuel cost curve **(Nov 10)**

16. Explain the following terms with reference to power plants: Heat input -power output curve, Heat rate input, Incremental input, Generation cost and Production cost. **(Nov 10)**

17. Draw flow chart for economic scheduling with out considering line losses. **(Nov 10)**

18. Explain in detail the terms production costs, total efficiency, incremental efficiency and incremental rates with respect to Thermal power plant. **(Nov 09, Feb 08, Mar 06, Apr 05)**

19. Explain optimal load flow solution without inequality constraints. **(Nov 09)**

20. A power system consists of two 100MWunits whose input cost data are represented by equations below:
    $C_1 = 0.04\,P_1^2 + 22\,P_1 + 800$ Rupees/hour
    $C_2 = 0.045\,P_2^2 + 15\,P_2 + 1000$ Rupees/hour
    If total received power P_R = 150 Mw. Determine the load sharing between units for most economic operation. **(Nov 09)**

21. i. Explain how the incremental production cost of a thermal power station can be determined.
    ii. Explain the various factors to be considered in allocating generation to different power stations for optimum operation. **(May 09, Nov 08, 07, 04, 03, Mar 06, Apr 05, MU Oct 02)**

22. i. Describe in detail, with suitable examples, the methods of optimum scheduling of generation of power from a thermal station.
    ii. What is Production cost of power generated and incremental fuel rate?

iii. Write the expression for hourly loss of economy resulting from error in incremental cost representation. **(May 09, Nov 07, 06)**

23. Discuss optimal power flow problems with and without inequality constraints. How are these problems solved? **(May 09)**

24. i. Define in detail the following: **(May 09)**
a. Control variables
b. Disturbance variables
c. State variables
ii. Draw incremental fuel cost curve.

25. A power system is operating an economic load dispatch with a system λ of 60 Rs./MWh. If raising the output of plant-2 by 100kW (while the other output kept constant) results in increased power losses of 12 kW for the system. What is approximate additional cost per hour, if the output of this plant is increased by 1MW. **(May 09)**

26. Incremental fuel costs in rupees per megawatt hour for two units are given by **(May 09)**

$$\frac{dF_1}{dP_1} = 0.1P_1 + 20 \, and \, \frac{dF_2}{dP_2} = 0.12P_2 + 10$$

the maximum and minimum loads on each unit are to 25MW and 120MW, respectively. Determine the incremental fuel cost and the allocation of load between units for minimum cost when the loads are:
a. 100MW b. 150MW.

27. i. Explain the various factors that affect optimum operation to be considered in allocating generators of different power stations, neglect line losses.
ii. Explain how the incremental production cost of a thermal power station can be determined. **(Jan 09)**

28. i. Derive the conditions to be satisfied for economic operation of a loss less power system.
ii. 150 MW, 220 MW and 220 MW are the ratings of three units located in a thermal power station. Their respective incremental costs are given by the following equations:

$$\frac{dc_1}{dp_1} = Rs(0.11p_1 + 12) \qquad \frac{dc_3}{dp_3} = Rs(0.1p_3 + 13) \qquad \frac{dc_2}{dp_2} = Rs(0.095p_2 + 14)$$

Where P_1, P_2 and P_3 are the loads in MW. Determine the economical load allocation between the three units, when the total load on the station is i. 350 MW ii. 500 MW. **(Nov, Feb 08, Nov 06, 05, 03)**

29. A power System consists of two, 125 MW units whose input cost data are represented by the equations:
$C_1 = 0.04 P_1^2 + 22 P_1 + 800$ Rupees/hour
$C_2 = 0.045 P_2^2 + 15 P_2 + 1000$ Rupees/hour
If the total received power P_R = 150 MW. Determine the load sharing between units for most economic operation. **(Nov 08, 03)**

30. The fuel cost functions in Rs./hr. for three thermal plants are given by
$C_1 = 400+8.4P_1+0.006P_1^2$, $100 \leq P1 \leq 600$
$C_2 = 650+6.78P_2+0.004P_2^2$, $300 \leq P3 \leq 650$
Where P_1, P_2, are in MW. Neglecting line losses and including generator limits, determine the optimal generation scheduling where PD = 1550MW. **(Nov 08)**

31. A simple two-plant system have the Incremental cost curves are
$dC1 / dP_{G1} = 0.01 P_{G1} + 2.0$

$dC2 / dP_{G2} = 0.01 P_{G2} + 1.5$ determine P_{G1} and P_{G2} when the load on the system is 1000MW. **(Nov 08)**

32. i. Explain the role of incremental fuel cost in thermal plant operation?
ii. Draw Heat curve and explain its significance. **(Nov 08)**

33. 100 MW, 150 MW and 280 MW are the ratings of three units located in a thermal power station. Their respective incremental costs are given by the following equations:
dc1/dp1 = Rs(0.15p1 + 12);
dc3/dp3 = Rs(0.21p3 + 13)
dc2/dp2 = Rs(0.05p2 + 14)
Where P_1, P_2 and P_3 are the loads in MW. Determine the economical load allocation between the three units, when the total load on the station is 300 MW. **(Nov 08)**

34. i. Derive an expression for optimal allocation of generators with in a power plant.
ii. The incremental fuel inputs for a two unit steam plant are given by

$\frac{dc_1}{dp_1} = 0.08p_1 + 15$ Rs/Mw - Hr. $\frac{dc_2}{dp_2} = 0.08p_2 + 20$ Rs/Mw - Hr.

Find the loss in operating economy if the two units share a load of 300 MW equally instead of operating in an optimum way. **(Feb 08, 07)**

35. i. Explain the following terms with reference to power plants: Heat input power output curve, Heat rate input, Incremental input, Generation cost and Production cost.
ii. What are the methods of scheduling of generation of steam plants? Explain their merits and demerits? **(Feb 08, Nov 07)**

36. Give step by step procedure for computing economic allocation of generation in a thermal station. **(Feb 08, Mar 06, Apr 05)**

37. Incremental fuel cost in Rupees per mega watt hour for two units comprising a plant are given by the following equations.
$\frac{dc_1}{dp_1} = .012p_1 + 21; \frac{dc_2}{dp_2} = .01p_1 + 18;$
Assume that both units are operating at all times, that total load varies from 40 to 200 MW and the maximum and minimum loads on each unit are to be 125 and 20 MW respectively. Find the incremental fuel cost & the allocation of loads between units for the minimum cost of various total loads. Derive the formula used. **(Nov 07)**

38. i. What is an incremental fuel cost? How is it used in thermal plant operation?
ii. Name the components of production cost and explain. **(Feb 07, Mar 06, Nov 07, 05, 04)**

39. Discuss about the optimum generator allocation without line losses. **(Feb 07, Nov 04, MU Apr 04)**

40. i. Explain the significance of equality and inequality constraints in the economic allocation of generation among different plants in a system
ii. Derive the condition for economic scheduling of generators in a plant. **(Nov 06, Mar 06)**

41. Write short notes on: Physical interpretation of co-ordination equation. **(Nov 06, Mar 06, Nov 04, Nov 03)**

42. The incremental fuel costs for two plants are given by $\frac{dc_1}{dp_1} = 0.15 p_1 + 30$; $\frac{dc_2}{dp_2} = 0.17 p_2 + 28$

Where C is in $Rs./Hr$ and P is in MW. If both units operate at all time and maximum and minimum load on each unit are 100 MW and 20 MW respectively. Determine the economic operating schedule of the plant for loads of 40 MW, 120 MW and 180 MW. **(Nov 04)**

43. i. A power System consists of two, 125 MW units whose input cost data are represented by the equations:
$C_1 = 0.04\,P_1^{\,2} + 22\,P_1 + 800$ Rupees/hour
$C_2 = 0.045\,P_2^{\,2} + 15\,P_2 + 1000$ Rupees/hour
If the total received power P_R = 200 MW. Determine the load sharing between units for most economic operation.
ii. Discuss the general problem of economic operation of large interconnected areas. **(Nov 04, 03)**

44. What are the methods of scheduling of generation of steam plants? Explain their merits and demerits? **(Nov 04)**

45. i. Derive the coordination equations for economic scheduling including the effect of network losses in a purely thermal system and explain the λ-iteration method of sulving them with the help of flow chart.
ii. What is load factor and state the criterion for economic operation of power system. **(Nov 04)**

46. Explain the terms:
i. Heat rate curve
ii. Cost curve
iii. Incremental fuel cost
iv. Incremental production cost. **(Nov 02, MU Apr 04, Oct 02, IES 93)**

47. A load centre is at an equidistant from the two thermal generating stations G_1 and G_2 as shown in the figure. The fuel cost characteristics of the generating stations are given by
$F_1 = a + bP_1 + cP_1^{\,2}$ Rs/hour
$F_1 = a + bP_2 + 2cP_2^{\,2}$ Rs/hour
Where P_1 and P_2 are the generation in MW of G_1 and G_2, respectively.
For most economic generation to meet 300 MW of load, P_1 and P_2, respectively, are
i. 150, 150
ii. 100, 200
iii. 200, 100
iv. 175, 125 **(GATE 05)**

48. Incremental fuel costs (in some appropriate unit) for a power plant consisting of three generating units are
$IC_1 = 20 + 0.3\,P_1$
$IC_2 = 30 + 0.4\,P_2$
$IC_3 = 30$
Where P_1 is the power in MW generated by unit i, for i = 1, 2 and 3. Assume that all the three units are operating all the time. Minimum and maximum loads on each unit are 50 MW and 300 MW respectively. If the plant is operating on economic load dispatch to supply the total power demand of 700 MW, the power generated by each unit is
i. P_1 = 242.86 MW; P_2 = 157.14 MW; and P_3 = 300 MW
ii. P_1 =157.14 MW; P_2 = 242.86 MW; and P_3 = 300 MW
iii. P_1 = 300.0 MW; P_2 = 300.0 MW; and P_3 = 100 MW
iv. P_1 = 233.3 MW; P_2 = 233.33 MW; and P_3 = 233.4 MW **(GATE 03)**

49. A power system has two generators with following cost curves
Generator 1: $C_1(P_{G1}) = 0.006\,P_{G1}^{\,2} + 8P_{G1} + 350$ (Thousand Rs/ hr)
Generator 2: $C_2(P_{G2}) = 0.009\,P_{G2}^{\,2} + 7P_{G2} + 400$ (Thousand Rs/ hr)
The generator limits are $100\ \text{Mw} \le PG_1 \le 650\ \text{Mw}$
$50\ \text{Mw} \le PG_2 \le 500\ \text{Mw}$
A load demand of 600 Mw is supplied by the generator in an optimal manner. Neglecting losses in the

transmission network determine optimal generation of each generator **(GATE 01)**

50. In a power system the fuel inputs per hour of plants 1 and 2 are given as
$F_1 = 0.20P_{12} + 30P_1 + 100$ Rs/ hr
$F_2 = 0.25\,P_{22} + 40\,P_2 + 150$ Rs/ hr
The limits of generators are $20 \leq P_1 \leq 80$ Mw
$40 \leq P_2 \leq 200$ Mw
Find the economic operating schedule of generation, if the load demand is 130 MW, neglecting transmission losses. **(GATE 98)**

51. The incremental cost characteristics of two generators delivering 200 MW are as follows

$$\frac{dF_1}{dP_1} = 2.0 + 0.01P_1 \qquad \frac{dF_2}{dP_2} = 1.6 + 0.2P_2$$

For economic operation, the generations P_1 and P_2 should be
i. P_1=P_2=100 MW ii. P_1=80MW, P_2=120MW
iii. P_1= 200 MW, P_2=0 MW iv. P_1=120 MW, P_2=80 MW **(GATE 00)**

52. The fuel inputs of plants 1 and 2 are given as
$F_1 = 0.2P_1^2 + 40\,P_1 + 120$ Rs/ hr $F_2 = 0.25P_2^2 + 30\,P_2 + 150$ Rs/ hr
Determine the economic operating schedule and the corresponding cost of generation if the maximum and minimum loading of each machine is 100 MW and 25 MW, the demand is 180MW and transmission losses are neglected. If the load is equally shared by both units, determine the saving obtained by loading the units as per incremental cost. **(IES 03)**

53. The cost function of a 50 MW genrator is given by (P_i is the genrator loading)
$F(P_i) = 225 + 53\,P_i + 0.02\,P_i^2$ When 100% loading is applied, the incremental fuel cost (IFC) will be
i. Rs. 55 per MWh ii. Rs. 55 per MW iii. Rs. 33 per MWh iv. Rs. 33 per MW **(IES 00)**

54. The incremental generating costs of generating costs of two generating units are given by
$IC_1 = 0.1\,X + 10$ Rs./MWh
$IC_2 = 0.15\,Y + 18$ Rs./MWh
Where X and Y are power (in MW) generated by th e two units. For a total demand of 300MW, the value (in MW) of X and Y will be respectively.
i. 172 and 128 ii. 128 and 172 iii. 175 and 125 iv. 200 and 100 **(IES 97)**

55. The incremental cost characteristic of the two units in a plant are
$IC_1 = 0.1\,P_1 + 8.0$ Rs./MWh
$IC_2 = 0.15\,P_2 + 3.0$ Rs./MWh
When the total load is 100 MW, the optimum sharing of load is

	P1	P2
i.	40 MW	60 MW
ii.	33.3 MW	66.7 MW
iii.	60 MW	40 MW
iv.	66.7 MW	33.3 MW

(IES 96)

56. Consider the following three incremental cost curves.
$P_{G1} = -100 + 50\,I_{C1} - 2\,(I_{C1})^2$
$P_{G2} = -150 + 60\,I_{C2} - 2.5\,(I_{C2})^2$
$P_{G3} = -\ 80 + 40\,I_{C3} - 1.8\,(I_{C3})^2$
Where I_C s are in Rs/ Mwh and P_{GS} are in MW. The total load at a certain hour of the day is 400 MW. Neglect transmission loss and find optimum values of generation. i.e. P_{G1}, P_{G2} and P_{G3}. **(IES 95)**

"Life is not so short but that there is always time enough for courtesy."
- Author:Ralph Waldo Emerson

57. The incremental fuel cost for two generating units are given by
$IC_1 = 25 + 0.2\,PG_1$
$IC_2 = 32 + 0.2\,PG_2$
where PG_1 and PG_2 are real power generated by the units.
The economic allocation for a total load of 250 MW, neglecting transmission loss is given by
i. $PG_1 = 140.25$ MW, $PG_2 = 109.75$ MW
ii. $PG_1 = 109.75$ MW, $PG_2 = 140.25$ MW
iii. $PG_1 = PG2 = 125$ MW
iv. $PG_1 = 100$ MW, $PG_2 = 150$ MW **(IES 95)**

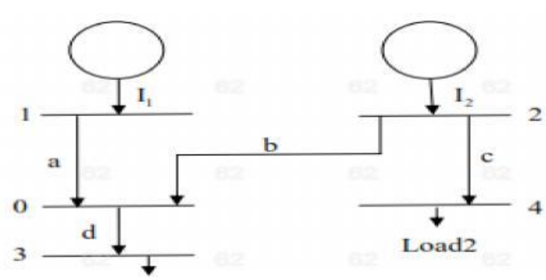
58. A constant load of 300 Mw is supplied by two 200 MW generators, 1 and 2 for which the respective incremental fuel costs are $\frac{dF_1}{dP_1} = 0.10P_1 + 20Rs/Mwh$, $\frac{dF_2}{dP_2} = 0.12P_2 + 15Rs/Mwh$ with parameters P in MW and costs F in Rs/ hr. Determine
i. The most economical division of load between the generators
ii. The saving in Rs/ day there by obtained compare the equal load sharing between generators. **(IES 94)**

59. A power plant has three units with the following input-output characteristics:
$Q_1 = 0.002\ P_1^2 + 0.86\ P_1 + 20$ tons/hour
$Q_2 = 0.004\ P_2^2 + 1.08\ P_2 + 20$ tons/hour
$Q_3 = 0.0028\ P_3^2 + 0.64\ P_3 + 36$ tons/hour
Where P_1, P_2 and P_3 are the generating powers in MW. The fuel cost is Rs 25 per ton. The maximum and minimum possible generation for each unit are 120 MW and 39 MW respectively. Find the optimal scheduling for a total load of 200 MW. **(IES 91)**

UNIT-II

1. a) What are coordination equations ? Give their physical significance.
   b) Derive the transmission loss formula for a system consisting of n-generating plants supplying several loads interconnected through a transmission network. **(Dec 14)**

1. i. Derive expression for loss coefficients in terms of current distribution factors.
   ii. Figure shows a system having two plants 1 and 2 connected to busses 1 and 2, respectively. There are two loads and a network of four branches. The bus 0 is the reference bus with voltage of $1.0\angle 0^0$ pu. The branch currents and impedances are
   $I_a = 2 - j0.5$ pu $Z_a = 0.015 + j0.06$ pu
   $I_b = 1.6 - j0.4$ pu $Z_b = 0.015 + j0.06$ pu
   $I_c = 1 - j0.25$ pu $Z_c = 0.01 + j0.04$ pu
   $I_d = 3.6 - j0.9$ pu $Z_d = 0.01 + j0.04$ pu
   Calculate the loss formula coefficients of the system in per unit and in reciprocal megawatts, if the base is 100 MVA.



(Nov 13)

2. i. Explain about the exact coordination equation and derive the penalty factor.
   ii. Two thermal plants are interconnected and supply power to a load having incremental fuel costs are
   $IC_1 = 20+10P_1$ Rs/MWh
   $IC_2 = 15+10P_2$ Rs/MWh

where P_1 and P_2 are expressed in p.u. in 100 MVA base.

"*The best portion of a good man's life: his little, nameless, unremembered acts of kindness and love.*"

- Author:William Wordsworth

The transmission loss is given by $P_L = 0.1P_1^2 + 0.2P_2^2 + 0.1P_1P_2$ p.u.
If the incremental cost of received power is 50 Rs./MWh, find the optimal generation? **(Nov 13)**

3. i. Explain economic operation of power system with transmission losses is taking into account and explain the significance of penalty factor.
   ii. A System consists of two thermal plants connected by transmission line It has been observed if the only load located is at plant2 of 200MW is transmitted from plant 1 to plant 2. The power loss is 16MW. Calculate the B_{mn} coefficients and also P_1,P_2,P_{Loss} and P_{demand} with the system with λ=12.5. **(Nov 12)**

4. The fuel cost for a two unit steam power plant are given by
$C_1 = 0.1\,P_1^2 + 25\,P_1 + 1.6$ Rupees/hour
$C_2 = 0.1\,P_2^2 + 32\,P_2 + 2.1$ Rupees/hour
Where p's are in megawatt. If there is an error of 1% in the representation of the input data, find the loss in operating economy for a load of 250 MW. **(May 11, Nov 10)**

5. Two generating stations A & B have full load capacities of 300 MW and 250 MW respectively. The inter connector connecting the two stations has a motor-generator set (Plant `C') near station A of full load capacity of 100 MW. Percentage changes of speed of A, B and C are 5, 4 and 3 respectively. The loads on bus bars A and B are 200 MW and 100 MW respectively. Determine the load taken by set C and indicate the direction in which the energy is owing. **(Nov 10)**

6. Write the expression for hourly loss of economy resulting from error in incremental cost representation. **(Nov 10)**

7. Give algorithm for economic allocation of generation among generators of a thermal system taking into account transmission losses. Give steps for implementing this algorithm and also derive necessary equations. **(Nov 10, 08, 07, 04)**

8. i. Explain with diagram the physical interpretation of co-ordination equation. **(May 09)**
   ii. Give various uses of general loss formula and state the assumptions made for calculating Bmn coefficients.

9. A simple two-plant system have the IC's are
$dC_1 / dPG_1 = 0.01\,PG_1 + 2.0$
$dC_2 / dPG_2 = 0.01\,PG_2 + 1.5$ and the total load on the system is distributed optimally between two stations as PG_1 = 60MW and PG_2 = 110MW, corresponding l = 2.6 and the loss coefficients of the system are given as

P	Q	Bpq
1	1	0.0015
1	2	-0.0015
2	2	0.0025

Determine the transmission loss. **(May 09)**

10. A constant load of 300 MW is supplied by two 200 MW generators 1 and 2, for which the respective incremental fuel costs are:

$$\frac{dC_1}{dP_{G1}} = 0.10\,P_{G1} + 20.0$$

"*Only your compassion and your loving kindness are invincible, and without limit.*"
- Author:Thich Nhat Hanh

$$\frac{dC_2}{dP_{G2}} = 0.12\,P_{G2} + 15.0$$

With power PG in MW and costs C in Rs/hr. Determine:

i. The most economical division of load between the generators.

ii. The saving in Rs./ day there by obtained compared to equal load sharing between two generators. **(May 09)**

11. Discuss optimal power flow procedures with its inequality constraints, and how to handle dependent variables with penalty function. **(May 09)**

12. Explain optimal load flow solution without inequality constraints. **(May 09)**

13. i. Derive the conditions to be satisfied for economic operation of a loss less power system.

ii. 150 MW, 220 MW and 220 MW are the ratings of three units located in a thermal power station. Their respective incremental costs are given by the following equations:

$dc_1/dp_1 = Rs(0.11p_1 + 12)$;

$dc_3/dp_3 = Rs(0.1p_3 + 13)$

$dc_2/dp_2 = Rs(0.095p_2 + 14)$

Where P_1, P_2 and P_3 are the loads in MW. Determine the economical load allocation between the three units, when the total load on the station is

a. 350 MW b. 500 MW. **(May 09)**

14. i. Incremental fuel cost in Rupees per mega watt hour for two units comprising a plant are given by the following equations.

$$\frac{dc_1}{dp_1} = 0.12\,p_1 + 21; \frac{dc_2}{dp_2} = 0.1\,p_1 + 18$$

Assume that both units are operating at all times, that total load varies from 40 to 200 MW and the maximum and minimum loads on each unit are to be 125 and 20 MW respectively. Find the incremental fuel cost & the allocation of loads between units for the minimum cost of various total loads. Derive the formula used.

ii. Discuss the costs associated with hydro plants. **(May 09)**

15. i. Assume any relevant data and notation, derive the transmission loss formula.

ii. Discuss about the optimum generator allocation without line losses. **(Jan 09, Feb 07, Nov 04)**

16. The incremental production cost of two plants are given by :

$(IPC)1 = (0.07)P_1 + 16$Rs./MWh

$(IPC)2 = (0.08)P_2 + 12$Rs./MWh.

The loss coefficients of the system are given by $B_{11} = 0.001$; $B_{12} = B_{21} = -0.005$ and $B_{22} = 0.0024$. The total load to be met is 150 MW, determine economic operating schedule if the transmission line losses are coordinated and the losses are included but not co-ordinated. **(Feb 08)**

17. What is incremental transmission loss and derive the general transmission loss formula. **(Feb 08)**

18. The incremental costs in Rs. Per M.W.Hr.. for two units in a plant are given by

$\frac{dF_1}{dP_1} = 1.0p_1 + 200; \frac{dF_2}{dP_2} = 1.2p_2 + 160;$

The minimum and maximum generation on each unit are to be 20 MW and 125 MW respectively. Determine the economic allocation between the units for a total load of 150 MW. **(Feb 08)**

19. Develop the loss formula coefficients for a two plant system. State the assumptions made. **(Nov 07)**

20. The transmission loss coefficients in p.u. on a base of 100 MVA are given by

$$\begin{bmatrix} 0.009 & -0.001 & -0.002 \\ -0.001 & 0.0015 & -0.003 \\ -0.002 & -0.003 & 0.025 \end{bmatrix}$$

The three plants, A, B and C supply powers of P_A = 100MW, P_B = 200MW, P_C= 300MW, into the network. Calculate the transmission loss in the network in MW and the incremental losses with respect to plants A,B,C. **(Nov 07)**

21. Discuss the various constraints to be considered for economic load dispatch problem.
 i. Discuss and define the loss formula coefficients.
 ii What is the objective in economic scheduling? **(Feb 07, Nov 06, Nov 05)**

22. The equations of the input costs of three power plants operating in conjunction and supply power to a system network are obtained as follows:
$C_1 = 0.06P_1^2 + 15 P_1 + 150$ Rupees/ hour
$C_2 = 0.08P_2^2 + 13 P_2 + 180$ Rupees/ hour
$C_3 = 0.10P_3^2 + 10 P_3 + 200$ Rupees/ hour
The incremental loss-rates of the network with respect to the plants 1,2 and 3 are 0.06, 0.09 and 0.10 per MW of generation, respectively. Determine the most economical share of a total load of 120 MW which each of the plants would take up for minimum input cost of received power is Rupees per MWH.
(Feb 07, Nov 05, Nov 02)

23. Give various uses of general loss formula and state the assumptions made for calculating B_{mn} coefficients. **(Nov 06)**

24. i. The incremental costs for two generating plants are
$IC_1 = 0.1 P_1 + 20$ Rupees/MW hour
$IC_2 = 0.1 P_2 + 15$ Rupees/MW hour
Where P_1 and P_2 are in MW. The loss coefficients (B_{mn}) expressed in MW^{-1} unit are $B_{11} = 0.001$, $B_{22} = 0.0024$, $B_{12} = B_{21} = -0.0005$. Compute the economical generation scheduling corresponding to the Lagrangian multiplier λ = 25 Rs. / MW hr and the Corresponding system load that can be met with. If the total load is 150 MW, taking 5% change in the value of λ, what should be the value of λ in the next iteration?
 ii. What are the assumptions made in deriving the loss coefficients ? **(Mar 06, Nov 04, 02)**

25. i. Describe the need for co-ordination of different power stations.
 ii. What are Bmn coefficients and derive them. **(Nov 05)**

26. The incremental fuel costs for two plants are given by

$$\frac{dc_1}{dp_1} = 0.1p_1 + 20 Rs./Mw - Hr \qquad \frac{dc_2}{dp_2} = 0.15p_2 + 22.5 Rs./MW - Hr.$$

The system is operating at the optimum condition with $p_1 = p_2$ = 100MW and $\partial p_1/\partial p_2 = 0.2$. Find the penalty factor of plant 1 and the incremental cost of received power. **(Nov 03,02)**

27. . Discuss in detail the optimum load dispatch problem of two identical generators connected through a transmission link by considering the transmission losses into account.
(Nov 02, MU Apr 04, Oct 02, IES 93)

28. The fuel inputs to two plants are given by
$F_1 = 0.015P_1^2 + 16P_1 + 50$ and $F_2 = 0.025P_1^2 + 12P_2 + 30$.

The loss coefficients of the system are given by B_{11} = 0.005; B_{12}=-0.0012 and B_{22} = 0.002. The load to be met is 200 Mw. Determine the economic operating schedule and the corresponding cost of generation if the transmission line losses are coordinated. **(Nov 02)**

29. A system consists of two plants connected by a tie line and a load is located at plant 2. When 100 MW are transmitted from plant 1, a loss of 10MW takes place on the tie-line. Determine the generation schedule at both the plants and the power received by the load when 2)21 for the system is Rs.25 per Megawatt hour and the incremental fuel costs are given by the equations :

$$\frac{dF_1}{dP_1} = 0.03P_1 + 17 \text{ Rs/M whr} \qquad \frac{dF_2}{dP_2} = 0.06P_2 + 19 \text{ Rs/M whr}$$ **(Nov 02)**

30. In terms of power generation and B_{mm} coefficients, the transimission loss for a two-plant system is (Notations have their usual meaning).

i. $P_1^2B_{11} + 2P_1P_2B_{12} + P_2^2B_{22}$ ii. $P_1^2B_{11} - 2P_1P_2B_{12} + P_2^2B_{22}$

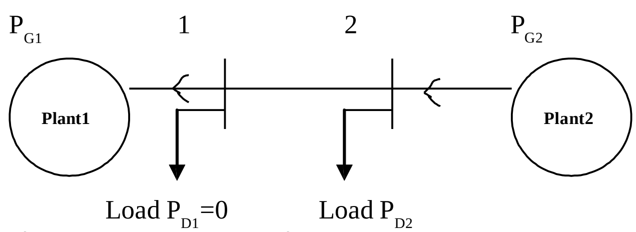
iii. $P_2^2B_{11} + 2P_1P_2B_{12} + P_1^2B_{22}$ iv. $P_1^2B_{11} + P_1P_2B_{12} + P_2^2B_{22}$ **(IES 00)**

31. The power generated by two plants are:

P_1 = 50 MW, P_2 = 40 MW, the loss coefficients are B_{11} = 0.001, B_{22} = 0.0025 and B_{12} = -0.0005 then power loss will be

i. 5.5 MW ii. 6.5 MW iii. 4.5 MW iv. 8.5 MW **(IES 97)**

32.



If 100 MW is transmitted from Plant-1 to the load a transmission loss of 10 KW incurred. Find the required generation for each plant and the power received by the load when the system cost is Rs. 25/MWh. The incremental fuel costs fro two plants are

$$\frac{I_{C1}}{I_{C2}} = \frac{dF_1}{dP_{G1}} = 0.02P_{G1} + 16Rs/Mwh$$ **(IES 96)**

$$I_{C2} = \frac{dF_1}{dP_{G2}} = 0.04P_{G2} + 20Rs/Mwh$$

33. The incremental cost characteristic of a two plant system are

$IC_1 = 1.0\,P_1 + 85$ Rs/MWh

$IC_2 = 1.0\,P_2 + 72$ Rs/MWh

Where P1 and P2 are in MW. The loss coefficient matrix in MW is given by

$$\begin{bmatrix} 0.015 & -0.001 \\ -0.001 & 0.02 \end{bmatrix}$$

Compute the optimal sceduling with λ= 150 Rs/MWh. The load on the system is 30 MW. For an improved value of λ with 10% change write the coordination equations. **(IES 92)**

UNIT-III

1. Explain hydro thermal economic load scheduling.Derive the necessary equations . **(Dec 14)**

1. Discuss about optimal scheduling of hydrothermal system and find out the necessary equations and gradient vector to solve the system. **(Nov 13)**

2. i. Discuss the short term Hydro thermal scheduling problems and discuss how the problem is solved by Lambda (λ) Gamma (λ) = method.

   ii. A two plant system having thermal station near to the load centre and hydro power station at a remote location. The characteristics of both the station are given as.

   $F_T(P_T) = 26+0.045P_T) P_T$ Rs/hr

   $W_H = (7+0.004P_H)P_H$ m^3/sec

   $\gamma = 4x10^{-4}$ Cost/m^3

   The transmission loss coefficient is $0.0025MW^{-1}$ Determine the power generation at each station and power received by the load when λ =65. **(Nov 12)**

3. In a two plant operation system, the hydro plant is operation for 10 hrs, during each day and the steam plant is to operate all over the day. The characteristics of the steam and hydro plants are

   $C_T = 0.04\ P_{GT}^2 + 30\ P_{GT} + 10$ Rs/hr

   $W_H = 0.12\ P_{GH}^2 + 30\ P_{GH}$ m^3/ sec

   When both plants are running, the power flow from steam plant to load is 150 MW and the total quantity of water is used for the hydro plant operation during 10 hrs is 150 × 106 m^3. Determine the generation of hydro plant and cost of water used. Neglect the transmission losses. **(May 11, Nov 10)**

4. In a two plant operation system, the hydro plant is operate for 8 hrs. During each day and the steam plant is operate all over the day. The characteristics of the steam and hydro plants are

   $C_T = 0.04\ P_{GT}^2 + 30\ P_{GT} + 20$ Rs/hr

   $W_H = 0.0012\ P_{GH}^2 + 7.5\ P_{GH}$ m_3/ sec

   When both plants are running, the power flow from steam plant to load is 190 MW and the total quantity of water is used for the hydro plant operation during 8 hrs is 220 x 106 m3. Determine the generation of hydro plant and cost of water used. Neglect the transmission losses. **(May 11)**

5. Discuss the combined hydro- electric and steam station operation. **(May 11)**

6. Derive the coordination equation for the optimal scheduling of hydrothermal Interconnected power plants. **(May 11)**

7. In a two plant operation system, the Hydro plant is operate for 12 hrs. during each day and the hydro plant is operate all over the day. The characteristics of the steam and hydro plants are

   $C_T = 0.3\ P_{GT}^2 + 20\ P_{GT} + 5$ Rs/hr

   $W_H = 0.4P_{GH}2+20$ PGH m^3/ sec

   When both plants are running, the power flow from steam plant to load is 300 MW and the total quantity of water is used for the hydro plant operation during 12 hrs is 180 × 106 m^3. Determine the generation of hydro plant and cost of water used. **(Nov 10)**

8. What are the methods of scheduling of generation of steam plants? Explain their merits and demerits? **(Nov 10)**

9. Describe the objective function is minimize the cost of generation of hydro thermal scheduling. **(Nov 10)**

10. i. Explain about spinning reserve in hydro power plants.

    ii. Explain about co-ordination in hydro thermal system. **(May, Jan 09)**

11. Explain: long range hydro scheduling, deriving necessary expressions. **(May 09, Feb 07, Nov 06)**

12. Write the advantages of operation of hydro thermal combinations. **(May 09)**

13. Determine the daily water used by hydro plant and daily operating cost of thermal plant with the load connected for total 24 hrs from the given data.
The load connected, P_D = 400MW
Generation of thermal plant, P_{GT} = 200MW
Generation of hydro plant, P_{GH} = 300MW. **(May 09)**

14. Derive the co-ordination equation for the optimal scheduling of hydro-thermal interconnected power plants. **(Nov, Feb 08)**

15. Explain Hydro-thermal scheduling problem. **(Nov 08, 02)**

16. Derive Mathematical Formulation for Hydro thermal scheduling. **(Nov 08)**

17. Explain different constraints to be considered for mathematical modeling of hydro thermal scheduling **(Nov 08)**

18. Explain the problem of scheduling hydro - thermal power plants. What are the constraints in the problem? **(Feb 08)**

19. Discuss the costs associated with hydro plants. **(Nov 07)**

20. Write short notes on:
    i. Equations of Load flow.
    ii. Solving of Load flow equations. **(Feb 07, Nov 07, 05)**

21. Devolop load flow equation suitable for solutions by Gauss Seidel method using Nodal admittance approach **(Feb 07, Nov 07, 06, 02)**

22. State what is meant by base-load and peak-load stations. Discuss the combined hydro electric and steam station operation. **(Mar 06, Nov 05, 03)**

23. Explain in detail the short term hydro thermal scheduling. **(Nov 04, Nov 02)**

24. Devolop load flow equation suitable for solutions by Newton-Raphson method using nodal admittance approach. **(Nov 02)**

25. Describe optimal scheduling of Hydro thermal system without considering losses. **(Nov 02)**

26. Differentiate between long range hydro scheduling and short range hydro schduling. **(MU Apr 04)**

27. Write in detail about economic co-ordination of power generation among hydro and thermal plants. **(MU Apr 04)**

28. Discuss the optional power flow problem formulation and discuss their solution by successive LP methods **(MU Apr 04)**

29. A hydro electric satation has to operate with a mean head of 50 m. It makes use of water collected over a catchment area of 200 km^2 over which the average annual rainfall is 420 cm with a 30% loss due to evaporation. Assuming the turbine efficiency as 85% and the alternator efficiency as 80% calculate the average power that can be generated. **(IES 93)**

30. Explain long range and short range Hydro-scheduling problems. **(R1-Ch7)**

31. Explain hydro electric plant models with diagrams. **(R1-Ch7)**

32. Derive the condition for best efficiency in hydro thermal system using langrangian method. **(R1-Ch7)**

33. A hydro plant and a steam plant are to supply a constant load of 80 MW for 1 MWK (168h). The unit characteristics are
Hydro plant: $q = 250 + 10P_H$ acre-ft/h
$0 \leq P_H \leq 90$ MW
Steam plant: $H_s = 50 + 11P_S + 0.02\, P_S^2$
$11.25 \leq P_S \leq 45$ MW
Solve for T_S^* ,the run time of steam plant. **(R1-Ch7)**

34. Explain the Dynamic-programming solution to the hydrothermal scheduling problem. **(R1-Ch7)**

35. Reformulate the optimal hydro thermal scheduling problem considering the inequality constraints on the thermal generation and water storage employing penalty functions. Find out the necessary equations and gradient vector to solve the problem. **(R1-Ch7)**

36. Explain the significance of patton's Security function. Explain the Security constrained unit commitment and startup considerations. **(T2-Ch7)**

37. Find the optional generation schedule for a typical day, where in load varies in threes steps of 8 hours each as 8MW, 12MW and 6MW respectively. There is no water inflow into the reservoir of the hydro plant. The initial water storage in the reservoir is 120 m^3/s and final water storage is 80 m^3/s. Basic head is 35m, e = 0.0075, Reservoir is rectangular. Non effective water discharge be assumed as 3 m^3/s. IFC of thermal plant is $(1.5\, P_{GT} + 36)$ Rs/Hr. Transmission losses neglected. **(T2-Ch7)**

UNIT-IV

1. a) Derive the model of speed governing system and hence draw its block diagram.

   b) A 100 MVA synchronous generator operates on full load at a
   frequency of 50Hz.The load is suddenly reduced to

   50 MV. Due to time lag in governor system, the steam valve begins to close after 0.4sec.Determine the change in frequency that occurs in this time.

(Dec14)

1. i. Explain Governor characteristics of a single Generator.
   ii. Derive the transfer function of an overall excitation system.

(Nov 12)

2. Two turbo alternators rated for 110MW and 210MW have a governor droop characteristics of 5% from no

load to full load. They are connected in parallel to share the load of 250MW. Determine the load shared by each machine assuming free governor action. **(May 11, Nov 10)**

3. i. Derive the transfer function of speed governing system?
   ii. Explain turbine model with block diagram? **(May 11, Jan 09)**

4. Two generators of rating 100 MW and 200 MW are operating with droop characteristic of 6% from no load to full load. Determine the load shared by each generator, if a load of 270 MW is connected across the parallel combination of those generators. **(May 11)**

5. A 80 MVA synchronous generator operates on full load at a frequency of 50Hz. The load is suddenly

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"*The kindness and affection from the public have carried me through some of the most difficult periods, and always your love and affection have eased the journey.*" - Author:Diana, Princess of Wales

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reduced to 40 MW. Due to time lag in the governor system, the steam valve begins to close after 0.3 secs. Determine the change in frequency that occurs in this time. H=4 KW-s/KVA of generator capacity. **(Nov 10, May 09)**

6. Derive the model of a speed governing system and represent it by a block diagram. **(Nov 10)**

7. A system consists of 4 identical 250 MVA generators feeding a load of 510 MW The inertia constant H of each unit is 2.5 on the machine base. The load varies by 1.4% for a 1 % change in frequency. If there is a drop in load of 10 MW, determine the system block diagram expressing H and B on the base of 1000 MVA. Give the expression for speed deviation, assuming there is no speed governor. **(Nov 10)**

8. i. What is meant by control area and free governor operation. **(Nov 09)**
   ii. Explain about load frequency control and economic dispatch control.

9. A three-phase induction motor delivers 500 hp at an efficiency of 0.91, the operating power factor being 0.76 lagging. A loaded synchronous motor with a power consumption of 100 KW is connected in parallel with the induction motor. Calculate the necessary kVA and the operating power factor of the synchronous motor if the overall power factor is to be unity. **(May 09)**

10. Briefly explain swing equation with simplified diagram. **(May 09)**

11. With a neat diagram, explain briefly different parts of a turbine speed governing system. **(Feb 07, Nov 02)**

12. i. Derive the model of a speed governing system and represent it by a block diagram.
    ii. A 100 MVA synchronous generator operates on full load at a frequency of 50 Hz. The load is suddenly reduced to 50 MW. Due to time lag in the governor system, the steam valve begins to close after 0.4 secs. Determine the change in frequency that occurs in this time. Given H=5 KW-S/KVA of generator capacity. **(Feb 07, Mar 06, Nov 06, 05, 03, 02, Anu Nov 04, IES 95)**

13. Derive the generator load model and represent it by a block diagram. **(Mar 06)**

14. i. Describe the various blocks of IEEE Type-1 excitation system and develop the mathematical model of the system. **(Apr 05, 04 Nov, Apr 03)**
    ii. Explain IEEE type-1 model of an excitation system and hence derive the transfer function. **(Aug, Apr 06, Jan 05, 03, 01, Mar, Dec 02)**

15. i. Explain about the various performance requirements of excitation system.
    ii. Explain the elements of an excitation system. **(Apr 06)**

16. Explain the turbine model and represent as a block diagram and obtain transfer function of the models. **(Apr 06, 04, Jan 03, Dec 02)**

17. i. Explain the turbine speed governing mechanism and hence derive the transfer function of speed governing system.
    ii. Explain what is meant by Cross-coupling between control loops. **(Apr 06, 05, 03, Nov 03)**

18. Explain the characteristics of an excitation system and develop a transfer function of first order for the same. **(Aug, Apr 06, Apr 05, 04, Nov, Apr 03, Dec 02, Jan 03, 02, 01)**

19. What is an exciter ? Why it is necessary for Synchronous Generator ? **(Apr 06, 05)**

20. Explain the turbine model and hence discuss transfer functions of reheat and non-reheat models. **(Apr 05, 03, Nov 03)**

21. With the help of a neat sketch, explain operation of various components of a fly ball speed Governor system. **(Apr 04)**

22. Explain the mathematical model of a Generation-load model and hence derive the transfer function. **(Apr 04)**

23. i. Derive the small signal transfer function of Generator – governor model. Explain various time constants in it and their significance.
    ii. How a steam turbine can be modeled using an approximate linear model. **(Apr 04)**

24. Derive the transfer function of speed-governing mechanism and hence derive the transfer function. **(Apr 04)**

25. Explain the functions of an excitation and develop the block diagram for voltage regulator scheme. Develop the transfer function model of each block. **(Apr 04, 03, Nov 03)**

26 What are all the feed back control systems that are provided for a synchronous Generator? Explain their importance and how they are independent from each other. **(Nov 03)**

27. i. Explain the necessity of speed-governing system, develop the mathematical model and derive the transfer function. **(Apr 04)**
    ii. Draw the block diagram of the excitation system and hence develop the transfer function. **(Mar 02, Dec 02/Jan 03)**

28. Clearly explain how a synchronous generator is modeled for steady state analysis. Draw the phasor diagram and obtain the power angle equation for a non salient pole synchronous generator connected to an infinite bus. Sketch the power angle curve. **(Mar 02, Apr 03)**

29. Explain the steady-state modelling of a synchronous machine. **(Mar 02, Dec 02/Jan 03)**

30. A 2-pole 50 Hz, 11 KV turbo alternator has a ratio of 100 MW, pf 0.85 lagging. The rotor has a moment of inertia of 10,000 kgm^2.Calculate H and M. **(ANU Dec 04)**

31. Explain any two types of excitation systems of a generator with relevant diagrams. State the requirements of a good excitation systems. **(MU Oct 02)**

32. For 800 MJ stored energy in the rotor at synchronous speed, what is the inertia constant H for a 50 Hz, four pole turbo-generator rated 100 MVA, 11 kV ? **(IES 05)**
    a. 2.0 MJ/MVA b. 4.0 MJ/MVA c. 6.0 MJ/MVA d. 8.0 MJ/MVA

33. Two 200 MVA alternators operate in parallel. The frequency drops in the first machine from 50 Hz at no load to 48 Hz at full load, whereas in case of the other machine, the frequency drops from 50 Hz to 47 Hz under the same conditions :
    i. How the two machines will share a total load of 300 MW ?
    ii. Determine the maximum load at unity power factor which can be delivered by the two machines without overloading any of them. **(IES 03)**

34. An alternator with negligible damping is connected to an infinite bus. Write down its swing equation in usual form. How inertia constant H is defined here ? **(IES 00)**

UNIT-V

1. Draw the block diagram model of an isolated power system. Derive an expression for steady state Change in frequency. **(Dec 14)**

1. i. With a neat diagram explain the process of speed governing system.
   ii. Discuss about Block diagram representation of IEEE Type-1 Model. **(Nov 13)**

2. Derive the model of a speed governing system and represent it by a block diagram. **(Nov -2013)**

3. Two generators rated 300 MW and 600 MW are operating in parallel. Their governors have droop characteristics of 4% and 5% respectively from no load to full load. Assuming that the generators are operating at 50 Hz at no load, determine how would a load of 750 MW be shared between them. What will be the system frequency at this load? Assume free governor action. **(Nov 13)**

4. i. With first order approximation explains the dynamic response of an isolated area for load frequency control.
   ii. With a block diagram explain the load frequency control for a single area system. **(Nov 13)**

5. i. Draw the complete block diagram for single area load frequency control system and in detail about steady state analysis for controlled case with necessary equation.
   ii. Asingle area system has the following data
   Speed regulation, R=4 Hzlp.uMW
   $_p$=10s Power System time constant. T
   $_p$=75 Hzlp.uMWPower system gain, K
   When a 2% load change occurs, determine area frequency regulation characteristic (AFRC) and static frequency error, what is the value of steady state frequency error if the governor is blacked:
   (Nov 12)

6. A single area system has the following data:
   Speed regulation, R = 4 Hz / pu MW
   Damping co-efficient, B = 0.1 pu MW / Hz
   Power system time constant, TP = 10 sec
   Power system gain, KP = 75 Hz / pu MW
   When a 2% load change occurs, determine the area frequency response characteristic and static frequency error what is the value of steady state frequency error if the governor is blocked. **(May 11)**

7. Discuss in detail the economic dispatch control in a single area load frequency control. **(May 11)**

8. A single area consists of three generating units with the following characteristics. **(May 11)**

Unit	Rating (MVA)	Speed Droop R(per unit on unit base)
1	100	0.01
2	500	0.015
3	500	0.015

   The units are loaded as P_1 = 80 MW; P_2 = 300 MW; P_3 = 400 MW.
   i. Assume B = 0; what are the new generations on each unit for a 50 MW load increase?
   ii. If B = 1.0 p.u. (i.e. 1.0 p.u. on load base.), what are the new generations on each unit for a 60 MW load increase?

9. Explain what do you understand by control area and control area error. **(May 11)**

10. A Generator in single area load frequency control has the following parameters:
   Total generation capacity = 2500 MW

"*If you light a lamp for somebody, it will also brighten your path.*"

- Author:Buddhist saying

Normal operating load =1500 MW
Inertia constant=5 kW-seconds per kVA; Load damping constant, B=1 %; frequency, f=50 Hz; and Speed regulation, R=2.5 Hz / p.u MW. If there is a 1.5 % increase in the load, find the frequency drop

i. without governor control
ii. with governor control. **(Nov 10)**

11. A single area consists of two generators with the following parameters:
Generator 1 = 1200 MVA; R=6 % (on machine base)
Generator 2 = 1000 MVA; R=4 % (on machine base)
The units are sharing 1800 MW at normal frequency 50 Hz. Unit supplies 1000 MW and unit 2 supplies 800 MW. The load now increased by 200 MW.
i. Find steady state frequency and generation of each unit if B=0.
ii. Find steady state frequency and generation of each unit if B=1.5. **(Nov 10)**

12. i. Explain the necessity of maintaining a constant frequency in power system operation.
ii. Two generators rated 200 MW and 400 MW are operating in parallel. The droop characteristics of their governors are 4% and 5% respectively from no load to full load. Assuming that the generators are operating at 50 Hz at no load, how would a load of 600 Mw be shared between them? What will be the system frequency at this load? Assume free governor operation. Repeat the problem if both the governors have a droop of 4%. **(May 09)**

13. i. Explain the concept of "control area" in the load frequency control of a power system.
ii. Show how the steady state error of frequency in a typical load frequency control of a power system is reduced to zero. **(May 09)**

14. i. Obtain the dynamic response of load frequency control of isolated power system for first order approximation.
ii. Obtain the dynamic response of load frequency controller with and without integral control action.

15. Two generating stations A and B of capacities 20MW and 10MW and speed regulation of 2% and 3% respectively. Two stations are connected through are inter connector and motor generator set. The set is connected to bus bar of A and has a capacity of 3 MW and full load slip of 4%. Determine the load of the inter connector when there is load of 8MW on bus bar B due to its own consumers but A has no external load. **(May 09, Nov 08)**

16. Discuss in detail the dynamic response of load frequency control of an isolated power system with a neat block diagram. **(May 09)**

17. i. Explain what do you understand by control area and control area error.
ii. Two generators of rating 100 MWand 200 MWare operating with droop characteristic of 6% from no load to full load. Determine the load shared by each generator, if a load of 270 MW is connected across the parallel combination of those generators. **(May 09)**

18. Explain the dynamic response in load frequency control of an isolated power system under uncontrolled case without making any approximations in the analysis. **(May 09)**

19. i. What is flat frequency control? Explain its requirements.
ii. A 500 MW generator has speed regulation of 4%. If the frequency drops by 0.12Hz with unchanged reference, determine the increase in turbine power. Also find by how much the reference power setting be changed if the turbine power remain unchanged. **(Jan 09)**

20. Explain the necessity of maintaining a constant frequency in power system operation.
Write notes on
i. Control area concept.
ii. Area control error **(Nov 08, 06, 05, 03, Feb 08, 07, Mar 06,)**

21. Two generators rated 200 MW and 400 MW are operating in parallel. The droop characteristics of their governors are 4% and 5% respectively from no load to full load. The speed changers are so set that the generators operate at 50 Hz sharing the load of 600 MW in the ratio of their ratings. If the load reduces to 400 MW, how will it be shared among the generators and what will the system frequency be? Assume free governor operation. The speed changers of the governors are reset so that the load of 400 MW is shared among the generators fat 50 Hz in the ratio of their ratings. What are the no load frequencies of the generators? **(Nov 08, 02)**

22. A power system has load of 1250 MW at 50 Hz. If 50 MW load is tripped, find the steady state frequency deviation when
i. there is no speed control
ii. the system has a reserve of 200 MW spread over 500 MW of generation capacity with 5 % regulation on this capacity.
All the generators are operating with valves wide open. Due to dead band only 80 % of governors respond to load change. Assume load damping constant B=1.5. **(Nov 08)**

23. i. Explain the concept of control area in a load control problem.
ii. Derive the expression for the frequency deviation, when a step load disturbance occurs in a single control area. **(Nov 08)**

24. Two synchronous generators operate in parallel and supply a total load of 400MW, the capacities of machines are 200MW and 500MW and both have generator drooping characteristics of 4% from no load to full load. Calculate the load taken by the each machine. Assuming free governor action also find system frequency at this load. **(Nov 08)**

25. What are the various specifications that are to be considered in load frequency control? **(Nov 08)**

26. The following data is available for an isolated area, capacity 4000MW, frequency 50Hz, operating load 2500MW, speed regulation constant 2HZ/pu MW. Inertia constant = 5secs. 2% of change in load takes place for 1% change in frequency. Find
i. Largest change in step load if steady state frequency is not to exceed by more than 0.2Hz
ii. Change in frequency as a function of time after a step change in load. Derive the formula used. **(Feb 08)**

27. Obtain the dynamic response of load frequency control of isolated power system for first order approximation. **(Feb 08)**

28. i. What are the disadvantages in a power system if the frequency is not maintained constant.
ii. Explain how the variation of load effects the frequency of a power system. **(Feb 08, 07)**

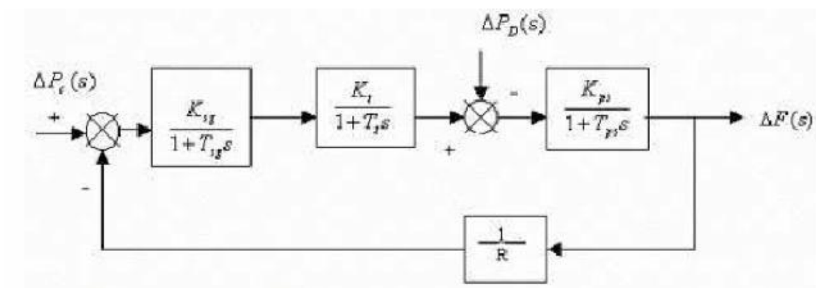
29. A control area has a total rated capacity of 10,000MW. The regulation R for all the units in the area in 2Hz/pu MW. A 1% change in frequency causes a 1% change in load. If the system operates at half of the rated capacity and the load increases by 2%
i. Find the static frequency drop
ii. If the speed governor loop were open, what would be the frequency drop.
Derive the formula used. **(Feb 08, Nov 06)**

30. Two generators rated 200 MW and 400 MW are operating in parallel. The droop characteristics of their governors are 4% and 5% respectively from no load to full load. Assuming that the generators are operating at 50 Hz at no load, how would a load of 600 MW be shared between them? What will be the system frequency at this load? Assume free governor operation. Repeat the problem if both the governors have a droop of 4%. **(Feb 08, 07, Nov 07, 06, 05, 03, Mar 06)**

31. Show how the steady state error of frequency in a typical load frequency control of a power system is reduced to zero. **(Nov, Feb 07, Mar 06)**

32. Draw the block diagram representation of load frequency control. **(Nov 07)**

33. Consider the block diagram model of LFC given in figure. Make the following approximation:
$(1 + sT_{sg})(1 + sT_t) = 1 + (T_{sg} + T_t)s = 1 + sT_{eq}$
Solve for $\Delta f(t)$ with parameters given below. Given $\Delta P_D = 0.01$ pu
$T_{eq} = 0.9$ s; $T_{ps} = 20$ s; $K_{sg}K_t = 1$; $K_{ps} = 100$; $R = 3$. **(Nov 07, Mar 06)**



34. Two generators rated 200 MW and 400 MW are operating in parallel. The droop characteristics of their governors are 4% and 5% respectively from no load to full load. The speed changers are so set that the generators operate at 50 Hz sharing the full load of 600 MW in the ratio of their ratings. If the load reduces to 400 MW, how will it be shared among the generators and what will be the system frequency ? Assume free governor operation. **(Feb 07, Nov 03, 02)**

35. i. Develop the mathematical model of hydraulic value actuator in load frequency control problems.
ii. Two generators rated 200Mw and 400Mw are operating in parallel. The droop characteristics of their governors are 4% and 6% respectively from no-load to full-load. Assuming that the generator are operating at 50Hz, how a load of 500Mw be shared between them. **(Aug, Apr 06, Nov,Apr 03)**

36. Two generators are supplying power to a system. Their ratings are 50 and 500Mw respectively. The frequency is 50Hz and each generator is half loaded. The system load is increased by 110Mw and as a result frequency drops to 49.5Hz. What must be the individual regulations if two generators should increase their turbine powers in properties to their ratings? Also express the regulation in p.u.Hz and p.u.Mw. **(Apr.06, Apr 03)**

37. Give a complete block diagram representation of Load-frequency control of an isolated power system? Explain various time constants in the block diagram? **(Apr 05, 04, 03)**

38. With first order approximation explain the dynamic response of an isolated area for load frequency control. **(Nov, Mar 06, Nov, Apr 05, Nov 04, 02, Anu Nov 04)**

39. Draw the schematic diagram showing the speed changer setting, governor and steam admission valve and indicate how steam input is regulated with the change in load. Derive the T.F.of the above system. **(Nov 06, 05)**

40. Explain the functions of various blocks of automatic load frequency control problems

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I believe the sign of maturity is accepting deferred gratification.

- Peggy Cahn

(Apr 05, 03, Nov 03)

41. i. With a neat block diagram explain the load frequency control for a single area system. **(Anu Apr 05)**

ii. Two generators rated 250 MW and 500 MW are operating in parallel. The droop characteristics are 4% and 6% respectively. Assuming that the generators are operating at 50 Hz at no load, how would a load of 750 MW be shared. What is the system frequency ? Assume free governor action. **(Nov 04, 03,02)**

42. With a neat block diagram explain the steady state analysis of an isolated power system. **(Nov 04, 02)**

43. What is load frequency problem? Briefly explain the various frequency control strategies used to regulate the power system frequency. **(Nov 04)**

44. Two generators rated 300 MW and 400 MW are operating in parallel. The droop characteristics of their governors are 4% and 6% respectively from no load to full load. The speed changers of the governors are set so that a load of 400 MW is shared among the generators at 50 Hz in the ratio of their ratings. What are the no load frequencies of the generators. **(Nov 04, 02)**

45. Why we need to maintain frequency and voltage of power system at rated values? If not, explain the consequences? **(Nov 03)**

46. i. Discuss in detail the importance of load frequency problem.

ii. With a neat diagram explain the process of speed Governing System. **(Nov 02)**

47. For a synchronous generator connected to an infinite bus through a transmission line, how are the change of voltage ($\triangle$V) and the change of frequency ($\triangle$f) related to the active power (P) and the relative power (Q)?

i. $\triangle$V is propotional to P and $\triangle$f to Q ii. $\triangle$V propotional to Q and $\triangle$f to P

iii. Both $\triangle$V and $\triangle$f are proportional to P iv. Both $\triangle$V and $\triangle$f are proportional to Q **(IES 07)**

48. Two generators rated 200 MW and 400 MW having governor droop characteristics of 4% and 5% respetively are operating in parallel. If the generators operate on no load at 50 Hz, the frequency at which they would operate with a total load of 600 MW is

i. 48.5 Hz ii. 47.69 Hz iii. 46.82 Hz iv. 49.04 Hz **(IES 02)**

49. The speed regulation parameter R of a control area is 0.025 Hz/Mw and the load frequency constant D is 2 Mw/Hz. The area frequency response characteristics (AFRC) is ____

i. 42.0 MW/Hz ii. 40 MW/Hz iii. 20 MW/Hz ii. 2 MW/Hz **(IES 01)**

50. Two alternators each having 4% speed regulation are working in parallel. Alternator '1' is rated for 12 MW and alternator '2' is rated for 8 MW. When the total load is 10 MW, the loads shared by alternators 1 and 2 would be respectively.

i. 4 MW and 6 MW ii. 6 MW and 4 MW

iii. 5 MW and 5 MW iv. 10 MW and zero **(IES 00)**

51. Two generators rated at 200 MW and 400 MW are operating in parallel. Both the governors have a drop of 4%, when the total load is 300 MW. They share the load as (suffix '1' is used for generator 200 MW and suffix '2' is used for generator 400 MW)

i. P_1 = 100 MW and P_2 = 200 MW ii. P_1 = 150 MW and P_2 = 150 MW

iii. P_1 = 200 MW and P_2 = 100 MW iv. P_1 = 200 MW and P_2 = 400 MW **(IES 99)**

52. Two synchronous generators are supplying a common load. Generator 1 has a no load frequency of 51.5 Hz and regulation of 1 MW/Hz. The total load 2.5 MW at .8 pf logging.

i. At what frequency, are the generators supplying this load and how much power is supplied by each generator?

ii. An additional load of 1 MW is attached to this system. What will be the new frequency and power generation of each alternator?

iii. How much is governor set point of generator set point of generator 2 to be adjusted to bring the system frequency at 50Hz for 3.5 MW system load? **(IES 97)**

53. The combined frequency regulation of machines in area of capacity 1500 MW and operation at a nominal frequency of 60 kHz is 0.1 pu on its own base capacity. The regulation in Hz/MW will be

i. 0.1/1500 ii. 60/1500 iii. 6/1500 iv. 60/150 **(IES 97)**

54. The following data pertain to two alternators working in parallel and supplying a total load of 80 MW:

Machine 1: 40 MVA with 5% speed regulation

Machine 2: 60 MVA with 5% speed regulation.

The load shareing between machines 1 and 2 will be:

i. $\frac{P_1}{48MW}$, $\frac{P_2}{32MW}$ ii. 40 MW, 40 MW iii. 30 MW, 50 MW iv. 32 MW, 48 MW **(IES 97)**

55. Two 200 MvA alternators operated in parallel. The frequency drops in the first machine from 50Hz at no load to 48 Hz at full load. Where as in case of the other machine, the frequency drops from 50 Hz to 47Hz under the same conditions

i. How the two machines will share a load of 300 Mw

ii. Determine the maximum load at unity power factor which can be delivered by the two machines without overloading any of them **(IES 96)**

56. A 100 MVA synchronous generator operates on full load of a frequency of 50Hz. The load is suddenly reduced to 50MW. Due to time lag in governor system, the steam value begins to close after 0.4 seconds. Determine the change in frequency that occurs in this time. Given H = 5 Kw - S/ KvA of generator capacity. **(IES 95)**

57. The following two synchronous machines are operating in parallel.

Machine A	50 MW	6% speed regulation
Machine B	50 MW	3% speed regulation

i. Determine the load taken by each machine for a total load of 80 MW when the speed changers are set to give rated speed at 100% rated output.

ii. The speed changers of machine A is so adjusted that 80MW is equally shared. Find the output of machine. A for rated speed and also its percentage speed at no load. **(IES 92)**

58. The power system has two synchronous generators. The Governor-turbine characterstics corresponding to the generators are

$P_1 = 50 (50 - f)$, $P_2 = 100(51 - f)$

Where f denotes the system frequency in Hz, and P1 and P2 are, resepectively, the power outputs (in MW) of turbines 1 and 2. Assuming the generators and transmission network to be losseless, the system frequency for a total load of 400 MW is

i. 47.5 Hz ii. 48.0 Hz iii. 48.5 Hz iv. 49.0 Hz **(GATE 01)**

UNIT-VI

1. Obtain the block diagram of two area load frequency control **(Dec 14)**

1. i. Explain about the combined operation of Load frequency control and Economic dispatch control.
   ii. Consider an isolated generator of 600MVA, inertia constant M=8 pu on the machine base. The unit is supplying a load of 300MVA. The load changes by 1.5% for a 1% change in frequency. Draw the block diagram for the equivalent generator load system. For an increase of 10MVA in the load, determine the steady state frequency deviation and the response? **(Nov 13)**

Maturity is the capacity to endure uncertainty.

- John Huston Finley

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2. i. Deduce the expression for static error frequency and tie-line power in an identical two area system.
   ii. The two control areas of capacity 2000MW and 8000 MW are interconnected through a tie-line. The parameters of each area based on its own capacity base are R=1Hzlp.u MW and B=0.02 p.u MW/Hz . If the control Area-2 experiences an increment in load of 180MW, determine static frequency drop and tie- line power. **(Nov 12)**

3. i. Explain how the tie-line power deviation can be incorporated in two-area system block diagram.
   ii. Two areas of a power system network are interconnected by a tie-line, whose capacity is 500 MW, operating at a power angle of 350. If each area has a capacity of 5000 MW and the equal speed regulation of 3 Hz/Pu MW, determine the tie line power deviation for step change in load of 85 MW occurs in one of the areas. Assume that both areas have the same inertia constants of H = 4 sec. **(May 11)**

4. Two control areas have the following characteristics:
   Area-1: Speed regulation = 0.02 pu
   Damping co-efficient = 0.8 pu
   Rated MVA = 1500
   Area-2: Speed regulation = 0.025 pu
   Damping co-efficient = 0.9 pu
   Rated MVA = 500
   Determine the steady state frequency change and the changed frequency following a load change of 120MW occurs in area-1. Also find the tie-line power flow change. **(Nov 10)**

5. Give a typical block diagram for a two-area system inter connected by a tie line and explain each block. Also deduce relations to determine the frequency of oscillations of tie line power and static frequency drop. List out assumptions made. **(Nov 10, 09, 07, 06, 05, 04, 02, Feb 08, 07, 06)**

6. The two area system has the following data:
   Capacity of area 1, P_{r1} =1000 MW,
   Capacity of area 2, P_{r2} =2000 MW,
   Nominal load of area 1, P_{D1}=500 MW
   Nominal load of area 1, P_{D1}=1500 MW
   Speed regulation of area 1=4%
   Speed regulation of area 2=3%
   Find the new steady state frequency and change in the line flow for a load change of area 2 by 125 MW. For both the areas each percent change in frequency causes 1 percent change in load. Find also the amount of additional frequency drop if the interconnection is lost due to certain reasons. **(Nov 10, May 09)**

7. Two control areas connected by a tie line have the following characteristics.

Area 1	Area 2
R=0.01 pu	R=0.02 pu
D=0.8 pu	D=1.0 pu
Base MVA=2000	Base MVA=500

   A load change of 100 MW (0.2 pu) occurs in area 1. What is the new steady state frequency and what is the change in the tie flow? Assume both areas were at nominal frequency (60 Hz) to begin. **(Nov 10)**

8. Two areas are connected via an inter tie line. The load at 50 Hz, is 15000 MW in area 1 and 35000 in area 2. Area 1 is importing 1500 MW from area 2. The load damping constant in each area is B=1.0 and the regulation R=6 % for all units. Area 1 has a spinning reserve of 800 MW spread over 4000 MW of generation capacity and area 2 has a spinning reserve of 1000 MW spread over 10000 MW generation.

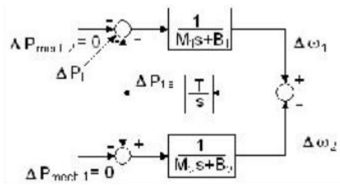
Determine the steady state frequency, generation and load of each area and tie-line power for

i. Loss of 1000 MW in area 1, with no supplementary control.

ii. Loss of 1000 MW in area 1, with supplementary controls provided on generators with reserve. **(May 09)**

9. Derive the transfer function ($\Delta F(s)/\Delta P_D(s)$) for proportional and integral control of a single area system. **(May 09)**

10. Given a block diagram of two interconnected areas shown in figure 6 (consider the prime-mover output to be constant i.e., a blocked governor): **(May 09)**



i. Derive the transfer functions that relate $\Delta\omega_1(s)$ and $\Delta\omega_2(s)$ to a load change $\Delta P_L(s)$.

ii. For the following data (all quantities refer to a 100 MVA base),

M_1=2.5 pu B_1=1.00

M_2=4.0 pu B_2=0.75

T=377 x 0.02 pu =7.54 pu

Calculate the final frequency for a load step change in area 1 of 0.2 pu (i.e., 200 MW). Assume the frequency was nominal and tie flow was 0 pu.

11. i. What is area control error? What are the control strategies? **(May 09)**

ii. For two-area load frequency control with gain blocks, derive an expression for steady values of change in frequency and tie line power for simultaneously applied unit step load disturbance inputs in the two areas.

12. i. Explain the operation of two generating stations connected by a tie line.

ii. Two generating stations A & B have full load capacities of 500 MW and 210 MW respectively. The inter connector connecting the two stations has a motor-generator set (Plant 'C') near station A of full load capacity of 50 MW. Percentage changes of speed of A, B and C are 5, 4 and 2.5 respectively. The loads on bus bars A and B are 250 MW and 100 MW respectively. Determine the load taken by set C and indicate the direction in which the energy is flowing. **(May 09, Nov, Feb 08, Nov 03)**

13. i. Explain how the tie-line power deviation can be unincorporated in two-area system block diagram.

ii. What are the features of the dynamic response of a two area system for step load disturbances? **(Jan 09)**

14. Two generating stations A and B have full load capacities of 200 MW and 75 MW respectively. The inter connector connecting the two stations has an induction motor/synchronous generator (plant C) of full load capacity of 25 MW. Percentage changes in speeds of A, B and C are 5, 4 and 3 respectively. The loads on the bus bars of A and B are 75 MW and 30 MW respectively. Determine the load taken by the set C and indicate the direction in which the energy is flowing. **(Nov 08)**

15. Two interconnected areas 1 and 2 have the capacity of 200MW and 500MW respectively. The incremental regulation and damping torque co-efficient for each area on its own base are 0.2 pu and 0.08 pu respectively. Find the steady state change in system frequency from a nominal frequency of 50 Hz and the change in steady state tie-line power following a 750MW change in load of area 1 **(Nov 08)**

16. Two control areas of 1000MW and 2000MW capacities are interconnected by a tie line. The speed regulations of the two areas respectively are 4 Hz / Pu MW and 2.5 Hz / Pu MW. Consider 2% change in load occurs for 2% change in frequency in each area. Find steady state change in frequency and tie-line power of 10MW change in load occurs in both areas. **(Nov 08)**

You cannot raise a man up by calling him down.

- William Boetcker

17. Two generating stations A and B have the capacities 500MWand 800MW respectively are inter-connected by a short line. The percentage speed regulations from no-load to full load of the two stations are 2 and 3 respectively. Find the power generation at each station and power transfer through the line if the load on bus of each station is 200MW. **(Nov 08)**

18. The two control areas of capacity 2000MWand 8000MWare interconnected through a tie-line. The parameters of each area based on its own capacity base are R = 1Hz / Pu MW and B = 0.02 Pu MW / Hz. If the control area-2 experiences an increment in load of 180MW, determine the static frequency drop and the tie-line power. **(Nov 08)**

19. i. Explain load frequency control problem in a Multi-area power system.
    ii. Derive an expression for steady-state change of frequency and tie-line power transfer of a two-area power system. **(Feb 08, Feb 07, Nov 06, 05)**

20. Draw the block diagram for two-area load frequency control with integral controller blocks, and explain each block. **(Feb 08)**

21. Explain the operation of two generating stations connected by a tie line. **(Feb 08, Nov 03)**

22. What is load frequency control problem? Why is it essential to maintain constant frequency in an inter-connected power system? **(Nov 07, 06, 05, 04)**

23. Two power stations A and B each have regulation of 0.1 p u and stiffness K of 1.0 p. u. The capacity of system A is 1350 MW of B 1150 MW. The two systems are interconnected through a tie line and are initially at 60 Hz. If there is 100 MW load change in system A, calculate the change in the steady-state values of frequency and power transfer P_{12} with the participation of governor control. **(Nov 07, 04)**

24. For two-area load frequency control with integral controller blocks, derive an expression for steady values of change in frequency and tie line power for simultaneously applied unit step load disturbance inputs in the two areas. **(Nov 07)**

25. Two power stations A B are inter connected by tie line and an increase in load of 250 MW on system B causes a power transfer of 150 MW from A to B. When the tie line is open the frequencies of system A is 50 c/s and of system B is 49.5c/s. Determine the values of K_A and K_B which are the power frequency constants of each generator. **(Nov 07, 06)**

26. For two-area load frequency control with gain blocks, derive an expression for steady values of change in frequency and tie line power for simultaneously applied unit step load disturbance inputs in the two areas. **(Nov 06, Mar 06)**

27. Explain the power frequency characteristics of an inter-connected power system? **(Nov 05)**

28. What is area control error? What are the control strategies? **(Mar 06)**

29. Two power systems A and B are inter connected by a tie line and have power frequency constants K_A and K_B per Hz. An increase in load of 500 MW on system 'A' causes a power transfer of 300 MW from 'B' to 'A'. When the tie line is opened the frequency of system 'A' is 49 HZ and of system 'B' 50 Hz. Determine the values of K_A and K_B, deriving any formulae used. **(Apr 05, Nov 03)**

30. Two power stations A and B are inter connected by tie line and an increase in load of 250 MW on system B causes a power transfer of 100 MW from A to B. When the tie line is open the frequencies of system a is 60 c/s and of system B is 59.5 c/s. Determine the values of K_A and K_B which are the power frequency constants of each generator. **(Nov 04)**

31. Two power stations A and B each have regulation (R) of 0.1 p u (on respective capacity bases) and stiffness K of 1.0 p. u. The capacity of system A is 1500 MW and of B 1000 MW. The two systems are interconnected through a tie line and are initially at 60 Hz. If there is 100 MW load change in system A, calculate the change in the steady-state values of frequency and power transfer P_{12} (with and without the participation of governor control). **(Nov 03)**

32. Explain tie line bias control of two-area power system. **(Nov 02)**

33. For two-area frequency control employing integral of area control error, obtain an expression for steady values of change in frequency for unit step disturbance in one of the areas. Assume both areas to be identical, comment upon the stability of the system for parameter values given below: **(Nov 02)**
$T_{sg} = 0.4s; T_t = 0.5s; T_{ps} = 20s; K_{ps} = 100; R= 3; K_i=1; b = 0.425; a_{12} =1; 2\Pi T_{12} = 0.05$.

34. Discuss the importance of optimal two area load frequency control with suitable analysis **(Nov 02)**

35. . With a neat composite block diagram of 2-area load frequency control, explain how the tie line power and frequencies are changing. **(Nov 02)**

36. What is meant by load frequency control of two area system? **(Nov 02)**
37. Develop mathematical modeling of load frequency control of two area system. **(Nov 02)**

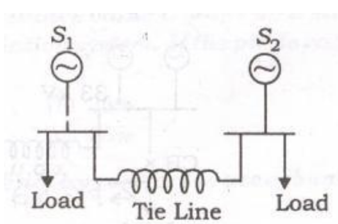
38. Expalin the linear mathametical model of 2-area power system. **(Anu Nov 04)**

39. Draw a block diagram to represent a two area system showing all necessary details and explain the various blocks. **(Anu Apr 05)**

40. Which of the following are the advantages of interconnected operation of power systems?
    i. Less reserve capacity requirement.
    ii. More reliability.
    iii. High power factor.
    iv. Reduction in short-circuit level.

    Select the correct answer using the codes given below:
    Codes:
    a. 1 and 2 b. 2 and 3 c. 3 and 4 d. 1 and 4 **(IES 98)**

41. Consider a power system with two plants S_1 and S_2 connected through a tie line as shown in figure.



When the load frequency control of the sytem is considered, the 'Flat tie-line control' system is preferred over the 'Flat frequency regulation system', because

i. It is advantageous to control the frequency from any one particular plant without disturbing the other one during load-swings on either S_1 or S_2 areas
ii. This ensures that only the more efficient plant's input is controlled for load variation in any area
iii. Only the tie line is required to absorb the load-swings
iv. The load-change in a particular area is taken acare of by the generator in that area. **(IES 97)**

42. The synchronizing coefficient between two areas of a 2-area power system is (symbols have usual meanings).

i. $\frac{\partial P}{\partial |V|}$ ii. $\frac{\partial P}{\partial \delta}$ iii. $\frac{\partial P}{\partial f}$ iv. $\frac{\partial P}{\partial Q}$ **(IES 95)**

43. A power system consists of 2 areas (Area 1 and Area 2) connected by a single tieline. It is required to carry out a loadflow study on this system. While entering the network data, the tie-line data (connectivity and parameters) is inadvertently left out. If the loadflow program is run with this incomplete data
i. The loadflow will converge only if the slack bus is specified in Area 1
ii. The loadflow will converge only if the slack bus is specified in Area 2
iii. The loadflow will converge if the slack bus is specified in either Area 1 or Area 2
iv. The loadflow will not coverge if only one slack bus is specified. **(GATE 02)**

44. Two power systems A and B each having a regulation (R) of 0.05 p.u of their respectively capacity bases and a stiffness (damping coefficient) of 0.75 p.u are connected through a tie line, initially carrying no power. The capacity of the system A is 2000 MW and that of system B is 3000 MW. It there is an increase in load of 200 MW in system A, What is the change in the steady state and power transfer. **(GATE 97)**

UNIT-VII

1. What is a control area? Discuss the proportional plus integral load frequency control. **(Dec 14)**

1. i. Explain Load frequency control of a two area system with block diagram representation.
ii. Two areas 1 and 2 are interconnected. The capacity of area 1 is 1500MW and area 2 is 500MW. The incremental regulation and damping torque coeffient for each area on its own base are 0.2 pu and 0.9 pu, respectively. Find the steady state frequency and change in steady state tie line power, for an increase of 60MW in are 1. The nominal frequency is 50HZ. **(Nov 13)**

2. i. Explain briefly why the proportional plus integral controller is incorporated in a single area load frequency controlled method and also draw the block diagram.
ii. A 100Mw unit with 0.007P.U turbine regulation operates in parallel with a600MW unit of identical turbine regulation. For a specific amount of power demand increase find the ratio of sharing of load by the units, system frequency is 50Hz. **(Nov 12)**

3. Find the expression for dynamic response of change in frequency for a step change in load for a single area control system with integral control action. Assume that $T_g \cong 0$; $T_t \cong 0$ and damping constant. **(May 11)**

4. Obtain an expression for steady state response of a load frequency controller with integral control. How it is different from with out integral control. **(Nov 10)**

5. Obtain the dynamic response of load frequency controller with integral control action in two area load frequency control system. **(Nov 10)**

6. Explain the state variable model of two area load frequency controller with integral action. **(Nov 10)**

7. A system consists of 4 identical 250 MVA generators feeding a load of 510 MW. The inertia constant H of each unit is 2.5 on the machine base. The load varies by 1.4% for a 1 % change in frequency. If there is a drop

in load of 10 MW, determine the system block diagram expressing H and B on the base of 1000 MVA. Give the expression for speed deviation, assuming there is no speed governor. **(Nov 10)**

8. Discuss the importance of combined load frequency control and economic dispatch control with a neat block diagram. **(May 09, Nov 04)**

9. i. Explain economic dispatch control problem in detail.
   ii. Explain how the frequency error in the load frequency control problem is reduced to zero. **(May, Jan 09)**

10. What are the requirements of control strategy in integral control? Explain the role played by the controller? gain setting in the frequency control. **(May 09)**

11. Explain the effect of integral gain on the performance of load frequency control in two area load frequency control. **(Nov 08)**

12. Derive the transfer function ($\Delta F_{(s)}/\Delta P_D(s)$) for proportional and integral control of a single area system **(Nov 08)**

13. Show that steady state frequency error can be reduced to zero if the proportional and integral controller is used in single area load frequency control. **(Nov 08)**

14. Explain proportional plus integral control for load frequency control for a single area system. **(Feb 08, 07, Mar 06, Nov 06, 05, 03)**

15. Obtain the dynamic response of load frequency controller with and without integral control action. **(Feb 08, Mar 06, Nov 06, 05, 02)**

16. Draw the block diagram of a power system showing the governor, turbine and syn.generator, indicating their transfer functions. For a step disturbance of ΔP_D, obtain the response of "increment in frequency", making suitable assumptions.
   i. Without proportional plus integral controller, and
   ii. With proportional plus integral control. **(Feb 08, Nov 07, 06, 05, Mar 06)**

17. Discuss the merits of proportional plus integral load frequency control of a system with a neat block diagram. **(Nov 04, Nov 02)**

18. Load frequency control uses
   i. proportional controllers alone
   ii. integral controllers alone
   iii. both proportional and integral controllers
   iv. either proportional or integral controllers **(IES 99)**

19. Load frequency control is achieved by properly matching the individual machines's
   i. reactive powers
   ii. generated voltages
   iii. turbine inputs
   iv. turbine and generator ratings **(IES 98)**

20. In the load-frequency control system with free governor action, the increase in load-demand under steady conditons is met
   i. only by increased generation due to opening of steam valve
   ii. only by decrease of load-demand due to drop in sytem frequency
   iii. partly by increased generation and partly by decrease of load-demand
   iv. partly by increased generation and partly by increased genrator excitation. **(IES 96)**

Fix your eyes on perfection and you make almost everything speed towards it.
- William Ellery Channing

21. In the single area control system we have following data T_p=10 Sec., T_g=T_t=0, K_p=100Hz/pu Mw, D = 3hz/pumw, ΔP_D = 0.1 pu Mw, K_i = 0.1. Compute the time error caused by a step disturbance of magnitide given above. Prove in particular that the error is reduced by increasing the given Ki. Express the error in seconds and cycle if the system frequency is 50Hz.

22. Find the expression for dynamic response of change in frequency for a step change in load for the single area control system with integral control under assumptions that Tg $\simeq$ 0, Tt $\simeq$ 0 and damping constant B $\simeq$ 0. Also find the response when the system is uncontrolled.

23. For an isolated power system with following data Pr = 100 Mw, P_D^0 = 50Mw, H = 5.0 sec., R = 2.5 Hz/PvMW. If load would increase 1 per unit for 1 per best frequency increase, find the static frequency change for the controlled case when the load is increased by 10 Mw. Estimate the critical magnitude of integral controller gain.

24. A single area system has the following data area capacity = 4000 Mw, operating load frequency f = 50Hz, H = 5 sec., D = 2.5% and % change in load for 1%. Change in frequency find
    i. Frequency response and static frequency error in the absence of secondary loop (integral control) it a step increase of 80Mw, in load occurs.
    ii. Find critical value of Ki of integral controller is used.

25. The time constant of the governing systems of steam turbine is 0.2 seconds. While that of turbine is 2 seconds. H = 5 sec., D = 4% (Hz/Pv Mw). Load changes by 1% for 1% change in frequency. The rated capacity is 1500 Mw and f = 50Hz. Find static frequency error for step change in load. If integrated controller is used.

UNIT-VIII

1. What are the different types of reactive power compensating equipment for transmission systems? State the advantages and disadvantages of each. **(Dec 14)**

1. i. What are the power system components, which absorb or generate reactive power?
   ii. A 415, 50HZ, three phase system delivers 500KW at 0.8 pf lag, shunt capacitor banks are installed to raise the pf to 0.92. Determine the value of capacitor needed for both bases (if the banks are connected in Star and Delta). **(Nov 13)**

2. i. Explain how the reactive power is generated and also explain the significance of reactive power an voltage stability and regulation state necessary equation for it.
   ii. Briefly explain the reactive power compensation types and also explain in detail about static Var Compensator to maintain voltage stability. **(Nov 12)**

3. Discus in detail the following components of excitation system. **(May 11)**
   i. Error Amplifier
   ii. SCR Power Amplifier
   iii. Main Exciter and
   iv. Alternator.

4. A 3 Phase overhead line has resistance and reactance per phase of 25Ω and 90Ω respectively. The supply voltage is 145 kV while the load end voltage is maintained at 132 kV for all loads by an automatically controlled synchronous phase modifier. If the kVAr rating of the modifier has the same value for zero loads as for a load of 50 MW, find the rating of the Synchronous Phase modifier. **(May 11)**

5. Find the rating of synchronous compensator connected to the tertiary winding of a 132 kV star connected,

- Roger Maris

33 kV star connected, 11 kV delta connected three winding transformer to supply a load of 66 MW at 0.8 p.f. lagging at 33 kV across the secondary. The equivalent primary and secondary winding reactances are 32 ohms and 0.16 ohms respectively while the secondary winding reactance is negligible. Assume that the primary side voltage is essentially constant at 132 kV and maximum of nominal setting between transformer primary and secondary is 1.1.

(May 11)

6. A single-phase 400V, 50 Hz motor takes a supply current of 50A at power factor of 0.8 lag. The motor p.f has been improved to unity by confectioning a condenser in parallel. Calculate the capacity of the condenser required. **(May 11, 09)**

7. A 220 kV line has tap changing transformer at both the ends. The transformer at the sending end has a nominal ratio of 11 220 kV and that at the receiving end is 220/11 kV. The line impedance is (20 + j 60) ohms and the load at the receiving end is 100 MVA, 0.8 p.f. lagging. If the product of two off nominal tap settings is 1, find the tap settings to give 11 kV at load bus. **(May 11)**

8. An inter connector with inductive reactance of 25 ohms and negligible resistance of two units of generation with voltages are 33KV and 30KV at its ends. The load of 6MW is to be transferred from 33KV to 30KV side of a inter connector determine the power factor of power transmitter and other necessary conditions between two ends. **(May 11)**

9. i. Explain about the losses occurred due to VAR flow in power systems.
   ii. Explain how the generators are acted as VAR sources in a power network.

(Nov 10, 07, 06, 05, 04, Mar 09, 06, Apr 05, Feb 08, 07)

10. The load at receiving end of a three-phase, over head line is 25.5 MW, power factor 0.8 lagging, at a line voltage of 33 kV. A synchronous compensator is situated at receiving end and the voltage at both the ends of the line is maintained at 33 kV. Calculate the MVAR of the compensator. The line has a resistance of 4.5 ohms per phase and inductive reactance (line to neutral) of 20 ohms per phase. **(Nov 10)**

11. i. Write short notes on compensated and uncompensated transmission lines.
    ii. Explain briefly about the shunt and series compensation of transmission systems.

(Nov 09, 05, 04, Feb 07, Mar 06)

12. What is load compensation? Discuss its objectives in power system. **(May 09)**

13. Two substations are connected by two lines in parallel with negligible impedance, but each containing a tap-charging transformer of reactance 0.18 p.u. on the basis of its rating of 200 MVA. Find the net absorption of reactive power when the transformer, taps are set to 1:1.1 and 1:0.9 respectively. Assume p.u., voltages to be equal at the two ends and at sub-station. **(May 09)**

14. Explain reason for variations of voltages in power systems and explain any one method to improve voltage profile. **(May 09, Feb 07, Nov 04, 03)**

15. i. With a neat phasor diagrams explain the reactive power balance and its effect on system voltage.
    ii. The load at the receiving end of a three-phase, over-head line is 25 MW, power factor 0.8 lagging, at a line voltage of 33 kV. A synchronous compensator is situated at the receiving end and the voltage at both ends of the line is maintained at 23 kV. Calculate the MVAr of the compensator. The line has resistance 5 ohm per phase and inductive reactance 20 ohm per phase. **(May 09, Nov, Mar 06)**

16. A 3-phase single circuit, 220kV, line runs at no load. voltage at the receiving end of the line is 205kV. Find the sending end voltage, if the line has resistance of 21.7ohms, reactance of 85.2ohms and the total suceptance of 5.32×10^{-4} mho. The transmission line is to be represented by πmodel. **(May 09)**

17. A single-phase motor connected to a 230 V, 50 Hz supply takes 30 A at a p.f of 0.7 lag. A capacitor is shunted

across the motor terminals to improve the p.f to 0.9 lag. Determine the capacitance of the capacitor to be shunted across the motor terminals. **(May 09)**

18. i. Describe in detail off load and on load tap changing transformers.
ii. Discuss in detail about the generation and absorption of reactive power in power system components. **(May 09)**

19. Explain clearly what do you mean by compensation of line and discuss briefly different methods of compensation. **(Nov 08, 07, 06, 04, 03, Feb 08, 07)**

20. Explain the operations of synchronous condenser and mention its applications in power systems and derive the expression for capacity of the synchronous condenser. **(Nov 08, 04)**

21. A three-phase transmission line has resistance and inductive reactance of 25 and 90 respectively. With no load at the receiving end a synchronous compensator there takes a current lagging by 900, the voltage at the sending end is 145 kV and 132 kV at the receiving end. Calculate the value of the current taken by the compensator. When the load at the receiving end is 50 MW, it is found that the line can operate with unchanged voltages at sending and receiving ends, provided that the compensator takes the same current as before but now leading by 90^0. Calculate the reactive power of the load. **(Nov 08, 07, 05)**

22. A 11 KV supply busbar is connected to an 11/132 kV, 100 MVA, 10 per cent reactance, transformer. The transformer feeds a 132 kV transmission link consisting of an overhead line of impedance (0.014 + j0.04) p.u. and a cable of impedance (0.03 + j0.01) p.u. in parallel. If the receiving end is to be maintained at 132 kV when delivering 80 MW. 0.9 p.f. lagging calculate the power and reactive power carried by the cable and the line. All p.u. values relate to 100 MVA and 132 kV bases. **(Feb 08)**

23. A three-phase induction motor delivers 500 hp at an efficiency of 0.91, the operating power factor being 0.76 lagging. A loaded synchronous motor with a power consumption of 100 KW is connected in parallel with the induction motor. Calculate the necessary KVA and the operating power factor of the synchronous motor if the overall power factor is to be unity. **(Feb 08, Mar 06, Nov 05, 04)**

24. What is a static compensator ? Explain with diagrams working principle of various types of static compensators. **(Feb 08, Nov 03, Anu Nov 04)**

25. What is load compensation? Discuss its objectives in power system. **(Nov 07, 06, Feb 07)**

26. i. Discuss in detail about the generation and absorption of reactive power system components.
ii. A load of (15 + j10) MVA is supplied with power from the busbars of a power plant via a three phase 110 KV line, 100 km lagging. The transmission line is represented by 4)12-model and has the following parameters. R=26.4 ohms, X = 33.9 ohms, B = 219 x 10^{-9} ohm. Voltage across the power plant bus bars V_1 = 116 kV. Find the power consumed from the power plant bus bars. **(Nov 07, 03, 02)**

27. Find the rating of synchronous compensator connected to the tertiary winding of a 132 KV star connected, 33 KV star connected, 11 KV delta connected three winding transformer to supply a load of 66 MW at 0.8 power factor lagging at 33 KV across the secondary. Equivalent primary and tertiary winding reactances are 32 ohm and 0.16 ohm respectively while the secondary winding reactance is negligible. Assume that the primary side voltage is essentially constant at 132 KV and maximum of nominal setting between transformer primary and secondary is 1:1.1. **(Nov 07, 06, 03)**

28. A three phase transmission line has resistance and inductive reactance (line to neutral) of 25 ohms and 85 ohms. With no load at the receiving end but with a synchronous compensator there taking a current lagging by 90^0, the voltage at the sending end is 145 KV and 132 KV at the receiving end. Calculate the value of the current taken by the compensator. When the load at the receiving end is 50 MW, it is found

that the line can operate with unchanged voltages at sending and receiving ends, provided that the compensator takes the same current as before but now leading by 90^0. Calculate the power factor of the load. **(Feb 07, Nov 04)**

29. With a neat phasor diagrams explain the reactive power balance and its effect on system voltage. **(Nov06)**

30. A load of (66+j60) MVA at the receiving end is being transmitted via a single circuit 220 KV line, having resistance of 21 ohms and reactance of 34 ohms. The sending end voltage is maintained at 220 KV. The operating conditions of power consumers require that at this load voltage drop across the line should not exceed 5 percent. In order to reduce voltage drop, standard single phase, 66 KV, 40 KVAR capacitors are to be switched in series in each phase of the line. Determine the required number of capacitors, rated voltage and installed capacitors of the capacitor tank. The losses in the line are neglected. **(Mar 06, Nov 03)**

31. i. What does on mean by load compensation ? **(Mar 06, Nov 04)**
    ii. With neat diagrams discuss shunt and series compensation. **(Apr 05)**
    iii. What are the specifications of load compensator ? **(Mar 06, Nov 02)**

32. i. Describe the effect of thyristor-controlled static shunt compensators to meet reactive power requirement in the power systems.
    ii. Compare the technical advantages of static compensator over synchronous condenser. **(Nov 05)**

33. Describe the necessity of connecting synchronous compensators and shunt capacitors in a power system. **(Nov 04)**

34. Two substations are connected by two lines in parallel of negligible impendance, each containing a transformer of reactance 0.18 p.u and rated at 120 MVA. Calculate the net absorption of reactive power when the transformer taps are set to 1:1.15 and 1:0.85 respectively i.e. tap changer is used. The p.u. voltages are equal at the two ends and are constant in magnitude. **(Nov 04)**

35. Two substations are connected by two lines in parallel with negligible impedance, but each containing a tap-charging transformer of reactance 0.18 p.u. on the basis of its rating of 200 MVA. Find the net absorption of reactive power when the transformer, taps are set to 1:1.1 and 1:0.9 respectively. Assume p.u., voltages to be equal at the two ends and at sub-station. **(Nov 04)**

36. i. Describe the effect of connecting shunt reactors connected in high voltage transmission system.
    ii. Describe the features of saturated reactor compensator with its V/I characteristics. **(Nov 04)**

37. A long transmission line has the constants A=0.97 1□2^0, B=84□75^0 find the additional reactive power requirement at the receiving end to meet a load of 63 MW at 0.8 p.f. lagging, when both the sending end and receiving and voltages are to be maintained at 132 kV. **(Nov 04)**

38. i. Explain how transformers are used to control the flow of real and reactive power in the power system network.
    ii. Explain the combined use of Tap-changing transformers and reactive power injection in a power system. **(Mar 06, Nov 05)**

39. A 400 KV line is fed through an 132/400 KV transformer from a constant 132 KV supply. At the load end of the line the voltage is reduced by another transformer of normal ratio 400/132 KV. The total impedance of line and transformers at 400 KV is (50 + j100) ohm. Both transformers are equipped with tap-changing facilities which are so arranged that the product of the two off-nominal setting is unity. If the load on the system is 250 MW at 0.8 p.f. lagging, calculate the settings of the tap-changers required to maintain the voltage of the load bus bar at 132 KV. **(Nov 03)**

40. Explain with diagrams, the operations of a fixed capacitor and thyristors controlled reactor. **(Nov 03)**

41. i. Describe the effect of connecting series capacitors in the transmission system.
    ii. A single circuit three-phase 220 KV line runs at no load. Voltage at the receiving end of the line is 210 KV. Find the sending end voltage, if the line has resistance of 20.5 ohms, reactance of 81.3 ohms and the total susceptance as 5.45 x 10^{-4} mho. The transmission line is to be represented by $4\overline{)12}$-model. **(Nov 02)**

42. Discuss the advantages and disadvantages of different types of compensating equipment for transmission systems. **(Nov 02)**

43. Discuss the effect of compensation on the maximum power transfer in a transmission line. **(Anu Nov 04)**

44. What is static VAR compensator? Where it is used? Also state merits of static VAR compesator over other methods of voltage control **(Anu Apr 05)**

45. A 3-phase 50 Hz transmission line has the following constants A=0.99□162^0, B=50□73.7^0 find the MVAR rating on no load and full load of a synchroniting phase modifier to maintain a sending and receiving voltages at 70 KV. and 66 KV respectively, when the line is delivering a load of 24 MVA, 0.8 pf lag **(Anu Apr 05)**

46. A shunt reactor of 100 MVAr is operated at 98% of its rated voltage and at 96% of its rated frequency. The reactive power absorbed by the reactor is;
    i. 98 MVAr ii. 104.02 MVAr iii. 96.04 MVAr iv. 100.04 MVAr **(GATE 98)**

47. A factory draws 100 kW at 0.7 p.f laggging from a 3-phase, 11 kV supply. It is desired to raise the p.f. to 0.95 lagging using series capacitors. Calculate the rating of the capcitor required. **(GATE 97)**

48. In a 400 kV network, 350 kV is recorded at a 400 kV bus .The reactive power absorbed by a shunt rated for 50 MVAR ,400 kV connected at the bus is
    i. 61.73 MVAR ii. 55.56 MVAR iii.45 MVAR iv. 40.5 MVAR **(GATE 94)**

49. The power factor of an industrial 3 phase load of 490 KW is to be improved from 0.7 lagging to 0.97 lagging by connecting loss free delta connected capacitors across 6.6 KV, 50 Hz supply. The cost of suitable capacitors and control gear is Rs.200 per KVAR and annual tariff charge is 120 Rs. Per KVA maximum demand.
    The annual interest and depreciation charges are 15 per cent calculate.
    i. The total KVAR rating of capacitors required. ii. The required value of capacitance per phase
    iii. The net annual saving **(GATE 92)**

50. The combined effect of series and shunt compensation on transmission lines in terms of degree of series compensation (K_{se}), degree of shunt compensations (K_{sh}), and surge impedance of uncompensated line (Z_0) is given by which one of the following equations?
    i. $Z'_0 = Z_0\sqrt{1-K_{se}}\sqrt{1-K_{sh}}$ ii. $Z'_0 = [\sqrt{1-K_{se}}\sqrt{1-K_{sh}}]/Z_0$
    iii. $Z'_0 = Z_0\sqrt{(1-K_{se})}/\sqrt{(1-K_{sh})}$ iv. $Z'_0 = Z_0\sqrt{(1-K_{sh})}/\sqrt{(1-K_{se})}$ **(IES 04)**

51. A three phase inductive compensator (TCR) has an inductance of L Henry per phase and negligible resistance. It is controlled by a pair of antiparallel SCRs in each phase. The triggering angle α is varied to get the required compensation. The supply voltage is V volts per phase. Derive the expressions for the rms voltage and corresponding rms current per phase of the compensator. **(IES 99)**

52. To improve the power factor in three-phase circuits, the capacitor bank is connected in delta to make
    i. capacitance calculation easy ii. capcitance value small
    iii. the connection elegant iv. the power factor correction more effective **(IES 99)**

53. Describe the drawbacks of the thyristor controlled reactor (TCR) used for VAR control. **(IES 98)**

In short, the habits we form from childhood make no small difference, but rather they make all the difference. - Aristotle