OUTCOME BASED EDUCATION

M.E. DEGREE (Power System Engineering) PROGRAMME

CURRICULUM AND DETAILED SYLLABI FOR

I TO IV SEMESTERS

CORE & ELECTIVE COURSES

FOR THE STUDENTS ADMITTED FROM THE
ACADEMIC YEAR 2014-2015

THIAGARAJAR COLLEGE OF ENGINEERING

(A Govt. Aided ISO 9001-2008 certified Autonomous Institution affiliated to Anna University)

MADURAI – 625 015, TAMILNADU

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Department of Electrical and Electronics Engineering

VISION

- Transforming the individuals into globally competent electrical engineers to fulfill the technological needs of the society.

MISSION

- Establishing world class infrastructure in Electrical Engineering.
- Enhancing the knowledge of the faculty in cutting edge technologies through continuous improvement programmes.
- Providing well balanced curriculum in graduate, postgraduate and doctoral programmes.
- Adopting innovative content delivery, assessment and continuous improvement methods to achieve desired outcomes.
- Facilitating industry institution interaction in teaching & learning, consultancy and research activities to accomplish the technological needs of the society.
- Encouraging the faculty and students to carry out innovative research work
- Practicing ethical standards by the faculty and students.
- Motivating the students for active participation in co-curricular and extracurricular activities.

Specialization for M.E. Power System Engineering Programme

- Model & Analyze
- Planning, Operation & Control
- Renewable Energy

Programme Educational Objectives (PEO's)

PEO1: Graduates of the programme will have successful career in power system engineering and its related disciplines.

PEO2: Graduates of the programme will carryout innovative research in power system engineering and its related disciplines.

PEO3: Graduates of the programme will provide/offer optimum solutions to the challenging problems in power and energy sectors with ethical values and social responsibility.

PEO4: Graduates of the programme will demonstrate life-long independent and reflective learning skills in their career.

PEO5: Graduates of the programme will exhibit project management skills and ability to work in collaborative, multidisciplinary tasks in their profession.

Graduate Attributes (Gas) of NBA for PG Engineering and Technology Programmes

GA1 Scholarship of Knowledge

Acquire in-depth knowledge of specific discipline or professional area, including wider and global perspective, with an ability to discriminate, evaluate, analyse and synthesise existing and new knowledge, and integration of the same for enhancement of knowledge.

GA2 Critical Thinking

Analyse complex engineering problems critically, apply independent judgement for synthesising information to make intellectual and/or creative advances for conducting research in a wider theoretical, practical and policy context.

GA3 Problem Solving

Think laterally and originally, conceptualise and solve engineering problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, cultural, societal and environmental factors in the core areas of expertise.

GA4 Research Skill

Extract information pertinent to unfamiliar problems through literature survey and experiments, apply appropriate research methodologies, techniques and tools, design, conduct experiments, analyse and interpret data, demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in one or more domains of engineering.

GA5 Usage of modern tools

Create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering activities with an understanding of the limitations.

GA6 Collaborative and Multidisciplinary work

Possess knowledge and understanding of group dynamics, recognise opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.

GA7 Project Management and Finance

Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after considerisation of economical and financial factors.

GA8 Communication

Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.

GA9 Life-long Learning

Recognise the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.

GA10 Ethical Practices and Social Responsibility

Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.

GA11 Independent and Reflective Learning

Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

Programme Outcomes (POs) for M.E. Power System Engineering

After the successful completion of the M.E. Power System Engineering programme, students should be able to:

PO1: Scholarship of Knowledge

Acquire in-depth knowledge in power system engineering (model, analyze, operation and control) with wider and global perspective, with an ability to discriminate, evaluate, analyse and synthesise existing and new knowledge, and integration of the same for enhancement of knowledge.

PO2: Critical Thinking

Analyse complex power system engineering problems critically, apply independent judgement for synthesising information to make intellectual and creative advances for conducting research in a wider theoretical, practical and policy context.

PO3: Problem Solving

Think laterally and originally, conceptualise and solve power system engineering problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, cultural, societal and environmental factors.

PO4: Research Skill

Extract information pertinent to unfamiliar problems through literature survey and experiments, apply appropriate research methodologies, techniques and tools, design, conduct experiments, analyse and interpret data, demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in power system engineering domain.

PO5: Usage of modern tools

Create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex power system engineering activities with an understanding of the limitations.

PO6: Collaborative and Multidisciplinary work

Possess knowledge and understanding of group dynamics, recognise opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.

PO7: Project Management and Finance

Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after considerisation of economical and financial factors.

PO8: Communication

Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.

PO9: Life-long Learning

Recognise the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.

PO10: Ethical Practices and Social Responsibility

Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.

PO11: Independent and Reflective Learning

Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

Table 1: PEO – PO Mapping

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11
PEO 1											
PEO 2											
PEO 3											

PO – GA Mapping

GAs are taken from page No. 14 – 16 of PG PG Engineering Programmes Tier-I NBA manual. For each GA, corresponding PO is articulated considering three specialization areas of M.E. Power System Engineering programme such as Model & Analyze, Planning, Operation & Control, and Renewable Energy. Therefore there is a direct one-to-one mapping between Gas and Pos as illustrated in the Table 2.

Table 2: PO-GA Mapping

	GA1	GA2	GA3	GA4	GA5	GA6	GA7	GA8	GA9	GA10	GA11
PO1											
PO2											
PO3											
PO4											
PO5											
PO6											
PO7											
PO8											
PO9											
PO10											
PO11											

Thiagarajar College of Engineering: Madurai-625015

Department of Electrical and Electronics Engineering

M.E. POWER SYSTEM ENGINEERING

For the students admitted from 2014-15

Scheduling of Courses

Sem.	**Theory Courses**						**Practical / Project**	**Total Credits**
I	14PS110 Applied Mathematics for Electrical Engineers 3:1	14PS120 Systems Theory 3:1	14PS130 Power System Modelling and Analysis 3:1	14PS140 Digital Protection for Power System 3:1	14PS150 Power System Dynamics and Stability 3:1	14PS160 Power Converters for Distributed Generation Systems 3:0	14PS170 Power System Laboratory – I 0:1	24
II	14PS210 Power System Security 3:0	14PS220 Power System Operation and Control 3:1	14PSPx0 Elective -I 3:1	14PSPx0 Elective -II 3:1	14PSPx0 Elective -III 3:1	14PSPx0 Elective -IV 3:1	14PS270 Power System Laboratory - II 0:1	24
III	14PS310 Electricity Deregulation 3:1	14PSPx0 Elective -V 3:1	14PSPx0 Elective -VI 3:1	--	--	--	14PS340 Project -I 0:4	16
IV	--	--	--	--	--	--	14PS410 Project - II 0:12	12
							Total Credits	**76**

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.E. DEGREE (Power System Engineering) PROGRAM

COURSES OF STUDY

(For the students admitted from 2014-2015)

FIRST SEMESTER

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
14PS110	Applied Mathematics for Electrical Engineers	BS	3	2	-	4
14PS120	Systems Theory	PC	3	2	-	4
14PS130	Power System Modelling and Analysis	PC	3	2	-	4
14PS140	Digital Protection for Power System	PC	3	2	-	4
14PS150	Power System Dynamics and Stability	PC	3	2	-	4
14PS160	Power Converters for Distributed Generation Systems	PC	3	-	-	3
PRACTICAL						
14PS170	Power System Laboratory - I	PC	-	-	2	1
	Total		**18**	**10**	**2**	**24**

SECOND SEMESTER

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
14PS210	Power System Security	PC	3	-	-	3
14PS220	Power System Operation and Control	PC	3	2	-	4
14PSPx0	Elective-I	PE	3	2	-	4
14PSPx0	Elective-II	PE	3	2	-	4
14PSPx0	Elective-III	PE	3	2	-	4
14PSPx0	Elective-IV	PE	3	2	-	4
PRACTICAL						
14PS270	Power System Laboratory - II	PC	-	-	2	1
	Total		**18**	**10**	**2**	**24**

THIRD SEMESTER

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
14PS310	Electricity Deregulation	PC	3	2	-	4
14PSPx0	Elective-V	PE	3	2	-	4
14PSPx0	Elective-VI	PE	3	2	-	4
PRACTICAL						
14PS340	Project - I	PC	-	-	12	4
	Total		**9**	**6**	**12**	**16**

FOURTH SEMESTER

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
PRACTICAL						
14PS410	Project - II	PC	-	-	36	12
	Total		-	**-**	**36**	**12**

Total credits: 76

BS : Basic Science
PC : Programme Core
PE : Programme Elective
L : Lecture
T : Tutorial
P : Practical

Note:

1 Hour Lecture is equivalent to 1 credit

2 Hours Tutorial / Practical is equivalent to 1 credit

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015
M.E. DEGREE (Power System Engineering) PROGRAM
SCHEME OF EXAMINATIONS

(For the Students admitted from 2014-2015)

FIRST SEMESTER

S.No	Course code	Name of the course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam	Max. Marks	Terminal Exam	Total
THEORY								
1	14PS110	Applied Mathematics for Electrical Engineers	3	50	50	100	25	50
2	14PS120	Systems Theory	3	50	50	100	25	50
3	14PS130	Power System Modelling and Analysis	3	50	50	100	25	50
4	14PS140	Digital Protection for Power System	3	50	50	100	25	50
5	14PS150	Power System Dynamics and Stability	3	50	50	100	25	50
6	14PS160	Power Converters for Distributed Generation Systems	3	50	50	100	25	50
PRACTICAL								
7	14PS170	Power System Laboratory - I	3	50	50	100	25	50

SECOND SEMESTER

S.No	Course code	Name of the course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam	Max. Marks	Terminal Exam	Total
THEORY								
1	14PS210	Power System Security	3	50	50	100	25	50
2	14PS220	Power system Operation and Control	3	50	50	100	25	50
3	14PSPx0	Elective-I	3	50	50	100	25	50
4	14PSPx0	Elective-II	3	50	50	100	25	50
5	14PSPx0	Elective-III	3	50	50	100	25	50
6	14PSPx0	Elective-IV	3	50	50	100	25	50
PRACTICAL								
7	14PS270	Power System Laboratory - II	3	50	50	100	25	50

THIRD SEMESTER

S.No	Course code	Name of the course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam	Max. Marks	Terminal Exam	Total
THEORY								
1	14PS310	Electricity Deregulation	3	50	50	100	25	50
2	14PSPx0	Elective-V	3	50	50	100	25	50
3	14PSPx0	Elective-VI	3	50	50	100	25	50
PRACTICAL								
4	14PS340	Project - I	-	150	150	300	75	150

FOURTH SEMESTER

S.No	Course code	Name of the course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam	Max. Marks	Terminal Exam	Total
PRACTICAL								
1	14PS410	Project - II	-	150	150	300	75	150

* CA evaluation pattern will differ from course to course and for different tests. This will have to be declared in advance to students. The department will put a process in place to ensure that the actual test paper follow the declared pattern.

List of Electives – M.E. Power System Engineering

Programme Electives			
Course Code 14PSPx0	Course Name	Pre/Co requisites	Credits
Model & Analyze			
14PSPA0	Power System Voltage Stability	Power System Stability	4
14PSPB0	Electrical Transients in Power system	Power System Analysis	4
14PSPC0/ 14CIPQ0	Real Time Operating Systems	Micro Processors / Micro controllers	4
14PSPD0	Distributed Generation Systems	Generation, Transmission & Distribution	4
14PSPE0	Flexible AC Transmission Systems	Power System Analysis Power Electronics	4
Planning, Operation & Control			
14PSPF0	Power System Optimization	Power System Analysis	4
14PSPG0	Power Plant Instrumentation and Control	Measurement and Instrumentation	4
14PSPH0	Power System Reliability	Power System Analysis	4
14PSPJ0	SCADA	Micro Processors, Instrumentation, DSP	4
14PSPK0	Smart Grid	Power system Analysis	4
14PSPL0	HVDC Transmission	High voltage engineering	4
Renewable Energy			
14PSPM0	Renewable Energy Sources	Generation, Power Plant Engineering	4
14PSPN0	Power Quality	Power System Analysis, Power Electronics	4
14PSPP0	Soft Computing Techniques	Fuzzy Logic, Neural Networks	4
14PSPQ0/ 14CIPA0	Control of Electric Drives	Electrical machines, power Electronics	4

14PS110/14CI110	**APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS**	Category	L	T	P	Credit
		BS	3	1	0	4

Preamble

An engineering PG student needs to have some basic mathematical tools and techniques to apply in diverse applications in Engineering. This emphasizes the development of rigorous logical thinking and analytical skills of the student and appraises him the complete procedure for solving different kinds of problems that occur in engineering. Based on this, the course aims at giving adequate exposure in Linear Algebra to find the singular value decomposition and Pseudo inverse of the matrix, Random Process to deal the Random Experiments with the state space S and parameter set T, stationary Functions, Gaussian Process…, Calculus of Variations to find the maximum or minimum value of a definite integral involving certain functions.

Prerequisite

- Matrix,
- Probability and Statistics,
- Calculus.

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Compute the pseudo- inverse of the rectangular matrix and Decompose the non-square matrix by singular value decomposition	Apply
CO2.	Derive the probability density function of a function of random variables.	Apply
CO3.	Estimate the functions of time when the probability measure is associated through random process	Apply
CO4.	Optimize the functional involving several variables and higher derivatives.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S	S	S	M	S		S	S		
CO2.	S	S	S	M	M	S	L	S	S		
CO3.	S	S	S	S	M	S		S	S		
CO4.	S	S	S	S	M	S	M	S	S		

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	10	20	20	20
Apply	80	70	70	70
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define Generalized eigen vectors.
2. Determine the singular value decomposition of $\begin{pmatrix} 1 & 2 \\ 1 & 1 \\ 1 & 3 \end{pmatrix}$
3. construct QR decomposition of the matrix$\begin{pmatrix} -4 & 2 & 2 \\ 3 & -3 & 3 \\ 6 & 6 & 0 \end{pmatrix}$
4. Find the canonical basis for the matrix. $\begin{bmatrix} 2 & 2 & 2 \\ 0 & 4 & 0 \\ 3 & -3 & 1 \end{bmatrix}$.
5. Obtain the generalized inverse of A =$\begin{pmatrix} 2 & 2 & -2 \\ 2 & 2 & -2 \\ -2 & -2 & 6 \end{pmatrix}$.

Course Outcome 2(CO2)

1. What is meant by independent random variable?
2. If the joint pdf of X and Y is f(x,y)= x+y,0<x<2,0<y<1
   = 0 else where
   Show that X and Y are statistically dependent.
3. The current I and resistance R in a circuit are independent continuous RVs with the following density functions.

   f(i) = 2i, 0≤i≤1
   = 0 else where,
   g(r) = $\frac{r^2}{9}$, 0≤ri≤3
   = 0 else where,
   find the p.d.f of the voltage E in the circuit where E IR.
4. Train A arrives at a station at random in the time interval(0,T) and stops for a minutes. Train A arrives at a station at random in the time interval(0,T) and stops for a minutes independently.
   a. Find the probability that X will arrive before Y
   b. Find the probability that twotrains meet.
   c. Assuming that the two trains meet, find the probability that X will arrive before Y
5. The joint pmf of a bivariate random variable (X,Y) is given by
   $P(x_i,y_j) = \begin{cases} k(2x_i + y_j), & x_i = 1,2;\ y_j = 1,2 \\ 0 & otherwise \end{cases}$
   Find the Value of k. Find the marginal probability mass function of x and y. Are they independent?

Course Outcome 3(CO3)

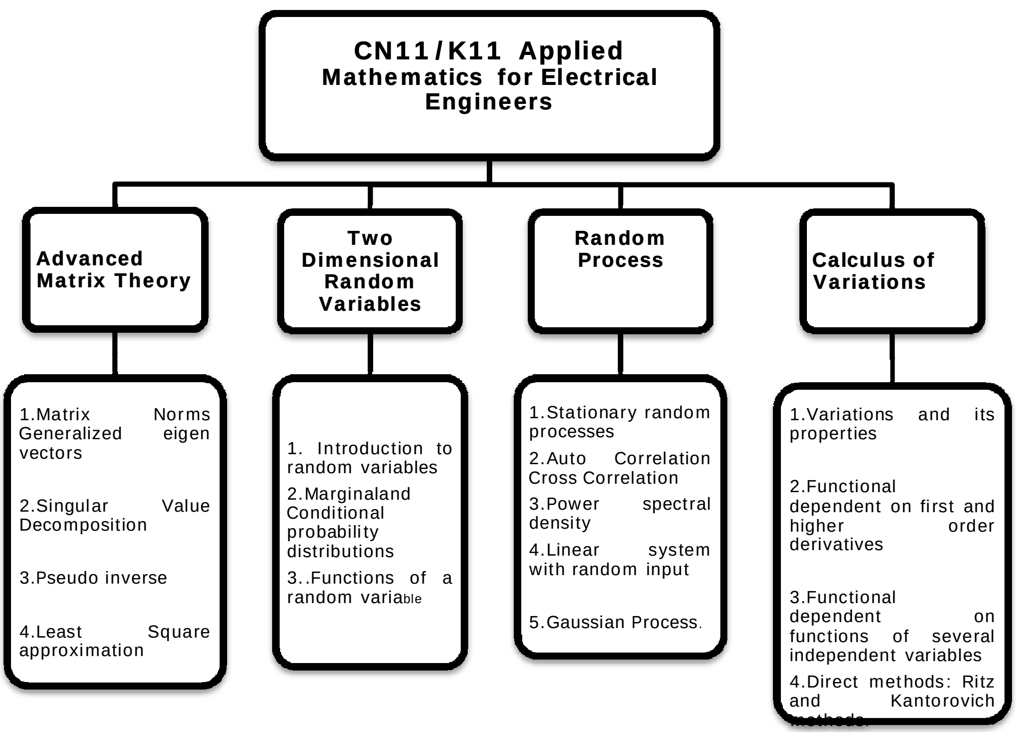
1. What is wide sense stationary process.
2. Check whether the random process X(t) =A$e^{i\omega t}$ is a WSS if E[A]=0
3. If the random process X(t)= sin($\omega t + y$) where y is a random variable uniformly distributed in the interval (0,2π),prove that for the process X(t), $C(t_1,t_2) = R(t_1,t_2)=\frac{\cos\omega(t_1-t_2)}{2}$
4. If the function of Gaussian process are uncorrelated, then P.T. they are Independentant.

5. Calculate the power spectral density of a stationary random process for which the auto correlation is $R_{XX}(\tau) = \sigma^2 e^{-\alpha|\tau|}$

Course Outcome 4(CO4)

1. Write the Solution of the Eulers equation v(y(x))= $\int F(y, \acute{y})$dx.
2. Determine the extremals of $\int_0^2 (y^{12} + z^{12} + 2y^3)$dx satisfying the conditions y(0)=0,y($\frac{\pi}{2}$)= 1,z(0)=1 and z($\frac{\pi}{2}$) = 0.
3. Apply Ritz method to find approximate solution of the problem y'' +y+x=0, 0≤x≤1,, y(0) =0= y(1).
4. Prove that the extremal of the isometric problem v(y(x))= $\int_1^4 y'^2$ dx, y(1)=3, y(4)=24 subject to $\int_1^4 y$ dx= 36 is a parabola
5. A curve C joining the points (x$(x_1, y_1), (x_2, y_2)$is revolved about the x-axis. Find the shape of the curve so that the surface thus generated is a minimum.

Concept Map



Syllabus

Advanced Matrix Theory

Matrix Norms – Jordon canonical form – Generalized eigen vectors – Singular Value Decomposition – Pseudo inverse – Least Square approximation – QR algorithm. (Treatment as per text book 1).

Two Dimensional Random Variables

Introduction to random variables. Marginal and Conditional probability distributions, Independent random Variables, Functions of a random variable, distribution of product and quotient of independent random variables. (Treatment as per text book 2).

Random Process

Classification – Stationary random processes – Auto Correlation – Cross Correlation – Power spectral density – Linear system with random input – Gaussian Process. (Treatment as per text book 3).

Calculus of Variations

Variations and its properties –Euler's equation – Functional dependent on first and higher order derivatives – Functional dependent on functions of several independent variables – Some applications – Direct methods: Ritz and Kantorovich methods. (Treatment as per text book 4).

Reference Books

1. Bronson,R, " Matrix Operations, Schaums Outline Series", McGraw Hill, New York, 1989.
2. Paul L.Meyer, "Introductory Probability and statistical applications", Addison-Wesley,1981.
3. Peebles JR., P.Z., "Probability Random Variables and Random Signal Principles", McGraw Hill inc.,(1993)
4. Gupta .A.S. ,"Calculus of variations and applications", Prentice Hall of India, New Delhi, 1999.
5. Irwin Miller, John E.Freund "Probability and Statistics for Engineers" Prentice Hall of India Pvt. Ltd.; New Delhi, 1977.
6. T.Veerarajan "Probability, Statistics and Random Processes" Tata McGraw-Hill, New Delhi, 2003.

Course Contents and Lecture Schedule

Module No	Topic	No. of Lecture Hours
1.0	**Advanced Matrix Theory**	
1.1	Matrix Norms	1
1.2	Jordon canonical form – Generalized eigen vectors	2
1.3	Singular Value Decomposition	2
1.4	Pseudo inverse	2
1.5	Least Square approximation	2
1.6	QR algorithm	1
2.0	**Two Dimensional Random Variables**	
2.1	Introduction to random variables	2
2.2	Marginal and Conditional probability distributions	1
2.3	Independent random Variables	1
2.4	Functions of a random variable	2
2.5	distribution of product and quotient of independent random variables	2
3.0	**Random Process**	
3.1	Classification	2
3.2	Stationary random processes	2
3.3	Auto Correlation, Cross Correlation	2
3.4	Power spectral density	2
3.5	Linear system with random input	2
3.6	Gaussian Process	2
4.0	**Calculus of Variations**	
4.1	Variations and its properties	2
4.2	Euler's equation	2
4.3	Functional dependent on first and higher order derivatives	2
4.4	Functional dependent on functions of several independent variables, Some applications	2
4.5	Direct methods: Ritz and Kantorovich methods	2
	Total	**40**

Course Designers:

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14PS120/14CI120	**SYSTEMS THEORY**	Category	L	T	P	Credit
		PC	3	1	0	4

Preamble

Modern control theory is a powerful technique for the analysis and design of linear and nonlinear, time-invariant or time varying MIMO systems. The classical design methods suffer from certain limitations due to the fact that the transfer function model is applicable only to linear time invariant systems, and that there too it is generally restricted to single-input, single-output (SISO) systems. This course aims at giving an adequate exposure in state space analysis, state space controller design, MIMO system, Non-linear system, stability analysis.

Prerequisite

Control Systems, Matrix Algebra, Vector calculus,

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Construct the state space model for the given electrical/electro-mechanical systems	Apply
CO2	Design pole placement controller and/orobserver for the given system to achieve desired specifications	Apply
CO3	Explain optimal state regulator and stochastic optimal regulator	Understand
CO4	Explain the frequency domain characteristics of MIMO system	Understand
CO5	Construct the phase plane trajectory of a given nonlinear system	Apply
CO6	Explain describing function for various nonlinearities	Understand
CO7	Identify the existence of limit cycle(s)for the given nonlinear system using describing function method	Apply
CO8	Identify the stability of the given linear and nonlinear system using Lyapunov stability theory	Apply

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	**S**	**M**	**M**	**M**								**M**
CO2	**S**	**M**	**M**	**M**								**M**
CO3	**M**	**S**	**S**									
CO4	**M**	**S**	**S**									
CO5	**S**	**M**	**M**	**M**								**M**
CO6	**S**	**M**	**M**	**M**								**M**
CO7	**S**	**M**	**M**	**M**								**M**

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	60	60	60	60
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Consider the hydraulic system shown in fig.1. Derive state space equations for the system with water levels h_1 and h_2 in the two tanks as the state variables x_1 and x_2 respectively and discharges q_1, q_{12} and q_2 as the outputs y_1,$y_2$and y_3 respectively.

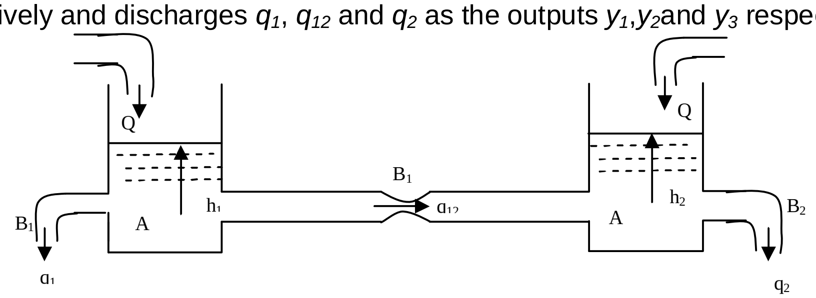
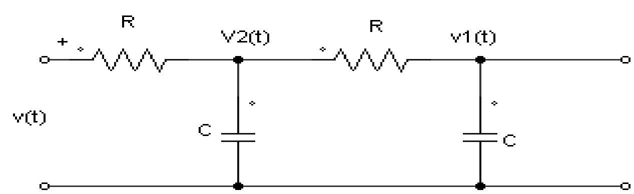


fig.1

2. Obtain the state model of the electrical network shown in fig.2 by choosing v1 (t) and v2 (t) as state variables.



3. A feedback system is characterized by the closed loop transfer function:

$$T(S) = \frac{S^2 + 3S + 3}{(S^3 + 2S^2 + 3S + 1)}$$

Draw a suitable signal flow graph and there from construct a state model of the system.

Course Outcome 2 (CO2):

1. A computer system has the double integrator plant

$$\frac{Y(s)}{R(s)} = \frac{1}{s^2}$$

(i) Taking x_1=y and $x_2 = \dot{y}$ as state variables, obtain the state variable model of the plant.

(ii) Find k_1 and k_2 such that $u = -k_1x_1 - k_2x_2$ gives closed-loop characteristic roots with $\omega_n = 1$ and $\xi = 0.707$

(iii) Design a full-order observer that estimates x_1 and x_2 given measurements of x_1. Pick the characteristic roots of the state-error equations with $\omega_n = 5$ and $\xi = 0.5$

2. A servo system has the plant described by the equation

$$X^{o}(t)=\begin{bmatrix}-1 & -2 & -2\\ 0 & -1 & 1\\ 1 & 0 & -1\end{bmatrix}X(t)+\begin{bmatrix}2\\0\\1\end{bmatrix}u(t)$$

$$Y(t)=\begin{bmatrix}1 & 1 & 0\end{bmatrix}X(t)$$

Find a suitable pole placement controller to place the closed pole locations at -2,-2,-3.

3. Obtain the error equation for full order and reduced order observer.

Course Outcome 3 (CO3):

1. Consider the system shown below. Determine the optimal feedback gain matrix K such that the following performance index is minimized:
J = 1/2 $\int_0^{\infty}(x^T\,Qx\,+2u^2)$dt; Q=$\begin{pmatrix}2 & 0\\ 0 & 2\end{pmatrix}$.

2. Explain the working of stochastic optimal state estimators.

3. Write the expression for performance index (J) of an optimal regulator problem.

Course Outcome 4 (CO4):

1. Define singular values
2. Define transmission zero
3. Explain the frequency domain analysis of MIMO systems

Course Outcome 5 (CO5):

1. A linear second order servo is described by the equation,$\ddot{y}$ + $2\zeta\omega_n\dot{y}$ + $\omega_n^2 y$ = ω_n^2, where ω_n = 1, y(0)=2, $\dot{y}$(0)=0, ζ=1.5. Determine the singular point and construct the phase trajectory.

2. Determine the kind of singularity for each of the following differential equations. Also locate the singular points on the phase plane:
   $\ddot{y}$+3$\dot{y}$+2y=0
   $\ddot{y}$+5$\dot{y}$+6y=6
   $\ddot{y}$-8$\dot{y}$+17y=34

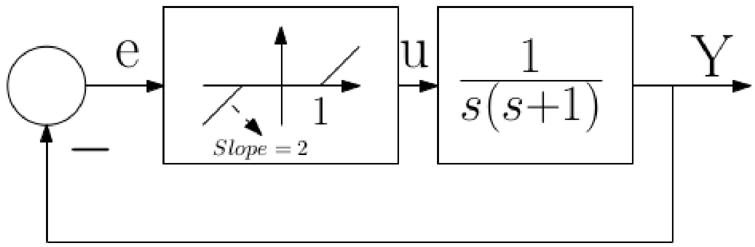
3. Define phase trajectory.

Course Outcome 6 (CO6):

1. Obtain the describing function of dead zone and saturation non linearity.
2. Explain in detail about different non linearity.
3. Obtain the describing function of relay with hysteresis.

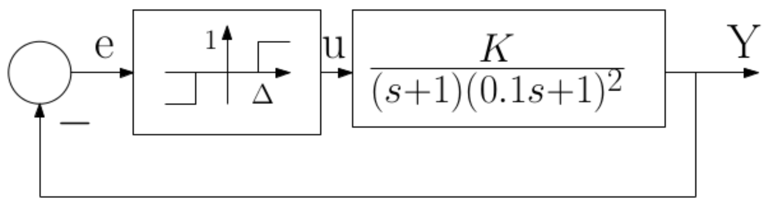
Course Outcome 7 (CO7):

1. Consider the system shown below. Using the describing function analysis, investigate the possibility of a limit cycle. If a limit cycle is predicted, determine its amplitude and frequency and investigate its stability.



2. Explain the stability analysis of non linear system by describing function method.

3. Investigate the stability of a relay controlled system shown in figure.



Course Outcome 8 (CO8):

1. Consider the linear autonomous system $\dot{x} = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix} x$
   Using direct method of Lyapunov, determine the stability of the equibrium state.

2. Check the stability of the equilibrium state of the system described by

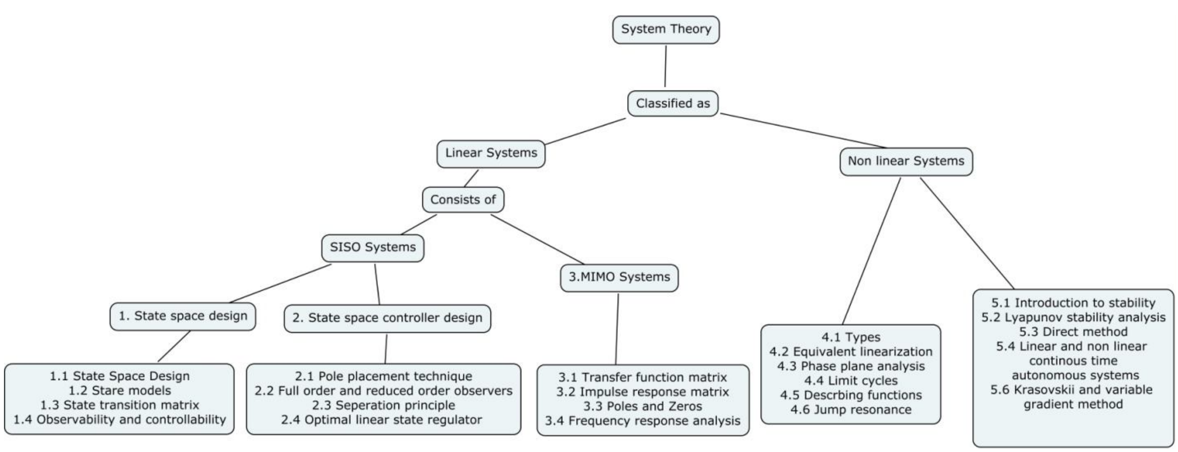
$$\dot{x}_1 = x_2$$
$$\dot{x}_2 = -x_1 - x_1^2 x_2$$

3. Consider a nonlinear system described by the equations

$$\dot{x}_1 = -3x_1 + x_2$$
$$\dot{x}_2 = x_1 - x_2 - x_2^3$$

   Using the Krasovskii method for constructing the Lyapunov function with P as identity matrix, investigate the stability of the equilibrium state.

Concept Map



Syllabus

State Space Analysis

Introduction - Concept of state space model for dynamic systems – Time invariance and Linearity- Non-uniqueness - Minimal realization – Canonical state models - Solution of state equations – State transition matrix - Free and forced responses – Controllability and observability- Stabilisability and detectability.

State Space Controller Design

Introduction – State Feedback control – Pole Placement by State Feedback – Full Order and Reduced Order Observers – Separation principle –Optimal linear state regulator – Stochastic optimal linear estimator.

MIMO Systems

Properties of transfer functions Matrix – Impulse response matrices – Poles and zeros of transfer function matrices – Critical frequencies – Resonance – Steady state and dynamic response – Bandwidth- Nyquist plots – Singular value analysis.

Non-Linear Systems

Types of non-linearity – Typical examples – Equivalent linearization – Phase plane analysis – Limit cycles – Describing functions- Analysis using Describing functions – Jump resonance.

Stability

Introduction – Equilibrium Points – Stability in the sense of Lyapunov – BIBO Stability – Stability of LTI Systems-Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems – The Direct Method of Lyapunov and the Linear Continuous Time Autonomous Systems – Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems – Krasovskii and Variable-Gradient Method.

Reference Books

1. M. Gopal, “Modern Control System Theory”, New Age International Publications, revised 2nd edition, 2005.
2. K. Ogatta, “Modern Control Engineering”, PHI Publications, 2002.
3. I.J.Nagarath , M. Gopal, “Control Systems Engineering”, New Age International Publications, 4th edition, New Delhi, 2006.
4. M.Gopal, “Digital Control and state variable methods – conventional and intelligent control systems”, Tata Mcgraw Hill 3rd edition, New Delhi, 2008.
5. Stanley M. Shinners, “Modern control system theory and design” Wiley-IEEE 2nd edition, 1998.

Course Contents and Lecture Schedule

Sl.No.	Topic	No. of Lecture Hours
1.0	**State Space Analysis**	
1.1	Introduction - Concept of state space model for dynamic systems	1
1.2	Time invariance and Linearity, Non-uniqueness, Minimal realization, Canonical state models	2
1.3	Solution of state equations – State transition matrix	2
1.4	Free and forced responses	1
1.5	Controllability and Observability	2
1.6	Stabilisability and Detectability	1
2.0	**State Space Controller Design**	
2.1	Introduction – State Feedback control	1
2.2	Pole Placement by State Feedback	2
2.3	Full Order and Reduced Order Observers	2
2.4	Separation principle	2
2.5	Optimal linear state regulator	2
2.6	Stochastic optimal linear estimator	1
3.0	**MIMO Systems**	

3.1	Properties of transfer functions Matrix	1
3.2	Impulse response matrices	2
3.3	Poles and zeros of transfer function matrices	1
3.4	Critical frequencies, Resonance, Steady state and dynamic response, Bandwidth	1
3.5	Nyquist plots	2
3.6	Singular value analysis	1
4.0	**Non-Linear Systems**	
4.1	Types of non-linearity – Typical examples	2
4.2	Equivalent linearization	1
4.3	Phase plane analysis	2
4.4	Limit cycles	1
4.5	Describing functions- Analysis using Describing functions	2
4.6	Jump resonance	1
5.0	**Stability**	
5.1	Introduction – Equilibrium Points	1
5.2	Stability in the sense of Lyapunov – BIBO Stability – Stability of LTI Systems	2
5.3	Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems	2
5.4	The Direct Method of Lyapunov and the Linear Continuous Time Autonomous Systems	1
5.5	Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems	1
5.6	Krasovskii and Variable-Gradient Method	2
	Total	**45**

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14PS130	POWER SYSTEM MODELLING AND ANALYSIS	Category	L	T	P	Credit
		PC	3	1	0	4

Preamble

Mathematical modeling and solution on digital computers is the only practical approach to systems analysis and planning studies for a modern day power system with its large size, complex and integrated nature. The stage has, therefore, been reached where postgraduate students must be trained in the latest techniques of analysis of large-scale power systems. A similar need also exists in the industry where a practising power system engineer is constantly faced with the challenge of the rapidly advancing field. This syllabus has been designed to fulfill this need. In this syllabus the representation of various components of a power system are presented and we next proceed to interconnect these components into a dynamical interconnected power system and then analyse it.

Prerequisite

- Matrix algebra.

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Model various power system components that are adequate for the basic system studies of load flow and short-circuit.	Understand
CO2	Develop nodal representation of the power system network.	Apply
CO3	Facilitate the modification of the Bus admittance matrix to reflect the network changes.	Apply
CO4	Form Bus impedance matrix by building algorithm.	Apply
CO5	Perform power flow analysis using GS, NR, FDLF methods.	Apply
CO6	Analyze the flow of active and reactive power in a power system	Analyse
CO7	Calculate the fault current for single line-to-ground, line-to-line, and double line-to-ground faults	Understand
CO8	Use the method of symmetrical components for analyzing unbalanced three-phase systems	Understand
CO9	Determine short circuit capacity using bus impedance matrix.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S		S	L				L	M		
CO2.	S		S								
CO3.	S		S								
CO4.	S		S								
CO5.	S	M	S	M	M				M		
CO6.	S		S								
CO7.	S		S								
CO8.	S		S								
CO9.	S		S								

S- Strong; M-Medium; L-Low

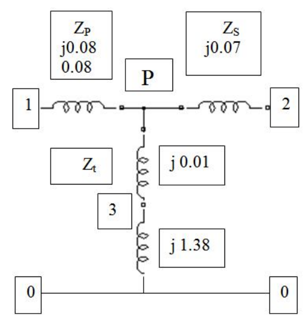
Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	30	30	30	30
Apply	30	30	30	30
Analyse	30	30	30	30
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Draw the per phase basis or modeling or representation of all components of power system.
2. A generator rated at 30MVA, 11KV has a reactance of 20%.Calculate its per unit reactance for a base of 50 MVA and 10KV.
3. A three-winding 132/6.6/33 kV, 3-phase, 50Hz transformer has the following measured impedances between the windings referred to the 132kV winding. The 6.6 kV secondary winding supplies a balanced load, taking a current of 200 A at 0.8 lagging power factor (p.f) and the 33KV tertiary supplies a star connected inductive reactor of (0+j50) ohm per phase. Determine the voltage required at the 132KV primary terminals to maintain 6.6KV at the secondary terminals. The base MVA is 30.

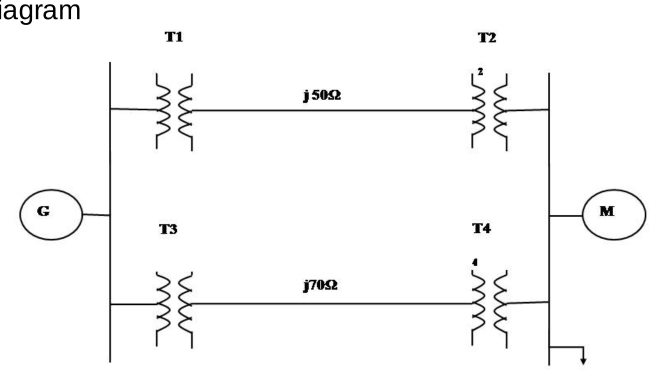


$$Z_{PS} = 0 + j\ 0.15 p.u$$

$$Z_{PT} = 0 + j\ 0.09\ p.u$$

$$Z_{ST} = 0 + j\ 0.08\ p.u$$

4. The single line diagram of a three phase power system is shown in fig. Select a common base of 100MVA and 13.8KV on the generator side. Draw per unit impedance diagram



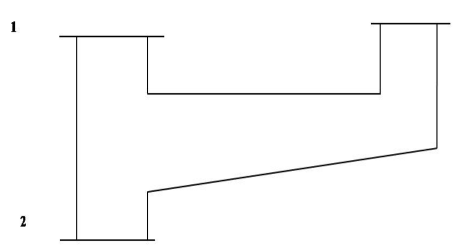
G: 90MVA, 13.8KV, X=18% ; T1:50MVA, 13.8/220KV, X=10%
T2:50MVA, 220/11KV, X=10% ; T3:50MVA, 13.8/132KV, X=10%
T4:50MVA, 132/11KV, X=10% ; M: 80MVA, 10.45KV, X=20%
LOAD: 57MVA, 0.8 p.f lagging at 10.45 KV; Line 1 = j 50Ω; Line 2 = j 70Ω

Course Outcome 2 (CO2):

1. For the network shown in figure below, form Y_{BUS} using bus incidence matrix. The impedance data for the network is given in table.

Element No.	Self		Mutual	
	Bus Code p-q	Impedance $Z_{Pq,pq}$	Bus Code r-s	Impedance $Z_{Pq,rs}$
1.	1-2(1)	0.6		
2.	1-3	0.5	1-2(1)	0.1
3.	3-4	0.5		
4.	1-2(2)	0.4	1-2(1)	0.2
5.	2-4	0.2		

2. Find out the bus admittance matrix of sample power system as shown in fig. Data for this system is given in table.

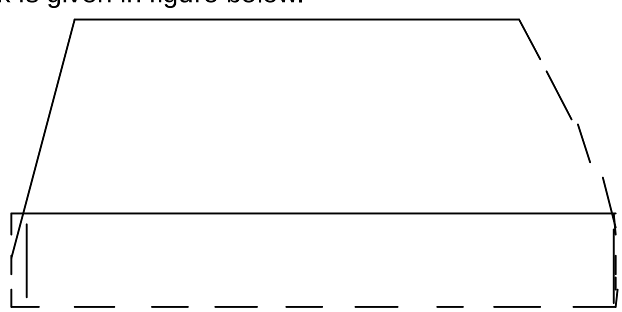


Bus code *i-k*	Impedance Z_{ik}	Line charging $y'_{ij}/2$
1 - 2	0.02+j0.06	j0.03
1 - 3	0.08+j0.24	j0.025
2 - 3	0.06+j0.18	j0.020

3. How modification of the bus impedance matrix is performed for changes in the network?
4. How a change in primitive value is incorporated in the Zbus?
5. Define primitive network.
6. Define incidence matrix.

Course Outcome 3 (CO3)

1. How a change in primitive value is incorporated in the Z_{bus}?
2. (a) For the network shown in figure below, form the incidence matrices K, A and The graph of the network is given in figure below.



   (b) Prove $Y_{BUS} = A^T[Y]A$

3. Analyze with an example system and show that when there is no mutual coupling, the diagonal and off-diagonal elements in the Y_{BUS} matrix can be computed from the formula

$$Y_{ij} = \sum_{j=1}^{n} y_{ij}$$

$$Y_{ij} = -y_{ij}$$

Where y_{ij} represents the Admittance between buses i and j and y_{ii} is the admittance between bus i and ground bus.

Course Outcome 4 (CO4)

1. Derive the equations for adding a coupled branch to a partial network by using building algorithm.
2. The bus Impedance matrix of a 2 bus, 2 element network is given below with node '0' as the reference.

$$Z_{BUS} = \begin{array}{cc} & \begin{array}{cc} \boxed{1} & \boxed{2} \end{array} \\ \begin{array}{c} \boxed{1} \\ \boxed{2} \end{array} & \begin{bmatrix} 0.2 & 0.2 \\ 0.2 & 0.8 \end{bmatrix} \end{array}$$

An element 2-3 is added to the network. The primitive network impedance matrix of the network is

$$Z_{BUS} = \begin{array}{cc} & \begin{array}{ccc} \boxed{0\text{-}1} & \boxed{0\text{-}2} & \boxed{2\text{-}3} \end{array} \\ \begin{array}{c} \boxed{0\text{-}1} \\ \boxed{0\text{-}2} \\ \boxed{2\text{-}3} \end{array} & \begin{bmatrix} 0.2 & 0.0 & 0.0 \\ 0.0 & 0.6 & 0.1 \\ 0.0 & 0.1 & 0.5 \end{bmatrix} \end{array}$$

Compute the new bus admittance matrix.

Course Outcome 5 (CO5)

1. The load flow bus data for the sample power system are given below. The voltage magnitude at bus 2 is to be maintained at 1.04 p.u. The maximum and minimum reactive power limits of the generator at bus 2 are 0.35 and 0.07 p.u respectively. Determine the set of load flow equation at the end of first iteration by using Newton Raphson method.

The schedule of generator and load

Bus code	Generator		Load		V
	Mw	Mvar	Mw	Mvar	
1		-	-	-	1.00
2	0.2	-	-	-	1+j0.0
3	-	-	-	0.25	1+j0.0

The line admittance

Bus code	Admittance
1-2	0.08+j0.24
1-3	0.02+j0.06
2-3	0.6+j1.8

2. How approximations are done in NR methods?
3. Mention the assumptions made in the FDLF method.

Course Outcome 6 (CO6)

1. Signify accelerating factor in load flow studies.
2. Consider the power system with the following data:

$$Y_{BUS} = \begin{bmatrix} -j12 & j8 & j4 \\ j8 & -j12 & j4 \\ j4 & j4 & -j8 \end{bmatrix}$$

Bus No	Type	Generator		Load		Voltage	
		P	Q	P	Q	Magnitude	Phase angle
1	Slack	-	-	-	1.0	1.0	0
2	P-V	5.0	-	0	1.05	1.05	-
3	P-Q	0	0	3.0	-	-	-

Assume that the bus 2 can supply any amount of reactive power. Assuming flat voltage profile perform the first iteration of power flow analysis using Newton Raphson method.

Course Outcome 7 (CO7)

1. One conductor of a three phase line is open. The current flowing to the delta connected load through line A is 10A and line B is 10 $\angle$180 A. Assuming that line C is opened, examine the change in symmetrical components' of currents?
2. What are all the assumptions made in the short circuit studies?
3. Define symmetrical fault on a power system.

Course Outcome 8 (CO8)

1. What is the significance of symmetrical component?
2. How do you determine short circuit KVA in three phase circuits?
3. For the sample system shown in figure below, the following data is given (Tables 1 and 2)

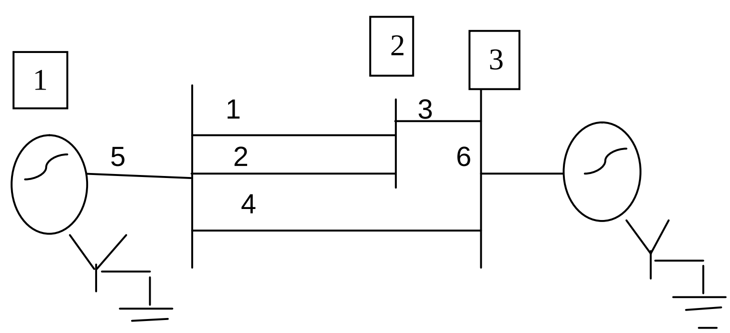


Table.1 Line Reactances

Bus code	Self-impedance			Mutual impedance	
	Positive	Negative	Zero	Zero sequence	Coupling element
1-2(1)	0.05	0.05	0.10	0.05	1-2(2)
1-2(2)	0.05	0.05	0.12	0.05	1-2(1)
2-3	0.06	0.06	0.12	-	-
1-3	0.1	0.1	0.15	-	-

Table.2 Generator Reactances

Generator Number	Impedance		
	Positive	Negative	Zero
1	0.25	0.15	0.04
2	0.20	0.12	0.02

Assume V_0^a =1+j0 for solving the following.

(i) Using symmetrical components, calculate the following for a symmetrical three-phase to ground fault at bus 3.

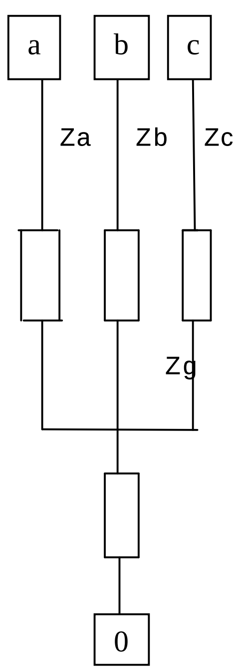
(1) Fault currents
(2) Line currents
(3) Bus voltages during fault.

(ii)Using symmetrical components, calculate the following for a single phase to ground fault at bus 3.

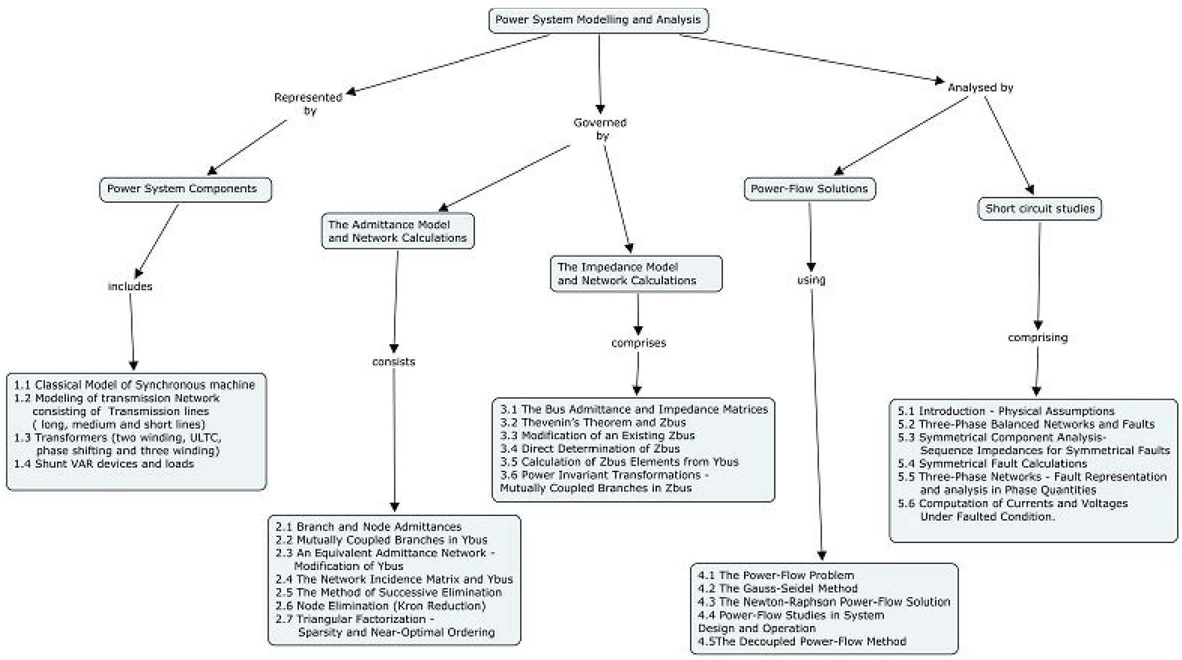
(1) Fault currents
(2) Line currents
(3) Bus voltage during fault.

Course Outcome 9 (CO9)

1. Which type of fault is severe whether symmetrical or unsymmetrical?
2. For the figure shown in below, write the node equations taking node 0 as reference and then eliminate the node connecting y_a, y_b, y_c , to obtain $Y_F^{a,b,c}$.



Concept Map



Syllabus

Power System Components

Classical Model of Synchronous machine – Modeling of transmission Network consisting of Transmission lines (long, medium and short lines) – Transformers (two winding, ULTC, phase shifting and three winding) – Shunt VAR devices and loads.

The Admittance Model and Network Calculations

Branch and Node Admittances - Mutually Coupled Branches in Y_{bus} - An Equivalent Admittance Network - Modification of Y_{bus} - The Network Incidence Matrix and Y_{bus} - The Method of Successive Elimination - Node Elimination (Kron Reduction) - Triangular Factorization - Sparsity and Near-Optimal Ordering.

The Impedance Model and Network Calculations

The Bus Admittance and Impedance Matrices - Thevenin's Theorem and Z_{bus} - Modification of an Existing Z_{bus} - Direct Determination of Z_{bus} - Calculation of Z_{bus} Elements from Y_{bus} - Power Invariant Transformations - Mutually Coupled Branches in Z_{bus}.

Power-Flow Solutions

The Power-flow Problem - The Gauss-Seidel Method - The Newton-Raphson Power-flow Solution - Power-flow Studies in System Design and Operation - The Decoupled Power-flow Method.

Short-Circuit Studies

Introduction - Physical Assumptions - Three-Phase Balanced Networks and Faults - Symmetrical Component Analysis - Sequence Impedances for Symmetrical Faults - Symmetrical Fault Calculations - Three-Phase Networks - Fault Representation and analysis in Phase Quantities -Computation of Currents and Voltages Under Faulted Condition.

Reference Books

1. John J. Grainger and Stevenson Jr. W.D., "Power System Analysis", TATA McGraw Hill International Fourth Edition, 1994

2. M.A.Pai,"Computer techniques in power system analysis", TATA McGraw Hill, Second Edition, 2006.
3. G.W.Stagg & A.H.EL-Abaid "Computer methods in power system analysis", TATA McGraw Hill International student Edition,1987.
4. L.P.Singh, "Advanced power system analysis and dynamics", Wiley Eastern Ltd., Revised fourth edition, 2006.
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8. Venkatesh, P., B.V Manikandan, S. Charles Raja, and A. Srinivasan, "Electrical Power Systems: Analysis, Security and Deregulation", PHI Learning Pvt. Ltd., First Edition, 2012.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Power System Components**	**06**
1.1	Classical Model of Synchronous machine	1
1.2	Modeling of transmission Network consisting of Transmission lines (long, medium and short lines)	2
1.3	Transformers (two winding, ULTC, phase shifting and three winding)	2
1.4	Shunt VAR devices and loads.	1
2.0	**The Admittance Model and Network Calculations**	**10**
2.1	Branch and Node Admittances	1
2.2	Mutually Coupled Branches in Y_{bus}	1
2.3	An Equivalent Admittance Network - Modification of Y_{bus}	3
2.4	The Network Incidence Matrix and Y_{bus}	2
2.5	The Method of Successive Elimination	1
2.6	Node Elimination (Kron Reduction)	1
2.7	Triangular Factorization - Sparsity and Near-Optimal Ordering	1
3.0	**The Impedance Model and Network Calculations**	**10**
3.1	The Bus Admittance and Impedance Matrices	2
3.2	Thevenin's Theorem and Z_{bus}	2
3.3	Modification of an Existing Z_{bus}	2
3.4	Direct Determination of Z_{bus}	1
3.5	Calculation of Z_{bus} Elements from Y_{bus}	1
3.6	Power Invariant Transformations - Mutually Coupled Branches in Z_{bus}.	2
4.0	**Power-Flow Solutions**	**08**
4.1	The Power-Flow Problem - The Gauss-Seidel Method	2
4.2	The Newton-Raphson Power-Flow Solution	3
4.3	Power-Flow Studies in System Design and Operation	2
4.4	The Decoupled Power-Flow Method	1
5.0	**Short-Circuit Studies**	**11**
5.1	Introduction - Physical Assumptions	1
5.2	Three-Phase Balanced Networks and Faults	1
5.3	Symmetrical Component Analysis- Sequence Impedances for Symmetrical Faults	2
5.4	Symmetrical Fault Calculations	3

5.5	Three-Phase Networks - Fault Representation and analysis in Phase Quantities	2
5.6	Computation of Currents and Voltages Under Fault Condition.	2
	Total	**45**

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14PS140	DIGITAL PROTECTION FOR POWER SYSTEM	Category	L	T	P	Credit
		PC	3	1	0	4

Preamble

Power system protection and switchgear is a subject which touches our lives every day, in a very non-intrusive manner. Reliable protection of electric energy systems against faults like short circuits is in fact, the cornerstone of power system reliability. In turn, it is one of the important reasons for electricity having been accepted as a cost-effective and efficient medium for transmission of energy (or power) over large distances. The technology of power system protection has evolved a lot since the era of electromechanical and solid-recorded by Current Transformers (CT) and Voltage Transformers (VT), by using digital signal processing techniques. Thus, the requirement of learning this subject has changed significantly over a period of time and in fact, this subject addresses this need in a comprehensive manner.

Prerequisite

- Protection and Switchgear

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Discuss the basic elements of static relays.	Understand
CO2	Explain the principles of amplitude and phase comparators.	Understand
CO3	Discuss the principles of time-over current relays.	Understand
CO4	Discuss the different types of faults and protection schemes of synchronous generators.	Understand
CO5	Explain the different types of faults and protective schemes of transformers.	Understand
CO6	Discuss the different types of protective schemes for transmission lines.	Understand
CO7	Discuss the basic components of a digital relay.	Understand
CO8	Realization of different digital relay characteristics using microprocessor	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	M									
CO2.	S	M									
CO3.	S		S						S		
CO4.	S		M								
CO5.	S		S								
CO6	S		M								
CO7	S										
CO8	S			M					M	S	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	20	20
Apply	20	20	30	30
Analyse	20	20	30	30
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the construction and operation of a static relay with a neat block diagram.
2. Describe the function of practical non-critical switching circuits and critical level detectors used in power system protection.
3. Define 'pick-up and reset level' of relay.

Course Outcome 2 (CO2):

1. Describe the basic operating principle of a vector-product device.
2. Explain the duality between phase and amplitude comparators.
3. Exhibit the cross-connection of two hall element devices with its purpose.

Course Outcome 3(CO3)

1. Define relay coordination.
2. Describe the operating principle and characteristics of various types of over current relays. Also, mention their applications.
3. With a block diagram, discuss how an intentional time delay is introduced in definite time OC relays?

Course Outcome 4(CO4)

1. Explain why the first ground fault on the rotor does not cause any damage while a second part can be catastrophic.
2. List the various types of faults and protection scemes against them in synchronous generators.
3. Explain why conventional differential protection cannot detect interturn faults on the same phase.

Course Outcome 5(CO5)

1. Discuss the applications of Buchholz relay.
2. A three phase power transformer having a line voltage ratio of 400V to 33kV is connected in star-delta. The CT.s on 400V side has current ratios 1000/5. What must be the CT ratio on 33kV side?
3. With a neat sketch, analyse the differential protection scheme for the protection of power transformers.

Course Outcome 6(CO6)

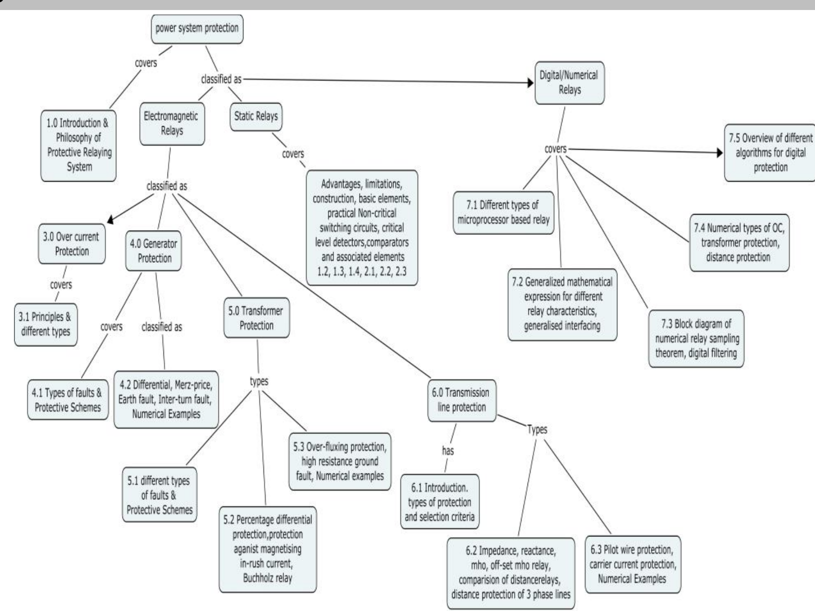
1. Discuss the principles of reactance relay
2. Explain the concept of carrier-aided distance protection schemes.

3. Explain why distance protection schemes are preferred than over current protection for the transmission lines.

Course Outcome 7(CO7)
1. State and explain Shannon's sampling theorem.
2. With the help of block diagram, discuss the operation of the numerical relay.
3. Explain the role of signal conditioner in a data acquisition system. Discuss the functions of various components of the signal conditioner.

Course Outcome 8(CO8)
1. Describe the theory and operating principle of a microprocessor based overcurrent relay.
2. Describe the realisation of a directional impedance relay using a microprocessor.
3. Derive a generalized mathematical expression of distance relays for numerical protection.

Concept Map



Syllabus

Introduction and Philosophy of a Protective Relaying System

Characteristic functions of protective relays- basic relay terminology

Introduction to Static Relays

Advantages of static relays over Electromagnetic Relays– Limitations, Basic construction and Basic elements of static relays - Practical non-critical switching circuits and critical level detectors-Influence of protective relays on associated equipment.

Comparators and Associated elements

Mixing transformers/circuits-Phase and amplitude comparators - Duality-Different types of comparators-Amplitude, Phase comparators, Vector product devices–Dynamic design of static Comparators.

Over current Protection

Introduction to over current relays – Basic principles and different types of time-over current relays - Practical circuits for time over current relays - Direct trip devices-Introduction to Relay Co-ordination- Co-ordination of over current relays in an Interconnected power system.

Generator Protection

Different types of faults and different types of Protective schemes in Synchronous generators – Generator differential protection, Merz-Price protection, Stator earth fault protection, Stator inter-turn fault protection, Rotor earth fault protection, numerical examples for typical generator protection schemes.

Transformer Protection

Different types of faults and different types of Protective schemes in transformers Percentage differential protection, Protection against magnetizing in-rush current, incipient fault protection (Buchholz relay), Over-fluxing protection, High resistance ground fault in transformers numerical examples for typical transformers protection schemes.

Transmission Line Protection

Types of line protection and selection criteria, Introduction to distance protection, Impedance relay, reactance relay, mho(admittance) relay, off-set mho relay, comparison of distance relays, Distance protection of three phase lines, Reasons for inaccuracy of distance relay reach – Three stepped distance protection – Pilot wire protection carrier current protection, numerical example for a typical distance protection scheme for a transmission line.

Digital/ Numerical Protection

Introduction to Digital protective relays - over current relay, impedance relay, Generalized mathematical expression for distance relays - mho relay, off-set mho, Quadrilateral relay characteristic realization, generalized interfacing for distance relays.

Block diagram of numerical relay, Sampling theorem, correlation with a reference wave, digital filtering, numerical over current protection, numerical transformer differential protection, numerical distance protection of transmission lines, Introduction to Fast Fourier Transform (FFT) and Discrete Wavelet Transform (DWT) to digital protection Overview of different algorithms for digital protection

Reference Books

1. Y.G. Paithankar and S.R Bhide, “Fundamentals of Power System Protection”, Prentice-Hall of India, 2003.
2. T.S. Madhava Rao, “Power System Protection- static relays with Microprocessor applications”, II Edition, TMH, 1989.
3. Sunil S.Rao, “Protection and switchgear”, Khanna Publishers-IV th Edition.
4. T.S. Madhava Rao, “Digital/Numerical Relays”, Tata McGraw- Hill Publishing Company, 2005.
5. Badri Ram and D.N. Vishwakarma, “Power System Protection and Switchgear”, Tata McGraw- Hill Publishing Company, 2002.
6. P.Kundur, “Power System Stability and Control”, McGraw-Hill, 1993.

7. L.P.Singh, “Digital Protection –Protective Relaying from Electromechanical to microprocessor”, New Age International (P) Limited Publishers – 2nd Edition, 1997.
8. A.T.Johns & S.K.Salman “Digital Protection for power systems”, IEE Power Engg. Series 15, 1995.
9. Batra, Basu and Chowdry, “Power System Protection”, Oxford and IPH Publishing Company.
10. Oza, Nair, Mehta and Makwana, “Power System Protection and Switchgear”, Tata McGraw- Hill.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	Introduction and Philosophy of Protective Relaying System	
1.1	Characteristic functions of protective relays- basic relay terminology	2
1.2	Introduction to Static Relays**,** Advantages of static relays over Electromagnetic Relays, Limitations of static relays	1
1.3	Basic construction and Basic elements of static relays	1
1.4	Practical non-critical switching circuits, critical level detectors, Influence of static protective relays on associated equipment	2
2.0	**Comparators and Associated elements**	
2.1	Mixing transformers/circuits, Phase & amplitude comparators, Duality	2
2.2	Different types of comparators-Amplitude, Phase comparators, Vector product devices	2
2.3	Dynamic design of static Comparators	1
3.0	**Over current Protection**	
3.1	Introduction to over current relays – Basic principles and different types of time-over current relays	2
3.2	Practical circuits for time-over current relays, Direct trip devices	2
3.3	Introduction to Relay Co-ordination, Co-ordination of over current relays in an Interconnected power system.	2
4.0	**Generator Protection**	
4.1	Different types of faults and different types of Protective schemes used for Synchronous generators	2
4.2	Generator differential protection, Merz-Price protection, Stator earth fault protection, Stator inter-turn fault protection, Rotor earth fault protection. Numerical examples for typical generator protection schemes.	3
5.0	**Transformer Protection**	
5.1	Different types of faults and different types of Protective schemes in transformers	2
5.2	Percentage differential protection, Protection against magnetizing in-rush current, incipient fault protection (Buchholz relay)	2
5.3	Over-fluxing protection, High resistance ground fault in transformers. Numerical examples for typical transformers protection schemes.	2
6.0	**Transmission Line Protection**	
6.1	Types of line protection and selection criteria, Introduction to distance protection	1
6.2	Impedance, reactance, mho(admittance), off-set mho relay, comparison of distance relays, Distance protection of three phase lines	2
6.3	Reasons for inaccuracy of distance relay reach – Three stepped distance protection –Pilot wire and carrier current protection, numerical example for a typical distance protection scheme for a transmission	3

	line.	
7.0	**Digital / Numerical Protection**	
7.1	Introduction to Digital protective relays - over current relay, impedance relay	2
7.2	Generalized mathematical expression for distance relays - mho relay, off-set mho, Quadrilateral relay characteristics realization, generalized interfacing for distance relays.	3
7.3	Block diagram of numerical relay, Sampling theorem, correlation with a reference wave, digital filtering	2
7.4	Numerical over current protection, numerical transformer differential protection, numerical distance protection of transmission lines, Introduction to Fast Fourier Transform(FFT) and Discrete Wavelet Transform(DWT) to digital protection	3
7.5	Overview of different algorithms for digital protection	1
	Total	**45**

Course Designers:

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14PS150	POWER SYSTEM DYNAMICS AND STABILITY	Category	L	T	P	Credit
		PC	3	1	0	4

Preamble

The aim of the subject is to develop an understanding of the basic concepts of synchronous machine, power system dynamics, excitation system, transient stability, small signal stability and power system stabilizer. Apply this knowledge to develop modelling of major power system components.

Prerequisite

- Power System Modeling and Analysis

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Model the power system components in stability studies.	Understand
CO2.	Explain the concept of Park's transformation and synchronous machine equations.	Understand
CO3.	Describe the concept of transient, steady state and dynamic stability.	Understand
CO4.	Analyze the stability of power system by point-by point method, Modified Euler's and Runge – Kutta method.	Analyze
CO5.	Determine the critical clearing angle and clearing time for power system using equal area criterion.	Apply
CO6.	Carry out a small signal stability analysis of a multi machine power system.	Understand
CO7.	Carry out dynamic performance measures of an excitation system.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S							S	M		
CO2.	S							S	M		
CO3.	S	S	S					S	M		
CO4.	S	S	S	L	M			S	M		
CO5.	S	S	S					S	M		
CO6.	S	S						S	M		
CO7.	S	S						S	M		

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	05	05	05	10
Understand	10	10	10	20
Apply	20	20	20	40
Analyse	15	15	15	30
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. How the following Power system components are modelled in stability studies?
   a) Synchronous machine b) Induction machine c)Loads
2. Draw the T and the π model of medium transmission line and obtain the expressions for sending end and receiving end voltages and currents in terms of line parameters.
3. Discuss the modelling of Tap-changing and Phase shifting transformer.

Course Outcome 2 (CO2):

1. Obtain the equation of Synchronous machine in physical quantities.
2. Develop the final machine dynamic equation of a synchronous machine.
3. Discuss in detail the Park's transformations applicable to synchronous machines.

Course Outcome 3 (CO3)

1. Distinguish between transient, steady-state and dynamic stability of a power system. For a given power system which of the stability limit is higher and why?
2. How can the transient stability of a system be improved? Discuss the traditional as well as new approaches to the problem.
3. A 50Hz generator of reactance 1 p.u is connected to an infinite bus through a line of reactance 0.5p.u. E = 1.1p.u and V = 1p.u. The inertia constant is 5 MW-sec/MVA. The generator is loaded to 50% of the maximum power limit. Find the frequency of natural oscillations.

Course Outcome 4 (CO4)

1. A synchronous generator feeding power to an infinite bus through a double circuit transmission line. A balanced three phase fault occurs at middle point of line. The per unit values of different quantities are: E = 1.05, V = 1, transient reactance of synchronous machine = 0.1, each line reactance = 0.4, H =2.7 MJ/MVA. Generator rating is 50MVA and supplying 50MW power to the infinite bus at the time of fault. Plot the swing curve for a sustained fault up to a time of 0.5sec by step-by-step method2.
2. Develop an algorithm and draw a flowchart for the solution of swing equation by modified Euler's method.
3. Give the necessary equations for solving the swing equations by Runge – Kutta fourth order method for a simple two - machine system.

Course Outcome 5 (CO5)

1. A large cylindrical rotor generator is delivering 1p.u power to an infinite bus through a transmission network. The maximum power which can be transfer for a pre-fault, during fault and post-fault conditions are 1.8, 0.4 and 1.3p.u respectively. Find the critical clearing angle.
2. A synchronous motor of a negligible resistance is receiving 25% of power that it is capable of receiving from an infinite bus. If the load on the motor is suddenly doubled, calculate the maximum value of power angle during the swinging of the motor around its new equilibrium position.
3. A 50Hz generator is supplying 40% of the power that it is capable of delivering through a transmission line to infinite bus. A fault occurs that increases the reactance between the generator and the infinite bus to 600% of the value before the fault. When the fault is isolated the maximum power that can be delivered is 80% of the original maximum value. Determine the critical clearing angle.

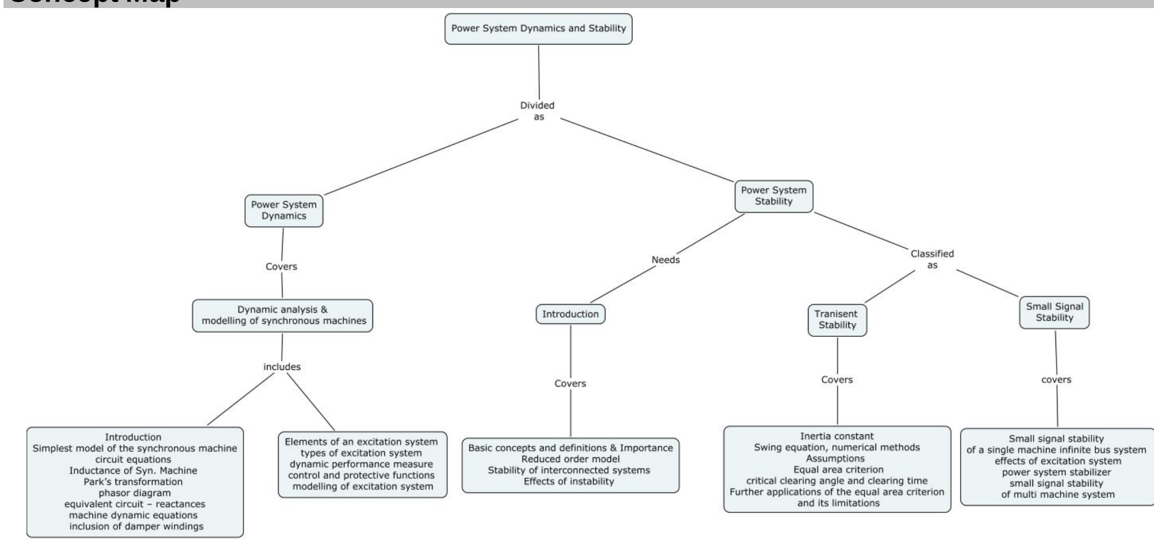
Course Outcome 6 (CO6)

1. Discuss in detail the small-signal stability of a SMIB system.
2. Explain the effect of the excitation system on the small signal stability performance of single machine infinite bus system.
3. Draw the block diagram of a power system stabilizer and explain its working.

Course Outcome 7 (CO7)

1. Draw the brushless excitation system and explain its working.
2. Draw the block diagram of the excitation system with control and protective circuits and explain its major components.
3. Draw the block diagram of an excitation system and derive the transfer function of each block. How stability compensation provided in it.

Concept Map



Syllabus

Dynamic analysis and modelling of synchronous machines

Simplest model of the synchronous machine – circuit equations – equation in physical quantities - Inductance of Synchronous Machine - Park's transformation to dq0 components – assumptions of balanced currents and voltages in the armature – phasor diagram – equivalent circuit – reactances – final machine dynamic equations – inclusion of damper windings

Excitation systems

Elements of an excitation system – types of excitation system – dynamic performance measure – control and protective functions – modelling of excitation system

Introduction to power system stability

Basic concepts and definitions – classification of stability –blackouts around the world – blackouts events - need for reduced order model - Stability of interconnected systems – Bad effects of instability – Importance of stability to system operation and design – Method of improving stability limits

Transient stability

Inertia constant and equivalent inertia constant –Power angle curve – Swing equation – Point by point solution, numerical methods (Modified Euler's method and Runke-Kutta 4th order method – Assumptions made in stability studies- Equal area criterion to test the transient stability of simple power systems – Calculation of critical clearing angle and clearing time – Further applications of the equal area criterion and its limitations

Small signal stability
Small signal stability of a single machine infinite bus system – effects of excitation system – power system stabilizer – small signal stability of multi machine system.

Reference Books

1. L.P.Singh, Advanced Power system Analysis and Dynamics, New Age International Publishers, 2007
2. Prabha Kundur, Power System Stability and Control, Tata McGraw Hill, 2006.
3. B.R.Gupta, Power System Analysis and Design, S.Chand, 2008.
4. P.W.Sauer and M.A.Pai, Power System Dynamics and Stability, Pearson Education, 2007
5. E.W.Kimbark, Power System Stability Vol.1, John Wiley, 1995.

Course Contents and Lecture Schedule

Module No.	Topic	No. of lecture hours
1.0 Dynamic analysis and Modelling of synchronous machines		
1.1	Introduction - Dynamic analysis and Modelling of synchronous machines - Simplest model of the synchronous machine	2
1.2	Circuit equations – Equation in physical quantities - Inductance of Synchronous Machine	2
1.3	Park's transformation to dq0 components – Assumptions of balanced currents and voltages in the armature – Phasor diagram	2
1.4	Equivalent circuit – Reactances – Final machine dynamic equations – Inclusion of damper windings	2
2.0 Excitation systems		
2.1	Elements of an excitation system – types of excitation system	2
2.2	Dynamic performance measure – control and protective functions	2
2.3	Modelling of excitation system	3
3.0 Introduction to power system stability		
3.1	Basic concepts and definitions – classification of stability – Blackouts causes - events	2
3.2	Need for reduced order model - Stability of interconnected systems	3
3.3	Bad effects of instability – Importance of stability to system operation and design	3
3.4	Method of improving stability limits	2
4.0 Transient stability		
4.1	Inertia constant and equivalent inertia constant –Power angle curve	2
4.2	Swing equation – Point by point solution, numerical methods (Modified Euler's method and Runke Kutta IV order method	3
4.3	– Assumptions made in stability studies- Equal area criterion to test the transient stability of simple power systems	3
4.4	Calculation of critical clearing angle and clearing time – Further applications of the equal area criterion and its limitations	2
5.0 Small signal stability		
5.1	Small signal stability of a single machine infinite bus system	3
5.2	Effects of excitation system	2
5.3	Power System Stabilizer	3

5.4	Small Signal Stability of Multi Machine System	2
	Total	**45**

Course Designers:

1. Dr.V.Ramanathan vreee@tce.edu
2. Dr.S.Latha sleee@tce.edu

14PS160	POWER CONVERTERS FOR DISTRIBUTED GENERATION SYSTEMS	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Application of power electronic converters play a major role in renewable energy system such as wind power, solar power, fuel cell plants, high speed micro turbine generator etc. Different types of advanced power converters derived from basic ac-ac, dc-dc, ac-dc, and dc-ac converters are analyzed with respect to those applications. The converters used for the control of smart grid distributed generation systems are also analyzed.

Prerequisite

- Power Electronics

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain HVDC transmission system and the power converters used in it.	Understand
CO2.	Explain the power converters used for solar energy conversion.	Understand
CO3.	Select rating of different components used in solar energy conversion for the given specifications.	Apply
CO4.	Explain the power converters used for wind energy conversion.	Understand
CO5.	Illustrate the applications of power converters in smart grid.	Understand
CO6.	Explain the harmonics generated by the power converters and their mitigation.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	M	M	S	L			M	M	M	
CO2.	S	M	M	S	L			M	M	M	
CO3.	S	M	M	S				M	M	M	
CO4.	S	M		S		M		M	M	M	
CO5.	S	M		S		M		M	M	M	
CO6.	S	M	M	S	L	M		M	M	M	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What is meant by breakeven distance?. Write its value for HVDC transmission through overhead lines and cable.
2. With neat diagrams, explain the different types of HVDC systems.
3. Compare Current Source Converter and Voltage Source Converter.
4. The maximum value of phase voltage applied to a 3-phase current source converter (CSC) in a HVDC system is 60.43 kV. The value of leakage reactance per phase of the transformer feeding the CSC is 5 mH and the overlap angle is 50. Calculate the output dc current and output dc voltage of the converter if the firing angle is 200 and system frequency is 50 Hz.
5. Deduce the expression for dc current flow in a HVDC system using the equivalent circuit of rectifier and inverter.

Course Out come 2 (CO2):

1. Draw the block diagram of solar energy conversion system.
2. List the different schemes for PV energy conversion.
3. In a buck boost converter operating at 20KHz, L=0.05 mH. The output capacitor C is sufficiently large and V_d=158V.The output is to be regulated at 10V and the converter is supplying a load of 10W.Calculate the duty ratio D.
4. Explain the principle of operation of boost converters.

Course Outcome 3(CO3)

1. Categorize the power converters for solar energy conversion.
2. Describe the parameters to be considered for the selection of inverters.
3. Differentiate the DC and AC power conditioners.

Course Outcome 4(CO4)

1. Illustrate the construction and principle of operation of a diode clamped multilevel inverter with necessary diagram and waveform.
2. Demonstrate the working principle of a three phase to three phase matrix converter with necessary diagram and also show the different type of switches that can be used in matrix converter.
3. Explain the working principle of constant speed wind power generating system with neat sketch.

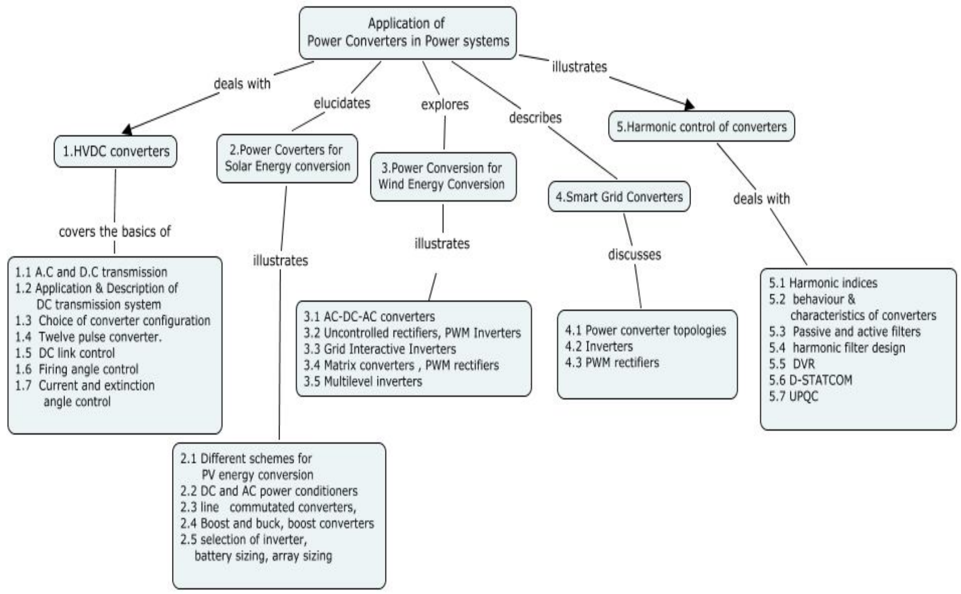
Course Outcome 5(CO5)

1. Draw the circuit of series active filter and analyze its operation in detail.
2. Explain the role of different power converters in smart grid.
3. Analyze the operation of PWM voltage source rectifier with neat circuit and waveform.

Course Outcome 6(CO6)

1. With neat diagram, explain the operation of D-STATCOM.
2. Illustrate the construction and principle of operation of UPQC in detail with necessary diagram
3. Define voltage THD and displacement power factor.
4. Illustrate the working principle of shunt active filter with neat sketch.

Concept Map



Syllabus

HVDC CONVERTERS

Introduction - Comparison of AC and DC transmission – Application & Description of DC transmission system - Choice of converter configuration – Converter bridge characteristics – Characteristics of a twelve pulse converter.

General principles of DC link control – Converter control characteristics – System control hierarchy - Firing angle control – Current and extinction angle control – Power control.

POWER CONVERTERS FOR SOLAR ENERGY CONVERSION

Basic components – Different schemes for PV energy conversion – DC and AC power conditioners – Principle of operation: line commutated converters (inversion mode) - Boost and buck-boost converters- selection of inverter, battery sizing, array sizing.

POWER CONVERTERS FOR WIND ENERGY CONVERSION

Basic components - AC-DC-AC converters - Uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters - Matrix converters – PWM rectifiers – Multilevel inverters.

SMART GRID CONVERTERS

Power converter topologies for smart grid Distributed Generation systems - Inverters & PWM rectifiers for smart grid Distributed Generation systems.

HARMONIC CONTROL OF CONVERTERS

Harmonic indices - Harmonic behaviour & characteristics of HVDC converters, Solar and Wind converters - Devices for controlling harmonics - Passive and active filters - Harmonic filter design - Custom power devices- D-STATCOM & UPQC.

Reference Books

1. K.R.Padiyar, HVDC Power Transmission Systems, New Age International (P) Ltd., New Delhi, 2002.
2. Ned Mohan, Tore Undeland & William Robbins, Power Electronics: Converters Applications and Design-John Willey and sons 2003.
3. D.Grahame Holmes & Thomas Lipo, Pulse width modulation for power converters, Wiley-Interscience, 2003.
4. Ali Keyhani, M.N.Marwali & Min Dai, Integration of green and renewable energy in electrical power systems, Wiley and sons, 2010.
5. Felix A.Farret & M.G.Simoes, Integration of alternative sources of energy, Wiley-IEEE press, 2007.

6. S.Choudhury, SP.Choudhury & P.Crossley, Micro grids and active distribution networks, IET publications, 2009.
7. Arindam Ghosh & Gerald Ledwich, Power quality enhancement using custom power devices, Kluwer Academic Publishers, 2002.
8. G.T.Heydt, Electric Power Quality, Stars in Circle Publications, 1994.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.	**HVDC Converters**	
1.1	AC and DC transmission	1
1.2	Application & Description of DC transmission system	1
1.3	Choice of converter configuration	1
1.4	Converter bridge characteristics – Characteristics of a twelve pulse converter	1
1.5	General principles of DC link control – Converter control characteristics	2
1.6	Firing angle control & Power control	1
1.7	Current and extinction angle control	1
2.	**Power converters for solar energy conversion**	
2.1	Basic components – Different schemes for PV energy conversion	2
2.2	DC and AC power conditioners	2
2.3	Line commutated converters	1
2.4	Boost and buck-boost converters	2
2.5	Selection of inverter, battery sizing, array sizing	1
3.	**Power converters for wind energy conversion**	
3.1	AC-DC-AC converters	2
3.2	Uncontrolled rectifiers, PWM Inverters	2
3.3	Grid Interactive Inverters	3
3.4	Matrix converters – PWM rectifiers	3
3.5	Multilevel inverters	2
4.	**Smart grid converters**	
4.1	Power converter topologies for smart grid Distributed Generation systems	3
4.2	Inverters	2
4.3	PWM rectifiers	2
5.	**Harmonic control of converters**	
5.1	Harmonic indices	1
5.2	Harmonic behaviour & characteristics of HVDC converters, Solar and Wind converters	3
5.3	Passive and active filters	2
5.4	Harmonic filter design	2
5.5	D-STATCOM	1
5.6	UPQC	1
	Total	**45**

Course Designers:

1. Dr.M.Saravanan mseee@tce.edu
2. Dr.V.Suresh Kumar vskeee@tce.edu

14PS170	POWER SYSTEM LABORATORY - I	Category	L	T	P	Credit
		PC	0	0	1	1

Preamble

The aim of this lab course is to train the Postgraduate students in solving and analyzing the power system problems using various software packages.

Prerequisite

Power System modeling and analysis

Power System Dynamics and Stability

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Solve power system problems using MATLAB.	Analyse
CO2.	Perform simulation studies using software packages.	Analyse

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.			S	S							
CO2.			S	S							

S- Strong; M-Medium; L-Low

Syllabus

Matlab Program

1. Determination of Bus admittance matrix.
2. Solution to non linear equations using Gauss-Seidal and Newton Raphson method.
3. Power flow solution using Gauss-Seidal / Newton Raphson method.
4. Load forecasting.
5. Economic load dispatch.
6. Short term Hydro Thermal scheduling by lambda-gamma iteration.

Matlab Simulink

7. Load frequency control.
8. Analysis of source current harmonics of single phase semi converter for different loads.
9. Simulation of Static VAR Compensator.
10. Design of filters using MATLAB DSP blockset.
11. Swing equation.

Study / Demo

12. Power system software packages - Power World Simulator / ETAP.

Course Designers:

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2.	Dr.S.Charles Raja	charlesrajas@tce.edu

14PS210	POWER SYSTEMS SECURITY	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Analytical frame work is needed and is used to control the bulk power systems in such a fashion to improve power system security. Power system practices try to control and operate power systems in a defensive posture so that the effects of these inevitable failures are minimized. In any energy management/ operations control centre, knowledge of security analysis, state estimation and optimal power flow is essential.

Prerequisite

- 14PS120 Power system modelling and analysis

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Assess the security level status of the large power system, if n-1 contingency takes place in the system	Understand
CO2.	Analyse the large power system in terms of real power performance index (PI) or other PIs	Analyse
CO3.	Estimate the state of the power system in terms of its measured values	Apply
CO4.	Identify the bad data in the measurement set, if present	Apply
CO5.	Optimise the power flow in terms of real and reactive power with the possible various objectives and constraints involved in energy management system	Apply
CO6.	Use appropriate OPF technique depending on the formulation of optimisation which involves non-linear objective and constraints	Analyse

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
1.	S		M	L							
2.	S	S	S	S	M						
3.	S		S	M	M						
4.	S		S	M	M						
5.	S		S	M							
6.	S		S	M							

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	40	40	40	40
Analyse	20	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the four operating states such as optimal dispatch, post contingency, secure dispatch and secure post-contingency with a suitable example?
2. Explain the three major functions of system security carried out in an operations control center?
3. The line reactance of the test system is X_{12}=0.2.p.u,X_{13}=0.4.p.u, X_{23}=0.25.p.u.Calculate the sensitivity matrix and obtain the base case DC power flow of the test system shown below. Suppose the outage of the generator at bus 3 takes place then obtain the post outage flow of the line 1-2 using generation shift sensitivity factor.
4. For a given system data calculate line outage sensitivity factors for outages on line 1-2 and 2-3

Line data

Line	Reactance(p.u)
1-2	0.2
1-4	0.25
2-3	0.15
2-4	0.30
3-4	0.40

Bus Data

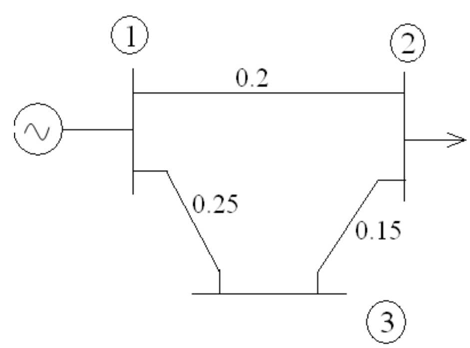
Bus	Load (MW)	Generation (MW)
1(slack)		150
2	--	350
3	220	--
4	280	--

Course Outcome 2 (CO2):

1. Explain the bounding algorithm in the contingency analysis with suitable examples
2. Discuss in detail about the factors affecting power system security?
3. Using flow chart explain the AC power flow security analysis with contingency Case selection?
4. Discuss the contingency ranking procedure using simple example and a flow chart?

Course Outcome 3 (CO3):

1. Explain the solutions procedure for state estimation using weighted least square method with a suitable example
2. Explain the method of least square in the state estimation problem with suitable example?
3. A sample power system is shown in figure below: Power injected at Bus 1 is 1.2p.u ; Power flow in the line1-2,P_{12} is 1.0pu; Load at Bus 2 is 1.2p.u ; Power flow in the 3-2 is P_{32} is 0.1pu. The weightage for the above measurements are 1.0, 0.9, 0.95 and 0.2 respectively. By applying DC load flow approximation, estimate the state of the system. Use Weighted least square method. Line Reactance is marked on the figure in p.u.



Course Outcome 4 (CO4):

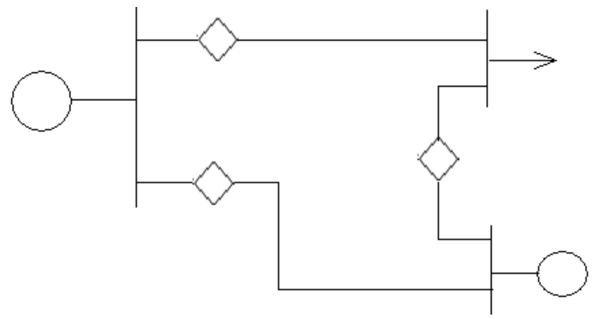
1. What is the importance of bad measurements and describe how detection and identification of bad measurements are done in state estimation?

2. Three meters are installed on the three bus system of figure 1 to measure line real power flows there

X_{12}=0.2.p.u ;M_{12}=0.6.p.u
X_{13}=0.4.p.u ;M_{13}=0.4p.u
X_{23}=0.25.p.u;M_{32}=0.405p.u

And the variances are same σ=0.01p.u

3. Compare the weighted least square estimates of the phase angles with bus3 as the reference



Using the chi square test for α=0.01, identify the bad measurement if present use the following table

K \ α=0.01	
1	6.64
2	9.21
3	11.35
4	13.28

4. The measurement set and system model matrix is given

[9.01A,3.02A,6.98V,4.40V] $\begin{bmatrix} 0.625 & -0.125 \\ -0.125 & 0.625 \\ 0.625 & 0.125 \\ 0.125 & 0.375 \end{bmatrix}$

Let us assign the measurement weights w_1=100 w_2=100, w_3=50 and w_4=50 respectively.

a) Compute the weighted least square estimates of state variables

b) Compute the chi-square test for α=0.01, identify the bad measurement if present?

Course Outcome 5 (CO5):

5. Solve the given problem upto first iteration using Lagrange multiplier method Assuming all the starting point variables are one.

Minimize f=0.25 $X_1^2 + X_2^2$
Subject to 5- X_1- X_3=0
X_1+0.2X_2 -3 <=0

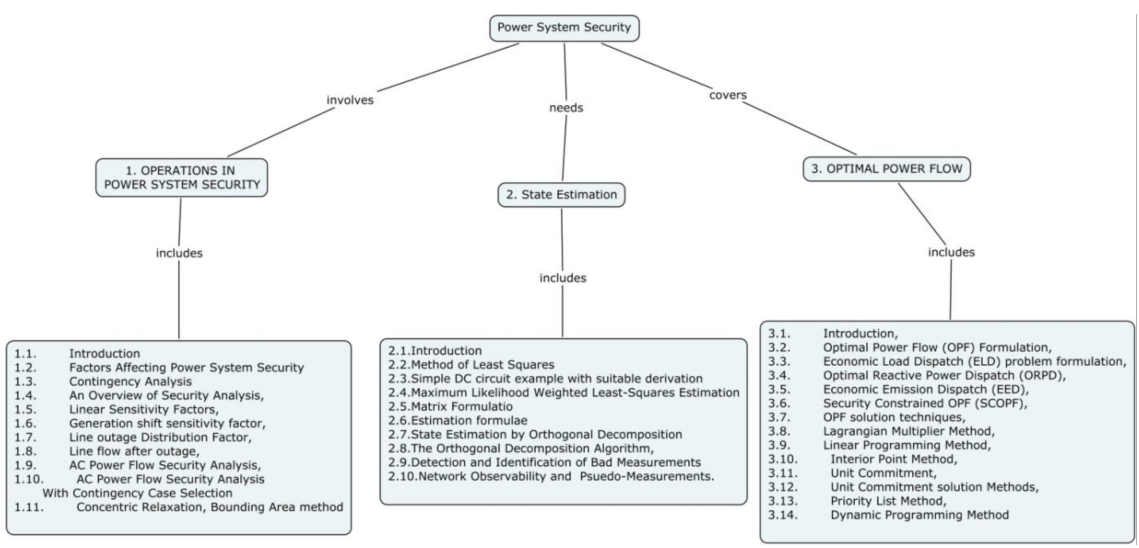
6. Determine X1 and X2 to minimize the function

f=0.25 $X_1^2 + X_2^2$
Subject to the constraints
5- X_1- X_3=0
X_1+0.2X_2 -3 <=0 using Lagrange multiplier method for one iteration.

Course Outcome 6 (CO6):

1. Solve the given problem upto first iteration using Lagrange multiplier method Assuming all the starting point variables are one.
   Minimize $f=0.25\ X_1^2 + X_2^2$
   Subject to $5- X_1- X_3=0$
   $X_1+0.2X_2 -3 <=0$
2. Determine X1 and X2 to minimize the function
   $f=0.25\ X_1^2 + X_2^2$
   Subject to the constraints
   $5- X_1- X_3=0$
   $X_1+0.2X_2 -3 <=0$ using Lagrange multiplier method for one iteration.
3. Solve the given problem upto first iteration using interior point method
   Maximize $Z= X_1+2X_2$
   Subject to $X_1+ X_2 + X_3 <=8$
   Assume initial starting point [1,1,2]
   $\alpha=0.7$ $\varepsilon=0.1$, $\gamma=1$
4. Explain any one method to solve nonlinear OPF problem
5. Formulate the LPOPF problem for the data given below
   Unit 1:$F(P)=600+6P+0.002P^2$
   $70<=P_1<=250$MW
   Unit 2: $F(P)=220+7.3P+0.003P^2$
   $55<=P_2<=135$MW
   Unit 3: $F(P)=100+8P+0.004P^2$
   $70<=P_3<=160$MW
   Three straight line segments with break points as below:
   Unit 1: Break points at 70,130,180,250MW
   Unit 2: Break points at 55,76,95,135 MW
   Unit 3: Break points at 70,80,120,160 MW

Concept Map



Syllabus

OPERATIONS IN POWER SYSTEM SECURITY: Introduction, Factors Affecting Power System Security, Contingency Analysis, An Overview of Security Analysis, Linear Sensitivity Factors, Generation shift sensitivity factor, Line outage Distribution Factor, Line flow after outage, AC Power Flow Security Analysis, AC Power Flow Security Analysis With Contingency Case Selection, Concentric Relaxation, Bounding Area method.

STATE ESTIMATION: Introduction, Method of Least Squares, Simple DC circuit example with suitable derivation, Maximum Likelihood Weighted Least-Squares Estimation, Matrix Formulation, Estimation formulae, State Estimation by Orthogonal Decomposition, The Orthogonal Decomposition Algorithm, Detection and Identification of Bad Measurements, Network Observability and Psuedo-Measurements.

OPTIMAL POWER FLOW: Introduction, Optimal Power Flow (OPF) Formulation, Economic Load Dispatch (ELD) problem formulation, Optimal Reactive Power Dispatch (ORPD), Economic Emission Dispatch (EED), Security Constrained OPF (SCOPF), OPF solution techniques, Lagrangian Multiplier Method, Linear Programming Method, Interior Point Method.

Reference Books

1. A.J.Wood and B.F. Wollenberg., Power generation, operation and control, John Wiley and sons, 1996.
2. John J. Graignaer and William D. Stevenson, Power system analysis, Tata Mc Graw Hill, 2003.
3. P.Venkatesh, B.V.Manikandan, S.Charles raja and A.Srinivasan, “Electrical power systems analysis, Security and Deregulation”, PHI 2012.

Course Contents and Lecture Schedule

Module No.	Topics	No. of Lecture hours
	OPERATIONS IN POWER SYSTEM SECURITY	
1.1.	Introduction	1
1.2.	Factors Affecting Power System Security	1
1.3.	Contingency Analysis	2
1.4.	An Overview of Security Analysis	1
1.5.	Linear Sensitivity Factors	1
1.6.	Generation shift sensitivity factor	1
1.7.	Line outage Distribution Factor	1
1.8.	Line flow after outage,	1
1.9.	AC Power Flow Security Analysis	2
1.10.	AC Power Flow Security Analysis With Contingency Case Selection	2
1.11.	Concentric Relaxation, Bounding Area method	2
	STATE ESTIMATION	
2.1.	Introduction	1
2.2.	Method of Least Squares	1
2.3.	Simple DC circuit example with suitable derivation	2
2.4.	Maximum Likelihood Weighted Least-Squares Estimation	2
2.5.	Matrix Formulation	1
2.6.	Estimation formulae	1
2.7.	State Estimation by Orthogonal Decomposition	1
2.8.	The Orthogonal Decomposition Algorithm,	1
2.9.	Detection and Identification of Bad Measurements	2
2.10.	Network Observability and Psuedo-Measurements.	2
	OPTIMAL POWER FLOW	
3.1.	Introduction,	1
3.2.	Optimal Power Flow (OPF) Formulation,	2
3.3.	Economic Load Dispatch (ELD) problem formulation	1

3.4.	Optimal Reactive Power Dispatch (ORPD)	1
3.5.	Economic Emission Dispatch (EED)	1
3.6.	Security Constrained OPF (SCOPF)	1
3.7.	OPF solution techniques	1
3.8.	Lagrangian Multiplier Method	1
3.9.	Linear Programming Method	1
3.10.	Interior Point Method	1
	Total	**40**

Course Designer:

1. Dr. P. Venkatesh pveee@tce.edu

14PS220	POWER SYSTEM OPERATION AND CONTROL	Category	L	T	P	Credit
		PC	3	1	0	4

Preamble

Power system operators have the responsibility to ensure equilibrium between load and generation at all time. The dispatch of power must be done economically satisfying frequency and voltage requirement. As constancy of frequency and voltage are important factors in determining the quality of power is vital to the satisfactory performance of power system.

Prerequisite

- Power System Dynamics and Stability
- Power System Modelling and Analysis

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Find the optimum unit commitment for a power system	Apply
CO2.	Calculate the economic load dispatch for a system comprised of *n* thermal plants.	Apply
CO3.	Distinguish between real and reactive power control.	Apply
CO4.	Explain the concept of AGC and analysis of multi-area system.	Apply
CO5.	Describe the various voltage control methods.	Apply
CO6.	Model reactive power compensation devices.	Apply
CO7.	Illustrate various operating states of power system and control actions required to obtain secured operation.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S	S					S	M		
CO2.	S	S	S					S	M		
CO3.	S	S	S					S	M		
CO4.	S	S	S					S	M		
CO5.	S	S	S					S	M		
CO6.	S	S	S					S	M		
CO7.	S	S						S	M		

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	30	30	30	30
Apply	50	50	50	50
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the forward dynamic programming method of solving UC problem.
2. Develop an algorithm and draw the flowchart for the solution of UC problem by Lagrangian-Relaxation method.
3. Construct a priority list for the units given below:

Unit 1 :

Min = 150 MW ; Max = 600 MW

H1 = 510 + 7.2 P_1 + 0.00412 P_1^2 ; MBTu /hr

Unit 2 :

Min = 100 MW ; Max = 400 MW

H2 = 310 + 7.85P_2 + 0.00194P_2^2; MBTu/hr

Unit 3 :

Min = 50 MW ; Max = 200 MW

H3 = 78 + 7.97P_3 + 0.00482P_3^2; MBTu/hr

With fuel costs

Fuel cost 1 = Rs 1.1 / MBTu

Fuel cost 2 = Rs 1.0 / MBTu

Fuel cost 3 = Rs 1.2 / MBTu

Course Outcome 2 (CO2):

1. Develop an iterative algorithm for solving the optimum dispatch equation of an n bus power system taking into account the effects of system losses.
2. A power system consists of two 100 MW units, whose input cost data are represented by the equations

   $F_1 = 0.05P_1^2 + 20\ P_1 + 800$;Rs/hr

   $F_2 = 0.06P_2^2 + 15\ P_2 + 1000$; Rs /hr

   if the total received power P = 150 MW

   (i) What would be the division of load between the units for the most economic operation.

   (ii) Find its savings per hour realized from economic allocation of load between the units in comparison with them sharing the output equally , when the load is 150 MW
3. A system consisting of two generating units, incremented costs are

   $\frac{dF_1}{dP_1}$ = 0.008 P_1 + 8 Rs/MWhr

   $\frac{dF_2}{dP_2}$ = 0.012 P_2 + 9 Rs/MWhr

   The system is operating on economic dispatch with $P_1 = P_2$ = 500 MW and $\frac{\partial P_{loss}}{\partial P_1}$ = 0.2 Find the penalty factor of plant 1.

Course Outcome 3 (CO3):

1. Draw the P.F and Q-V channels of a synchronous generator and explain how voltage and frequency are maintained constant.
2. What are the recent trends in real time control of power system.
3. Explain the operation of speed governing system and develop a linear mathematical model of a speed governing system.

Course Outcome 4 (CO4):

1. Develop state variable model for two area system with the help of a block diagram. State its merits.
2. Two identical 60 MW system generators operate in parallel. The governor settings on the machine are such that they have 4% and 3% droops from no load to full load. Determine (i) the load taken by each machine for a total load of 100 MW (ii) the percentage adjustment in the no load speed to be made by the speeder motor if the machine are to share the load equally
3. The p.f control of a single area system have the following data:

   K_P= 120 Hz /p.u MW ;T_P = 10 sec ; $T_G = T_T$ =0

   R = 2.5 Hz /p.u MW ;K_I= 0.1 ; P_D= 0.1 .u MW

Compute the time error caused by a step disturbance of magnitude given in the data. Prove in particular that the error is reduced by increasing the gain K_I . Express the error in seconds and cycles if the system frequency is 50 HZ.

Course Outcome 5 (CO5):

1. Describe various voltage control methods analytically.
2. The load at the receiving end of a 3 phase over head line is 25 MW ,pf 0.8 lag at a line voltage of 33 KV. A synchronous compensator is situated at the receiving end. Voltage at both ends of the line is maintained at 33KV. Calculate the MVAR rating of the compensator. The line has resistance 5 ohms/phase and inductive reactance 20 ohms/phase
3. Find the off-nominal tap ratio for the transformer fitted at the sending end and receiving end of a transmission system to keep the receiving end voltage equal to the sending end voltage when the load is 100 MVA at 0.8pf lag. Series impedance for the system is (0.05+j 0.25) p.u on the basis of 100 MVA and 132KV.

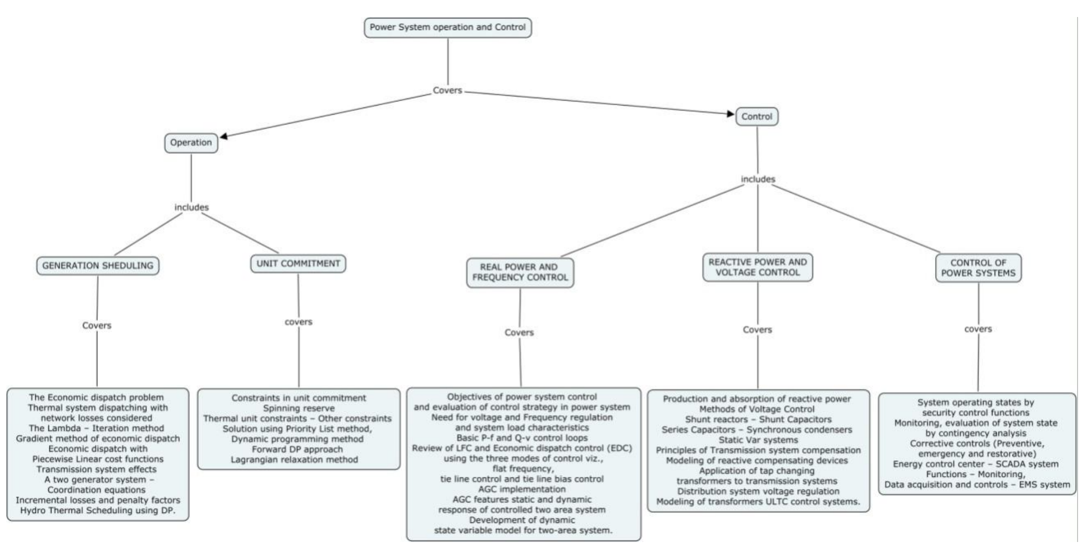
Course Outcome 6 (CO6):

1. What are the different operating states of a power system from security point of view? Explain
2. Draw the block diagram to show the hardware configuration necessary for carrying out SCADA and power system analysis applications in an energy control centre.
3. List the various contingencies that are generally considered for steady state security analysis. Explain the major functions of system security control.

Course Outcome 7 (CO7):

1. Discuss in detail the modelling of reactive power compensating devices in stability studies.
2. With the help of a circuit diagram, explain the working of step voltage regulator(SVR). Also draw SVR control mechanism.
3. Draw the functional block diagram of control system for automatic changing of transformer taps.

Concept Map



Syllabus

GENERATION SHEDULING
The Economic dispatch problem – Thermal system dispatching with network losses considered – The Lambda – Iteration method – Gradient method of economic dispatch – Economic dispatch with Piecewise Linear cost functions – Transmission system effects – A two generator system – Coordination equations – Incremental losses and penalty factors – Hydro Thermal Scheduling using DP.

UNIT COMMITMENT
Constraints in unit commitment – Spinning reserve – Thermal unit constraints – Bank & Other constraints – Solution using Priority List method, Dynamic programming method – Forward DP approach Lagrangian relaxation method- Adjusting λ.

REAL POWER AND FREQUENCY CONTROL
Objectives of power system control and evaluation of control strategy in power system – Need for voltage and Frequency regulation and system load characteristics – Basic P-f and Q-v control loops – Review of LFC and Economic dispatch control (EDC) using the three modes of control viz., flat frequency, tie line control and tie line bias control – AGC implementation – AGC features static and dynamic response of controlled two-area system - Development of dynamic state variable model for two-area system.

REACTIVE POWER AND VOLTAGE CONTROL
Production and absorption of reactive power – Methods of Voltage Control – Shunt reactors – Shunt Capacitors – Series Capacitors – Synchronous condensers – Static VAR systems – Principles of Transmission system compensation – Modeling of reactive compensating devices – Application of tap changing transformers to transmission systems – Distribution system voltage regulation – Modeling of transformers ULTC control systems.

CONTROL OF POWER SYSTEMS
System operating states by security control functions – Monitoring, evaluation of system state by contingency analysis – Corrective controls (Preventive, emergency and restorative) – Energy control center – SCADA system – Functions – Monitoring, Data acquisition and controls – EMS system.

Reference Books

1. Allen J.Wood and Bruce.F.Wollenberg, “Power Generation Operation and Control”, John Wiley & Sons, New York, 1996.
2. Kundur.P; “Power System Stability and Control”, EPRI Publications, California, 1994.
3. Elgerd.O.I, “Electric Energy System Theory – an Introduction”, Tata McGraw Hill, New Delhi – 2002.
4. V.Ramanathan & P.S.Manoharan “Power system operation and control”, Charulatha Publications, chennai, 2008.
5. Timothy J. E. Miller, “Reactive Power Control in Electric Systems” Wiley, 1982.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**GENERATION SHEDULING**	
1.1	Introduction – Power system operation control - Economic dispatch problem	2
1.2	The Lambda – Iteration method	1
1.3	Gradient method of economic dispatch – Economic dispatch with Piecewise Linear cost functions	2
1.4	Thermal system dispatching with network losses considered	2
1.5	A two generator system – Coordination equations	1
1.6	Incremental losses and penalty factors	1

1.7	Hydro Thermal Scheduling using DP	1
2.0	**UNIT COMMITMENT**	
2.1	Unit commitment problem- Spinning reserve – Thermal unit constraints	2
2.2	Bank & Other constraints	1
2.3	Solution using Priority List method	1
2.4	Dynamic programming method	1
2.5	Forward DP approach	1
2.6	Lagrangian relaxation method- Adjusting λ.	2
3.0	**REAL POWER AND FREQUENCY CONTROL**	
3.1	Objectives of power system control and evaluation of control strategy in power system	1
3.2	Need for voltage and Frequency regulation and system load characteristics	1
3.3	Basic P-f and Q-v control loops	1
3.4	Review of LFC and Economic dispatch control (EDC) using the three modes of control viz., flat frequency, tie line control and tie line bias control	2
3.5	AGC implementation – AGC features static and dynamic response of controlled two-area system	2
3.6	Development of dynamic state variable model for two-area system	1
4.0	**REACTIVE POWER AND VOLTAGE CONTROL**	
4.1	Production and absorption of reactive power – Methods of Voltage Control	1
4.2	Shunt reactors – Shunt Capacitors – Series Capacitors	2
4.3	Synchronous condensers – Static VAR systems	1
4.4	Principles of Transmission system compensation -Modeling of reactive compensating devices	1
4.5	Application of tap changing transformers to transmission systems	1
4.6	Distribution system voltage regulation	1
4.7	Modeling of transformers ULTC control systems	1
5.0	**CONTROL OF POWER SYSTEMS**	
5.1	System operating states by security control functions – Monitoring, evaluation of system state by contingency analysis	1
5.2	Corrective controls (Preventive, emergency and restorative)	1
5.3	Energy control center – SCADA system	2
5.4	Functions – Monitoring, Data acquisition and controls – EMS system	2
	Total	**40**

Course Designers:

1. Dr.V.Ramanathan vreee@tce.edu

2. Dr.C.K.Babulal ckbeee@tce.edu

14PS270	POWER SYSTEM LABORATORY - II	Category	L	T	P	Credit
		PC	0	0	1	1

Preamble

The aim of this lab course is to train the Postgraduate students in solving and analyzing the advanced power system problems and research oriented problems using various hardware/software procured by various projects.

Prerequisite

- K17 Power System Laboratory - I

Course Outcomes

On the successful completion of the course, students will be able to:

CO1.	Solve power system problems using MATLAB.	Analyse
CO2.	Perform simulation studies using software packages.	Analyse
CO3.	Make use of Real Time Data and Instruments for analyzing the performance of Power Systems	Precision

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.			S	S							
CO2.			S	S							
CO3.			S	S	**M**						

S- Strong; M-Medium; L-Low

Syllabus

1. Realization of overcurrent relay characteristics / distance relay characteristics using DSP.
   Incharge : Dr.M.Geethanjali
2. Reactive Power compensation using Voltage Source Converter based STATCOM hardware module.
   Incharge : Dr.P.Venkatesh
3. Power flow solution using Power world Simulator.
   Incharge : Dr.S.Charles Raja
4. Contingency analysis using Matlab coding.
   Incharge : Dr.N.Kamaraj
5. Security assessment of grid connected DGS using Matlab simulink.
   Incharge : Dr.N.Kamaraj
6. DC motor control using PLC drive.
   Incharge : Dr.M.Saravanan
7. Performance analysis of TCSC controller
   Incharge : Dr.S.Latha
8. Modelling of Synchronous generator using Simulink
   Incharge : Dr K.Selvi
9. Multi parameter measurement & monitoring in Electrical networks using Power quality analyzer
   Incharge: Dr V.Suresh Kumar
10. Analysis of southern regional dispatch centre energy report
    Incharge: Dr V.Saravanan

14PS310	**ELECTRICITY DEREGULATION**	Category	L	T	P	Credit
		PC	3	1	0	4

Preamble

The electricity industry throughout the world, which has long been dominated by vertically integrated utilities, is undergoing enormous changes. Deregulation is a fairly new paradigm and just as in the case of other industries where it has been introduced, the goal of deregulation is to enhance competition and bring consumers new choices and economic benefits. The electricity industry is evolving into a distributed and competitive industry in which market forces drive the price of electricity and reduce the net cost through increased competition. The process has, obviously, necessitated reformulation of established models of power system operation and control activities.

Prerequisite

- 14PS120 Power system modelling and analysis
- 14PS210 Power Systems Security

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain the restructuring process, new entities in power market and benefits.	Understand
CO2.	Apply the concepts and terminologies used in interchange evaluation, power pools and transaction issues.	Analyse
CO3.	Explain the Indian power system, issues, regulatory and policy developments and acts.	Understand
CO4.	Demonstrate the transmission open access, congestion management and pricing issues.	Apply
CO5.	Determine available transfer capability in restructured environment.	Analyse

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S			M						L	
CO2.	S	M	M	M							
CO3.	S									M	
CO4.	M		M	S	S		L				
CO5.			M	M	S						

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	40	40	40	40
Analyse	20	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the structure and different entities in deregulated electricity market with necessary diagram
2. What are all the different entities in deregulated market and explain them in brief?
3. Explain how vertically integrated electricity market is transformed in the deregulation process and also give year wise milestones of deregulation

Course Outcome 2 (CO2):

1. Give the comparison of two different market structures with respect to ISO and also explain any one market structure in detail
2. Explain the multi area joint dispatch problem with a suitable example?
3. Consider a four utility joint dispatch as shown in figure: the generation capacity and Composite cost functions are given in table. Find the system cost reductions when the utilities operate through a joint dispatch as compared to when they operate independently. Take Tkm =18MW

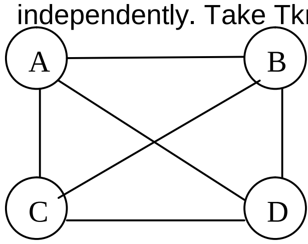


Fig. A four utility joint dispatch model

Table: multi utility power interchange system

Utility	a0 ($/Mwh)	b0 ($/Mwh)	c0 ($/Mwh)	Pmax (MW)	Pmin (MW)	PD (MW)
A	1.8	10.5	0.5	150	20	120
B	2.8	24.5	0.8	250	30	200
C	3.0	15.6	0.4	230	40	180
D	1.5	20.1	0.6	125	25	75

4. The operator of a centralized market for electrical energy has received the bids shown in following table for the supply of electrical energy during a given period.
   Build the supply curve and assume that this market operates unilaterally, that is, that the demand does not bid and is represented by a forecast. Calculate the market price, and the revenue of each company for each of the following loads:
   400 MW,600 MW

Table

Company	Amount (MWh)	Price ($ /Mwh)
Red	200	12.5
Red	50	14.0
Red	50	18.0
Blue	150	10.5
Blue	50	13.0
Blue	100	15.0
Green	50	13.5
Green	50	14.5
Green	50	15.5

Course Outcome 3 (CO3):

1. Explain the Indian power sector past and present status
2. Explain the growth of power sector in India
3. Describe the major milestones occurred in the Indian power sector before and after independence
4. What are the players in Indian power sector and explain in detail

Course Outcome 4 (CO4):

1. Write short notes on i) Types of transmission services in open access, ii) pricing of power transmission.
2. Explain the Mw-mile method of transmission pricing with a suitable example.
3. What are the different types of transmission services in open access? Explain them in detail?
4. Explain any one method of incremental cost based transmission pricing scheme and give the advantage involved in it?
5. Consider a six bus system comprising bus 1as slack and buses 2 and 3 are generator buses and three load buses namely 4,5 and 6 and of 70MW each. Generator power at buses 2 and 3 are 50 and 60 MW respectively. There are two transactions (seller to buyer) to the existing system.
   (i)T1 2-5 30MW (ii) T2 3-6 20 MW
   The total system demand is 210 MW. The transmission network parameters are given in table. The Line reactance is unit on a base of 100 MVA.

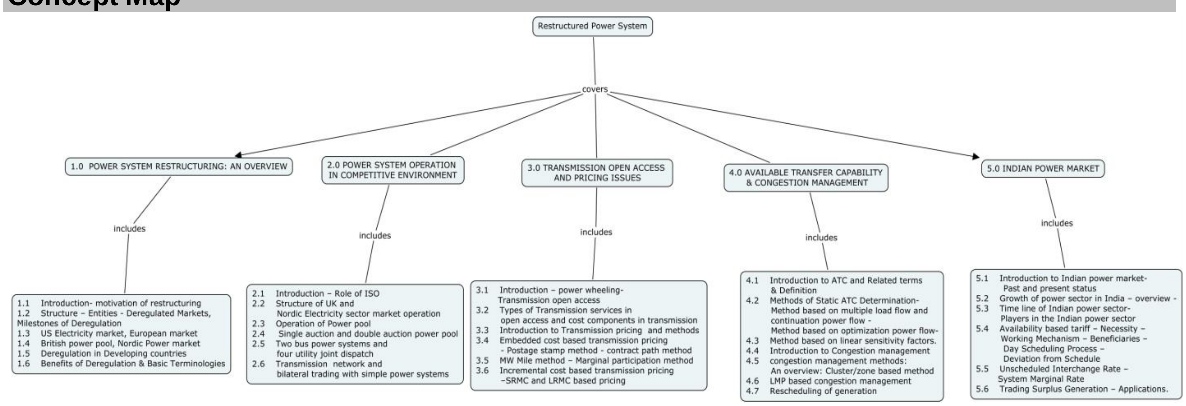
1-2	1-4	1-5	2-3	2-5	2-6	3-5	3-6	4-5	5-6
0.2	0.2	0.3	0.25	0.3	0.2	0.26	0.1	0.4	0.3

   Assume the distance of all the lines is 100 miles and the unit cost of the lines is 100 S/Mw- mile. Calculate the proportional cost of two transactions using MW-mile method.

Course Outcome 5 (CO5):

1. Explain with a necessary diagram how ATC determination is made using continuation power flow method
2. Explain with a necessary diagram how ATC determination is made using sensitivity factor method?
3. Explain accurate method of ATC calculations with relevant equations. Draw a flow chart for the computation of ATC.
4. Explain ATC determination using DCPTDF method with a flow chart?
5. Explain static ATC determination using multiple load flow and continuation power flow with a neat flowchart?
6. what are the various congestion management methods and explain it in detail

Concept Map



Syllabus

POWER SYSTEM RESTRUCTURING: AN OVERVIEW

Introduction- Motivation for Restructuring of Power System- Electricity Market Entities and Model- Milestones of Deregulation-International Scenario –Industrialized countries - In the US- The Scene in Europe- The British power pool-Nordic Deregulation process-Developing countries - Benefits of deregulation- Basic Terminologies

POWER SYSTEM OPERATION IN COMPETITIVE ENVIRONMENT

Introduction-Role of Independent system operator - Structure of UK and Nordic Electricity sector market operations –power pools – explanation of single auction power pool & double auction power pool with supply bid and demand - Two bus power system – four utility joint dispatch- Transmission networks and bilateral Electricity markets- bilateral trading in a two bus power system- three bus power system with feasible transactions

TRANSMISSION OPEN ACCESS AND PRICING ISSUES

Introduction-power wheeling -Transmission open access- Types of Transmission services in open access – cost components in transmission – Pricing of power transactions – Embedded cost based Transmission pricing - Postage stamp method - contract path method-MW Mile method – Marginal participation method – Incremental cost based transmission pricing –SRMC and LRMC based pricing

AVAILABLE TRANSFER CAPABILITY & CONGESTION MANAGEMENT

Introduction-Definition - Methods of Static ATC Determination - Method based on multiple load flow and continuation power flow - Method based on optimization power flow- method based on linear sensitivity factors. Congestion management –congestion management methods: An overview: Cluster/zone based method – Rescheduling of generation-LMP based congestion management.

INDIAN POWER MARKET

Introduction –Indian power sector past and present status-growth of power sector in India - overview - Time line of Indian power sector- Players in the Indian power sector - Availability based tariff - Necessity- working mechanism- Beneficiaries-Day Scheduling process- Deviation from Schedule-unscheduled interchange rate-system marginal rate- trading surplus generation-applications

Reference Books

1. Kankar Bhattacharya Maath H.J. Bollen and Jaap E.Daalder, “Operation of restructured power systems”, Kluwer academic publishers, USA ,first edition, 2001.
2. Daniel Kirschen and Goran Strbac ,”Fundamentals of power system economics”, John Wiley sons, 2004.
3. Loi Lei Lai, “Power system Restructuring and regulation” John Wiley sons, 2001.
4. P.Venkatesh, B.V.Manikandan, S.Charles Raja and A.Srinivasan , “ Electrical power systems analysis, Security and Deregulation”, PHI 2012.
5. M.Shahidepour, Hatim Tamin and Zuyi Li, “Market operations in electric power system forecasting, scheduling and risk management”, John Wiley sons, 2002.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0 POWER SYSTEM RESTRUCTURING: AN OVERVIEW		
1.1	Introduction- motivation of restructuring	1
1.2	Structure – Entities - Deregulated Markets, Milestones of Deregulation	2
1.3	US Electricity market, European market	2
1.4	British power pool, Nordic Power market	2
1.5	Deregulation in Developing countries	1
1.6	Benefits of Deregulation & Basic Terminologies	1
2.0 POWER SYSTEM OPERATION IN COMPETITIVE ENVIRONMENT		
2.1	Introduction – Role of ISO	1
2.2	Structure of UK and Nordic Electricity sector market operation	1
2.3	Operation of Power pool	1
2.4	Single auction and double auction power pool	2
2.5	Two bus power systems and four utility joint dispatch	2
2.6	Transmission network and bilateral trading with simple power systems	2
3.0 TRANSMISSION OPEN ACCESS AND PRICING ISSUES		
3.1	Introduction – power wheeling-Transmission open access	1
3.2	Types of Transmission services in open access and cost	2

	components in transmission	
3.3	Introduction to Transmission pricing and methods	1
3.4	Embedded cost based transmission pricing - Postage stamp method - contract path method	1
3.5	MW Mile method – Marginal participation method	2
3.6	Incremental cost based transmission pricing –SRMC and LRMC based pricing	2
4.0 AVAILABLE TRANSFER CAPABILITY & CONGESTION MANAGEMENT		
4.1	Introduction to ATC and Related terms & Definition	1
4.2	Methods of Static ATC Determination-Method based on multiple load flow and continuation power flow - Method based on optimization power flow-	2
4.3	Method based on linear sensitivity factors.	2
4.4	Introduction to Congestion management	1
4.5	congestion management methods: An overview: Cluster/zone based method	2
4.6	LMP based congestion management	1
4.7	Rescheduling of generation	1
5.0 INDIAN POWER MARKET		
5.1	Introduction to Indian power market- Past and present status	2
5.2	Growth of power sector in India – overview -	1
5.3	Time line of Indian power sector- Players in the Indian power sector	1
5.4	Availability based tariff – Necessity – Working Mechanism – Beneficiaries – Day Scheduling Process – Deviation from Schedule	2
5.5	Unscheduled Interchange Rate – System Marginal Rate	1
5.6	Trading Surplus Generation – Applications.	1
	Total	**45**

Course Designer:

1. Dr. P. Venkatesh pveee@tce.edu

14PSPA0	POWER SYSTEM VOLTAGE STABILITY	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Today the power system is being operated under stressed condition than was usual in the past. Environmental pressures on transmission expansion, increased electricity consumption in heavy load areas and new system loading patters due to restructuring are some of the reasons. Under these stressed conditions a power system can exhibit a new type of unstable behaviour characterized by slow or sudden voltage drops, escalating to the form of a collapse. A number of such voltage instability incidents have been experienced around the world. As a consequence voltage stability has become a major concern in power system planning and operation. Based on this, the course aims at giving an adequate exposure in physical phenomenon of voltage collapse, Transmission system, Generation, load aspects and Static voltage stability methods.

Prerequisite

- Power system modelling and analysis

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Classify and explain the time frames of power system stability.	Understand
CO2.	Explain maximum deliverable power.	Understand
CO3.	Describe the voltage dependence of loads.	Understand
CO4.	Demonstrate PV, PQ and PVQ curves.	Understand
CO5.	Apply Continuation power flow for voltage stability assessment.	Understand
CO6.	Identify weak buses and branches using Modal analysis.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S							L	M		
CO2.	S			M				L	M		
CO3.	S			M				L	M		
CO4.	S				M			L	M		
CO5.	S	M	S	M	S			L	M		
CO6.	S		S	M	M			L	M		

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	80	80	80	80
Apply	0	0	0	0
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State power system voltage stability.
2. Explain voltage collapse phenomenon.
3. Classify power system stability based on time frame.
4. Distinguish transient stability and voltage stability.

Course Outcome 2 (CO2):

1. Explain unconstrained maximum power.
2. Derive the expression for maximum power under a give power factor for a lossless SLIB system.
3. Explain how reactive power generation increases with load increase?

Course Outcome 3 (CO3):

1. Define load characteristics.
2. Draw and explain ZIP load characteristics.
3. Explain load restoration dynamics.
4. Describe saddle node bifurcation.

Course Outcome 4 (CO4):

1. Explain the term loadability limit with a help of PV curve.
2. Draw a sample PV curves and explain the shape of the characteristics.
3. Draw a sample PQ curves and explain the shape of the characteristics.
4. Draw PQV curves and explain the shape of the characteristics.

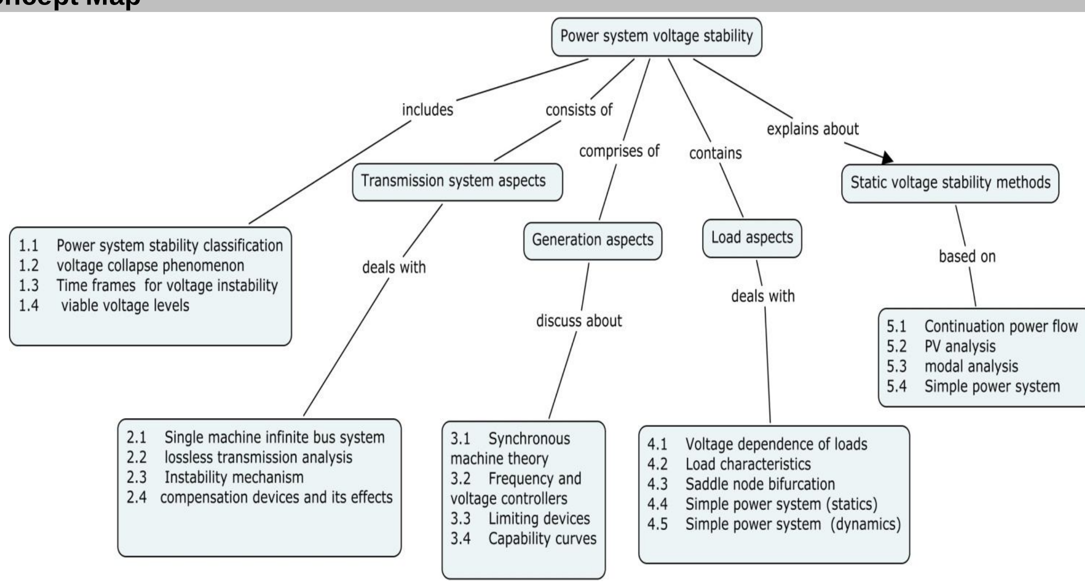
Course Outcome 5 (CO5):

1. Name various methods used for voltage stability assessment.
2. Explain the drawbacks of using NR method for voltage stability assessment.
3. Explain with flowchart the continuation power flow method.
4. Write the step by step procedure of implementing continuation power flow method to voltage stability assessment.

Course Outcome 6 (CO6):

1. What are weak buses?
2. Explain Modal analysis technique with necessary equations.
3. Write the procedure of finding the weak buses and lines using Modal analysis.

Concept Map



Syllabus

Introduction

Voltage stability- Power system stability classification – physical phenomenon of voltage collapse - time frames for voltage instability, mechanisms – maintaining viable voltage levels-Introduction to standards.

Transmission system aspects

Single load infinite bus system – maximum deliverable power – lossless transmission – maximum power – power voltage relationships – generator reactive power requirement – instability mechanism- Effect of compensation-Line series compensation – shunt compensation – static VAR compensator –VQ curves – effect of adjustable transformer ratio-FACTS devices.

Generation aspects

A review of Synchronous machine theory – Frequency and voltage controllers - Limiting devices affecting voltage stability – over excitation limiters – description – field current, armature current limiters – P and Q Expressions- capability curves.

Load aspects

Voltage dependence of loads – load characteristics – exponential load – polynomial load-Saddle node bifurcation – simple power system example (statics) – simple power system example (dynamics).

Static voltage stability methods

Continuation power flow methods, PV analysis, VQ analysis, Time domain analysis, modal analysis - Simple power system example.

Reference Books

1. T.Van Cutsem and C.Vournas, Voltage stability of electric power systems, Kluwer academic publishers 1998.
2. C.W.Taylor, Power system voltage stability, McGraw-Hill, Inc., 1994.
3. P.Kundur, Power system stability and control, McGraw-Hill, Inc., 1995.
4. IEEE Working Group on Voltage Stability. Voltage Stability Assessment: Concepts, Practices and Tools, 2002.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hors
1	**Introduction**	
1.1	Voltage stability - Power system stability classification	01
1.2	Physical phenomenon of voltage collapse	02
1.3	Time frames for voltage instability, mechanisms	01
1.4	Maintaining viable voltage levels	01
1.4.1	Introduction to standards	01
2.0	**Transmission system aspects**	
2.1	Single machine infinite bus system	02
2.2	Maximum deliverable power, lossless transmission	02
2.2.1	Power voltage relationships, generator reactive power requirement	02
2.3	Instability mechanism	02
2.4	Effect of compensation	01
2.4.1	Line series compensation, shunt compensation, Static VAR compensator, VQ curves, Effect of adjustable transformer ratio, FACTS devices	03
3.0	**Generation aspects**	
3.1	A review of Synchronous machine theory	02
3.2	Frequency and voltage controllers	02
3.3	Limiting devices affecting voltage stability	01
3.3.1	Over excitation limiters, field current, armature current limiters	02
3.4	P and Q Expressions, Capability curves	01
4.0	**Load aspects**	

4.1	Voltage dependence of loads	02
4.2	Load characteristics, exponential load, polynomial load	02
4.3	Saddle node bifurcation	02
4.4	Simple power system example (statics)	02
4.5	Simple power system example (dynamics)	02
5.0	**Static voltage stability methods**	
5.1	Continuation power flow methods	03
5.2	PV analysis, VQ analysis	02
5.3	Time domain analysis, modal analysis	02
5.4	Simple power system example	02
	Total	**45**

Course Designers:

1. Dr.C.K.Babulal ckbeee@tce.edu

14PSPB0	ELECTRICAL TRANSIENTS IN POWER SYSTEM	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Electromagnetic transient assessments of power systems provide detailed technical information appropriate for power system equipment design and specifications pertaining to a wide-variety of phenomena related to power system voltage levels. This subject explores the topic of transient problems on electric utility and industrial power systems. The purpose is to teach students the fundamentals and to enable them to recognize and solve transient problems in power networks and components. The EMTP is a powerful tool used worldwide for the computer simulation of transients in power systems. This subject stresses the physical aspects of the electromagnetic transient phenomena and also broadens the computational treatment of transients.

Prerequisite

- Electromagnetic field theory

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain the various sources of electromagnetic transient.	Understand
CO2.	Describe the formation and characteristics of travelling waves in transmission line	Understand
CO3.	Apply the ATP/EMTP software for transient studies.	Apply
CO4.	Model power apparatus under transient conditions	Apply
CO5.	Apply insulation co-ordination principles.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	L	M								
CO2.	S		M	M							
CO3.	S	M	S	M	S				M		
CO4.	S	S	S	M	S				M		
CO5.	S	S	S	S	M				S		

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	40	30	20	20
Understand	40	50	40	40
Apply	20	20	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What are the various sources of Transient Over voltages?
2. Distinguish between surge absorber and surge diverter.
3. Calculate the velocity of wave propagation for
   a. An overhead line pf capacitance 0.147 X 10 -10 F/m and inductance of 0.75 X 10 -6 H/m.

b. In a cable having an inductance of 0.75X 10-6H/m and a capacitance of 13.3 X 10-10 F/m.
c. Estimate the relative permittivity of the insulating material in case (ii).

Course Outcome 2 (CO2):

1. A step waveform with a magnitude of ‘E’ volts is propagating in a line which terminated at an inductance. Derive an expression for the voltage developed across the inductance. Illustrate the propagation of wave using lattice diagram.
2. A surge of 150kV travels on a line of surge impedance in 450 Ohms and reaches a junction of the line with two branch line. The surge impedance of the branches are 400Ohms and 40 Ohms. Find the transmitted voltage and current.
3. Explain in detail the various types of lightning strokes that can strike a transmission line. Also Derive an expression for the over voltage developed due to lighting stroke.

Course Outcome 3 (CO3):

1. How do you model a surge diverter for steep fronted waves? Also, explain the steps involved in simulating model sung EMTP.
2. State important properties of co-efficient of Potential, Capacitance and Induction.
3. What is meant by basic insulation level?

Course Outcome 4 (CO4):

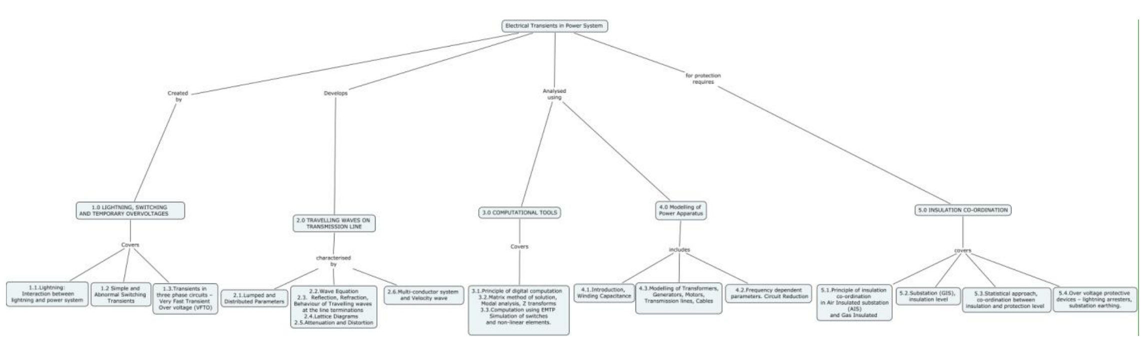
1. Discuss the application of
   - Ground wires
   - Surge Diverters
   - For the protection of a line against surge voltages.
2. A transmission line is 300km long and open at far end. The attenuation of surge is 0.9 over one length of travel at light velocity. It is energised by
   a. A step of 1MV
   b. A sine wave of 325kV peak

   Using Bewley’s Lattice Diagram, calculate the final value of open end voltage.
3. Explain in detail the various types of lightning strokes that can strike a transmission line. Also Derive an expression for the over voltage developed due to lighting stroke.

Course Outcome 5 (CO5):

1. How lightning arresters are classified?
2. Draw the equivalent Π section of a long transmission line.
3. Write the wave equation.
4. A 500k surge travels on an overhead line of surge impedance 400 Ohms towards a junction with cable which has a surge impedance of 40Ohms. Find
   a. Transmitted voltage
   b. Transmitted current
   c. Reflected voltage
   d. Reflected current

Concept Map



Syllabus

LIGHTNING, SWITCHING AND TEMPORARY OVERVOLTAGES

Lightning: Physical phenomena of lightning – Interaction between lightning and power system – Factors contributing to line design – Simple and Abnormal Switching Transients – Transients in three phase circuits – Very Fast Transient Over voltage (VFTO) – IEC standards and wave models.

TRAVELLING WAVES ON TRANSMISSION LINE

Lumped and Distributed Parameters – Wave Equation – Reflection, Refraction, Behaviour of Travelling waves at the line terminations – Lattice Diagrams – Attenuation and Distortion – Multi-conductor system and Velocity wave.

COMPUTATION OF POWER SYSTEM TRANSIENTS

Principle of digital computation – Matrix method of solution, Modal analysis, Z transforms, Computation using EMTP – Simulation of switches and non-linear elements.

MODELLING OF POWER APPARATUS UNDER TRANSIENT CONDITION

Introduction, Winding Capacitance, Frequency dependent parameters. Circuit Reduction. Modelling of Transformers, Generators, Motors, Transmission lines, Cables.

INSULATION CO-ORDINATION

Principle of insulation co-ordination in Air Insulated substation (AIS) and Gas Insulated Substation (GIS), insulation level, statistical approach, co-ordination between insulation and protection level – over voltage protective devices – lightning arresters, substation earthing.

Reference Books

1. Pritindra Chowdhari, "Electromagnetic transients in Power System", John Wiley and Sons Inc., 1996.
2. Allan Greenwood, "Electrical Transients in Power System", Wiley & Sons Inc. New York, 1991.
3. Klaus Ragaller, "Surges in High Voltage Networks", Plenum Press, New York, 1980.
4. Rakosh Das Begamudre, "Extra High Voltage AC Transmission Engineering", 2^{nd} edition, New Age International (P) Ltd., New Delhi, 1990.
5. Naidu M S and Kamaraju V, "High Voltage Engineering", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2004.

Course Contents and Lecture Schedule

Module No.	Topics	No. of lecture hours
1.0 LIGHTNING, SWITCHING AND TEMPORARY OVERVOLTAGES		
1.1.	Lightning: Physical phenomena of lightning – Interaction between lightning and power system	2
1.2.	Simple and Abnormal Switching Transients	4
1.3.	Transients in three phase circuits – Very Fast Transient Over voltage (VFTO) - IEC standards and wave models.	3
2.0 TRAVELLING WAVES ON TRANSMISSION LINE		
2.1.	Lumped and Distributed Parameters	2
2.2.	Wave Equation	1
2.3.	Reflection, Refraction, Behaviour of Travelling waves at the line terminations	2
2.4.	Lattice Diagrams	2
2.5.	Attenuation and Distortion	1
2.6.	Multi-conductor system and Velocity wave	2
3.0 COMPUTATION OF POWER SYSTEM TRANSIENTS		
3.1.	Principle of digital computation	1
3.2.	Matrix method of solution, Modal analysis, Z transforms	3
3.3.	Computation using EMTP – Simulation of switches and non-linear elements.	3
4.0 MODELLING OF POWER APPARATUS UNDER TRANSIENT CONDITION		
4.1.	Introduction, Winding Capacitance	1
4.2.	Frequency dependent parameters. Circuit Reduction	1

4.3.	Modelling of Transformers, Generators, Motors, Transmission lines, Cables	5
5.0 INSULATION CO-ORDINATION		
5.1.	Principle of insulation co-ordination in Air Insulated substation (AIS) and Gas Insulated	2
5.2.	Substation (GIS), insulation level	2
5.3.	Statistical approach, co-ordination between insulation and protection level	2
5.4.	Over voltage protective devices – lightning arresters, substation earthing.	1
	Total	**40**

Course Designer:

1. Dr.R. Rajan Prakash r_rajanprakash@tce.edu

Category	L	T	P	Credit
PE	3	1	0	4

14PSPC0/CNEP **REAL TIME OPERATING SYSTEM**

Preamble

This course provides a broad introduction to real time operating system (RTOS).It explores the functions of the RTOS to manage the sharing of internal memory among multiple tasks, to handle input and output to and from attached hardware devices, to send messages about the status of operation. It explains the design of embedded system by programming using µCOS-II.

Prerequisite

- Microprocessors
- Microcontrollers
- Embedded system

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explain the different program models for embedded system programming	Understand
CO2	Explain interprocess communication and synchronization in embedded system	Understand
CO3	Explain OS services, file, I/O and memory management, interrupt handling and scheduling mechanism in RTOS	Understand
CO4	Explain the RTOS Programming concepts	Understand
CO5	Design an Embedded System by programming using RTOS µCOS-II	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**S**										
CO2	**S**	**M**									
CO3	**S**	**M**									
CO4	**S**	**M**									
CO5	**S**	**M**			**S**						

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	30	20	20
Understand	30	30	30	30
Apply	40	40	50	50
Analyze	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What are the different program models used in programming?
2. List the basic elements of UML.
3. Illustrate the data flow graph model of programming with an example.

Course Outcome 2 (CO2)

1. What is a binary semaphore?
2. What are the different task states?
3. Illustrate the application of semaphore as resource key and for executing critical section codes with an example for each.

Course Outcome 3 (CO3)

1. Explain the following Kernel services in an OS
   i) Process management
   ii) Memory management
2. List any four basic functions provided by an RTOS.
3. Define context switching.

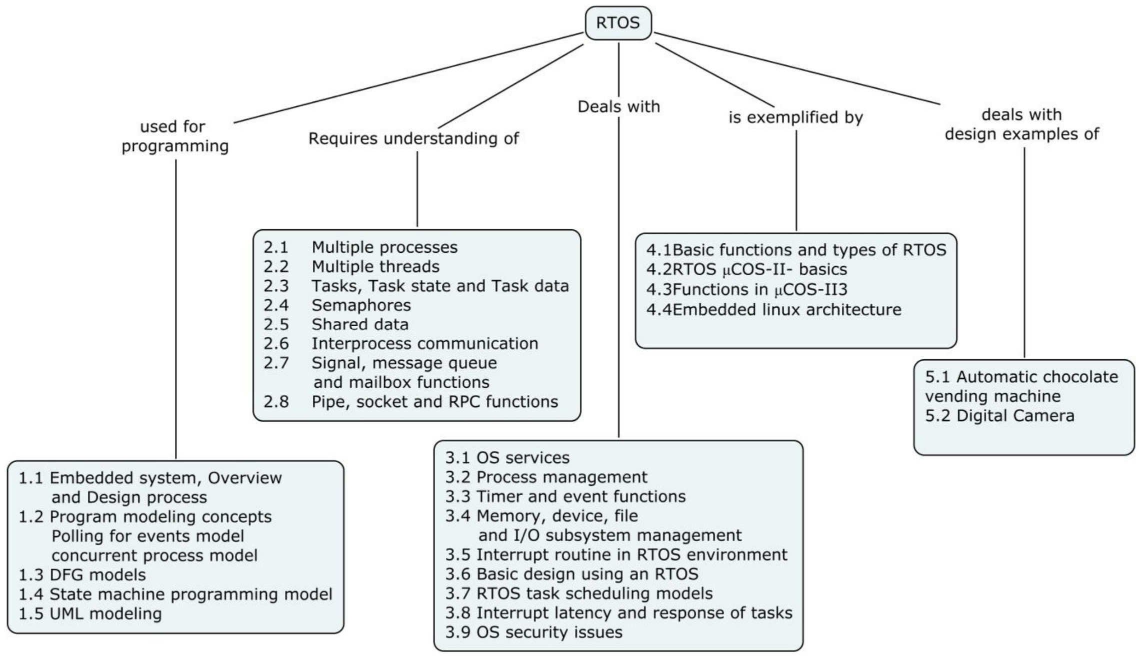
Course Outcome 4 (CO4)

1. Explain the application of any four task service functions in µCOS-II.
2. What are the types of RTOSes?
3. Write the use of OSTickInit ( ) and OSIntEnter ( ) functions in µCOS-II.

Course Outcome 5 (CO5)

1. Design the software architecture and synchronization diagram for the automatic chocolate vending machine and explain them.
2. Write the C program with comments in µCOS-II environment to initialize all the tasks and IPC functions along with the main ( ) and FirstTask ( ) functions for the automatic chocolate vending machine.
3. Design the software architecture and synchronization diagram for the digital camera and explain them.

Concept Map



Syllabus

Introduction and Programming of embedded systems
Embedded system, Overview and Design process, Program modeling concepts, Polling for events model, Concurrent process model, DFG models, State machine programming model, UML modeling
Interprocess communication and synchronization
Multiple processes, Multiple threads, Tasks, Task state and Task data, Semaphores, Shared data, Interprocess communication, Signal, message queue and mailbox functions, Pipe, socket and RPC functions.
Real time operating systems
OS services- process management, Timer and event functions, Memory, device, file and I/O subsystem management, Interrupt routine in RTOS environment, Basic design using an RTOS, RTOS task scheduling models, Interrupt latency and response of tasks, OS security issues.
RTOS programming
Basic functions and types of RTOSes, RTOS μCOS-II- basics, Functions in μCOS-II, Embedded linux system architecture

Design examples with μCOS-II
Automatic chocolate vending machine, Digital Camera.

Reference Books

1. Raj kamal, ‘Embedded Systems Architecture, Programming and Design’, Tata McGraw-Hill, second edition 2010.
2. David E.Simon, “An Embedded Software Primer”, Pearson Education, 2006
3. C.M. Krishna, Kang, G.Shin, “Real Time Systems”, McGraw Hill, 1997.
4. Phillip A. Laplante, Real Time Systems Design and Analysis, An Engineer’s Handbook, Second Edition, PHI India, 1997.

Course Contents and Lecture Schedule

S.No.	Topics	No. of Lecture Hours
1.	**Introduction and Programming of Embedded systems**	
1.1	Embedded system – Overview and Design process	1
1.2	Program modeling concepts- Polling for events model, concurrent process model	1
1.3	DFG models	2
1.4	State machine programming model	2
1.5	UML modeling	2
2.	**Interprocess communication and synchronization**	
2.1	Multiple processes	1
2.2	Multiple threads	1
2.3	Tasks, Task state and Task data	1
2.4	Semaphores	2
2.5	Shared data	2
2.6	Interprocess communication	2
2.7	Signal, message queue and mailbox functions	1
2.8	Pipe, socket and RPC functions	2
3	**Real time operating systems**	
3.1	OS services	1
3.2	Process management	1
3.3	Timer and event functions	2
3.4	Memory, device, file and I/O subsystem management	2
3.5	Interrupt routine in RTOS environment	2
3.6	Basic design using an RTOS	2
3.7	RTOS task scheduling models	2
3.8	Interrupt latency and response of tasks	2
3.9	OS security issues	1
4	**RTOS programming**	
4.1	Basic functions and types of RTOS	1
4.2	RTOS µCOS-II- basics	1
4.3	Functions in µCOS-II	3
4.4	Embedded linux architectures	1
5	**Design examples with µCOS-II**	
5.1	Automatic chocolate vending machine	2
5.2	Digital Camera	2
	Total	**45**

Course Designers:

1. Dr. P.S.Manoharan psmeee@tce.edu

14PSPD0	DISTRIBUTED GENERATION SYSTEMS	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Distributed Generation system would provide the platform for the use of renewable sources which are the key to a sustainable energy supply infrastructure since they are both inexhaustible and non-polluting. It provides adequate emergency power for major metropolitan load centers, remote villages and would safeguard in preventing the complete blackout of the interconnected power systems due to man-made events and environmental calamity and would provide the ability to break up the interconnected power systems into the cluster smaller regions. Based on this, the course aims at giving an adequate exposure in Distributed Generation systems, Modelling of Wind and solar systems, Economics of Distributed Resources, Wind Power Systems, and Photovoltaic Systems, State of the art of hybrid systems and major issues of connecting DG into the system.

Prerequisite

- Generation, Transmission and Distribution
- Power System Modelling and Analysis
- Renewable Energy Sources

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain the different technological options for use in mini-grid systems including PV, wind, Microgrid, hydro, biomass and fuel cell.	Understand
CO2.	Perform economic feasibility analysis.	Apply
CO3.	Demonstrate the modelling of DG systems (Solar & wind).	Understand
CO4.	Explain the components and control techniques of hybrid systems.	Remember
CO5.	Recognize the need of siting and sizing of distributed generation along with their effect on distribution system.	Understand
CO6.	Outline the impacts of DG on system protection.	Remember

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S										
CO2.		S	M								
CO3.	S										
CO4.	S				M						
CO5.	S		M	L					M		
CO6.	S		M	L							

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	50	50	50	50
Apply	30	30	30	30
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the operation of Micro turbine with neat diagram.
2. Draw and explain the functional diagram of Bio mass Gasification process.
3. Describe the function of Maximum power point trackers.

Course Outcome 2 (CO2):

1. Two 100-hp electric motors are being considered—call them "good" and "premium."
    a. The good motor draws 79 kW and costs $2400; the premium motor draws 77.5 kW
    b. and costs $2900. The motors run 1600 hours per year with electricity costing $0.08/kWh. Over a 25-year life, find the net present value of the cheaper alternative
    c. when a discount rate of 15% is assumed
2. A 3-kW photovoltaic system, which operates with a capacity factor (CF) of 0.25, costs $10,000 to install. There are no annual costs associated with the system other than the payments on a 6%, 20-year loan. Find the cost of electricity generated by the system. Take the capital recovery factor is 0.0872/yr.
3. Explain with suitable example the energy efficiency measurement of a CHP plant.

Course Outcome 3 (CO3):

1. Explain the modelling of doubly fed induction generator.
2. Describe the condition for rotor maximum efficiency of a wind turbine.
3. Compare the modelling of Linear and Non-linear solar energy models.

Course Outcome 4 (CO4):

1. Explain the control the reactive power of hybrid system using static synchronous compensator.
2. Describe the application of suitable control and simulation technique in hybrid power system.
3. Discuss the various frequency control methods of Hybrid systems.

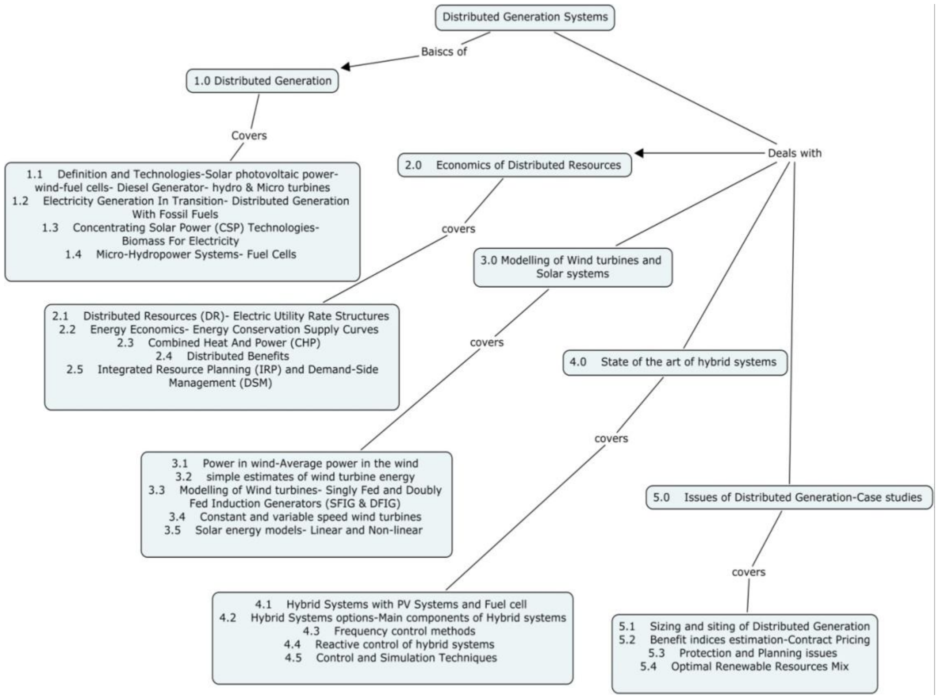
Course Outcome 5 (CO5):

1. Describe the various technical and economical benefits of DG.
2. List out the indices used to quantify the technical benefits.
3. With suitable example explain the need of optimal sizing and siting of DG.

Course Outcome 6 (CO6):

1. List out the various operating issues of protection of a system with DG
2. Explain the impact of DG in optimal contract pricing in a distribution system.
3. Describe the need of optimal renewable resource mix.

Concept Map



Syllabus

Distributed Generation

Definition and Technologies of Distributed Generation -Solar photovoltaic power-wind-fuel cells-Diesel Generator- Hydro and Micro turbines **–**Electricity Generation in Transition- Distributed Generation With Fossil Fuels- Concentrating Solar Power (CSP)Technologies- Biomass For Electricity **-** Micro-Hydropower Systems-Fuel Cells**.**

Economics of Distributed Resources

Distributed Resources (DR)- Electric Utility Rate Structures- Energy Economics- Energy Conservation Supply Curves **–**Combined Heat And Power (CHP)-Distributed Benefits-Integrated Resource Planning (IRP) and Demand-Side Management (DSM) – Scheduling and dispatch of DG.

Modelling of Wind turbines and Solar systems

Power in wind-Average power in the wind- simple estimates of wind turbine energy- Modelling of Wind turbines- Singly Fed and Doubly Fed Induction Generators (SFIG & DFIG) – Constant and variable speed wind turbines- Solar energy models- Linear and Non-linear.

State of the art of hybrid systems

Hybrid systems with PV Systems and Fuel cell-Hybrid systems options-Main components of Hybrid systems- Frequency control methods-Reactive control of hybrid systems-Control and Simulation Techniques.

Issues of Distributed Generation-Case studies

Sizing and siting of Distributed Generation-Benefit indices estimation-Contract Pricing -Protection Planning issues - Optimal Renewable Resources Mix.

Reference Books

1. Gilbert M.Masters, “Renewable and Efficient Electric Power Systems”, John Wiley & Sons,Inc.,Hoboken,New Jersey,2004.
2. Bansal.R, Bhatti.T.S, “ Small signal Analysis of isolated Hybrid power systems”, Narosa Publishing House Pvt.Ltd.New Delhi,2008.
3. Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright,Mike Hughes, “Wind Energy Generation Modelling and Control” John Wiley & Sons, Ltd,2009.
4. Zekai Sen “Solar Energy Fundamentals and Modeling Techniques” Springer-Verlag London Limited, 2008.
5. Tomas Petru and Torbjorn Thiringer, “Modeling of Wind Turbines for Power System Studies” IEEE Transactions on Power Systems, vol. 17, No.4, November 2002.

6. Paul Breeze, “Power Generation Technologies”, Newnes, An imprint of Elsevier, Linacre House, Jordan Hill, Oxford OX2 8DP,2005.
7. Thomas Ackermann, Goran Andersson, and Lennart Soder: “Distributed generation: a definition”, Electric Power System Research, 51, 2001, pp.195-204.
8. Pathomthat Chiradeja, and R. Ramakumar, “An Approach to Quantify the Technical Benefits of Distributed Generation”, IEEE Transactions on energy conversion, Vol. 19,No. 4, December 2004, pp.764-73.
9. Jesus Maria Lopez-Lezama, Antonio Padilha-Feltrin, Javier Contreras and Jose Ignacio Munoz, “Optimal Contract Pricing of Distributed Generation in Distribution Networks” IEEE Transaction on Power Systems, Vol. 26, No. 1, February 2011, pp.128-136.
10. Stefania Conti, “Analysis of distribution network protection issues in presence of dispersed generation”, Electric Power Systems Research 79 (2009) 49–56.
11. Y.M.Atwa, E.F.El-Saadany, M.M.A.Salama and R.Seethapathy, “Optimal Renewable Resources Mix for Distribution System Energy Loss minimization”, IEEE Transactions on Power Systems, Vol.24, No.1, Feb.2010, PP.360-370.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Distributed Generation**	
1.1	Definition and Technologies-Solar photovoltaic power-wind-fuel cells-Diesel Generator- hydro & Micro turbines	2
1.2	Electricity Generation In Transition- Distributed Generation With Fossil Fuels	1
1.3	Concentrating Solar Power (CSP) Technologies- Biomass For Electricity	2
1.4	Micro-Hydropower Systems- Fuel Cells	2
2.0	**Economics of Distributed Resources**	
2.1	Distributed Resources (DR)- Electric Utility Rate Structures	2
2.2	Energy Economics- Energy Conservation Supply Curves	2
2.3	Combined Heat And Power (CHP)	2
2.4	Distributed Benefits	1
2.5	Integrated Resource Planning (IRP) and Demand-Side Management (DSM) - Scheduling and dispatch of DG	3
3.0	**Modelling of Wind turbines and Solar systems**	
3.1	Power in wind-Average power in the wind	2
3.2	simple estimates of wind turbine energy	2
3.3	Modelling of Wind turbines- Singly Fed and Doubly Fed Induction Generators (SFIG & DFIG)	3
3.4	Constant and variable speed wind turbines	2
3.5	Solar energy models- Linear and Non-linear	3
4.0	**State of the art of hybrid systems**	
4.1	Hybrid Systems with PV Systems and Fuel cell	2
4.2	Hybrid Systems options-Main components of Hybrid systems	2
4.3	Frequency control methods	1
4.4	Reactive control of hybrid systems	2
4.5	Control and Simulation Techniques	1
5.0	**Issues of Distributed Generation-Case studies**	
5.1	Sizing and siting of Distributed Generation	2
5.2	Benefit indices estimation-Contract Pricing	2
5.3	Protection and Planning issues	2
5.4	Optimal Renewable Resources Mix	2
	Total	**45**

Course Designers:

1. Dr. N.Shanmuga Vadivoo nsveee@tce.edu

14PSPE0	**FLEXIBLE AC TRANSMISSION SYSTEMS**	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

FACTS is one aspect of the power electronics revolution that is taking place in all areas of electric energy. Rising energy costs and a greater sensitivity to environmental impact of new transmission lines necessitated the search and application of new controllers to minimize losses and maximize the stable power-transmission capacity of existing lines. Thyristor based controllers provides a very high speed of response in power system control. Flexible ac transmission system (FACTS) technology is the application of a variety of new power-electronic controllers for both active and reactive power on selected lines. FACTS controllers are becoming an integral component of modern power-transmission systems. Students are made to understand about the basics, modeling and control of different types of FACTS controllers.

Prerequisite

- Power Electronics
- Power system analysis & stability

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain the basic principles, characteristics of different types of FACTS controllers.	Understand
CO2.	Compare the performance of various FACTS controllers.	Apply
CO3.	Model FACTS controller for power flow and stability applications.	Understand
CO4.	Select a suitable FACTS controller for a particular application	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S			S				M		
CO2.	S	S	S	M							
CO3.	S			M	S				M		
CO4.	S	S		S	S				M		

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the working of TCR.
2. Explain the characteristics of TCSC.
3. Explain the working of UPFC.

Course Outcome 2 (CO2):

1. Compare SVC and STATCOM.
2. Compare SSSC and TCSC.
3. Compare TSSC and TCSC.

Course Outcome 3 (CO3):

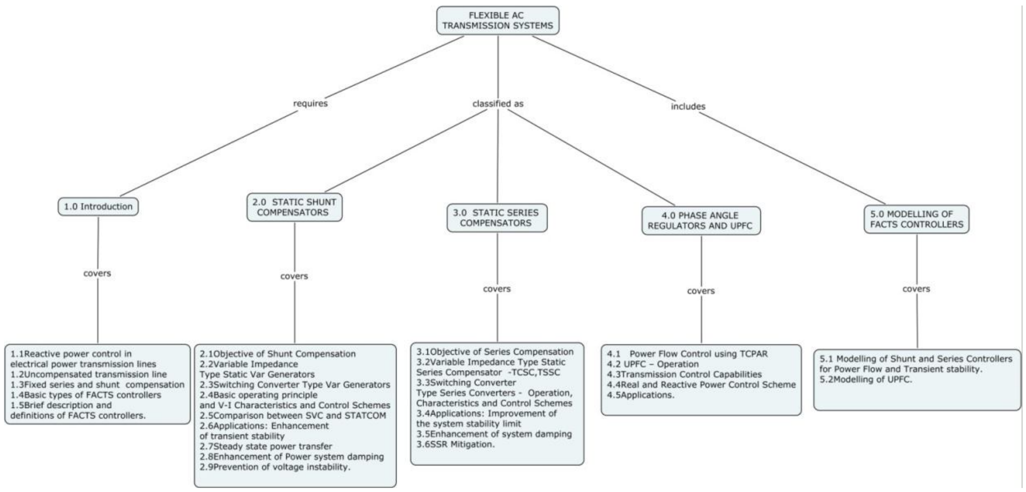
1. How TCSC is used to mitigate SSR?

2. Draw the UPFC model used for power flow studies.
3. Draw the phasor diagram for UPFC.
4. Discuss the application of STATCOM in Power System Damping.

Course Outcome 4 (CO4):

1. Explain the application of UPFC in power flow control
2. Explain the application of TCSC in stability studies
3. Select a suitable controller in improving the voltage profile at a bus.

Concept Map



Syllabus

INTRODUCTION

Reactive power control in electrical power transmission lines -Uncompensated transmission line – Fixed series and shunt compensation – Basic types of FACTS controllers – Brief description and definitions of FACTS controllers.

STATIC SHUNT COMPENSATORS

Objective of Shunt Compensation - Variable Impedance Type Static VAR Generators – Switching Converter Type VAR Generators - Basic operating principle and V-I Characteristics and Control Schemes – Comparison between thyristor based VSC and STATCOM. Applications: Enhancement of transient stability – Steady state power transfer – Enhancement of Power system damping – Prevention of voltage instability.

STATIC SERIES COMPENSATORS

Objective of Series Compensation - Variable Impedance Type Static Series Compensator - TCSC,TSSC – Switching Converter Type Series Converters - Operation, Characteristics and Control Schemes – Modelling of TCSC – Variable reactance model- Applications: Improvement of the system stability limit- Enhancement of system damping – SSR Mitigation.

PHASE ANGLE REGULATORS AND UPFC

Power Flow Control using TCPAR – UPFC – Operation – Transmission Control Capabilities – Real and Reactive Power Control Scheme - Applications.
UPQC & IPFC.

MODELLING OF FACTS CONTROLLERS Modelling of Shunt and Series Controllers for Power Flow and Transient stability. Modelling of UPFC.

Reference Books

1. Narain G. Hingorani, “Understanding FACTS -Concepts and Technology of Flexible AC Transmission Systems”, Standard Publishers Distributors, Delhi- 110006
2. Mohan Mathur.R, Rajiv K.Varma, “Thyristor – Based Facts Controllers for Electrical Transmission Systems”, IEEE press and John Wiley & Sons, Inc.
3. Enrique Acha, Claudio R.Fuerte-Esqivel, Hugo Ambriz-Perez, Cesar Angeles-Camacho” FACTS – Modeling and simulation in Power Networks” John Wiley & Sons.
4. Padiyar.K.S,” FACTS Controllers in Power Transmission and Distribution”, New Age International(P) Limited, Publishers, New Delhi, 2008

5. John.A.T, “Flexible A.C. Transmission Systems”, Institution of Electrical and Electronic Engineers (IEEE), 1999.
6. Sood.V.K,HVDC and FACTS controllers – Applications of Static Converters in Power System, Kluwer Academic Publishers, 2004.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**INTRODUCTION**	
1.1	Reactive power control in electrical power transmission lines	1
1.2	Uncompensated transmission line	1
1.3	Fixed series and shunt compensation	1
1.4	Basic types of FACTS controllers	2
1.5	Brief description and definitions of FACTS controllers.	1
2.0	**STATIC SHUNT COMPENSATORS**	
2.1	Objective of Shunt Compensation	1
2.2	Variable Impedance Type Static VAR Generators	1
2.3	Switching Converter Type VAR Generators	1
2.4	Basic operating principle and V-I Characteristics and Control Schemes	2
2.5	Comparison between thyristor based VSC and STATCOM	1
2.6	Applications: Enhancement of transient stability	2
2.7	Steady state power transfer	1
2.8	Enhancement of Power system damping	1
2.9	Prevention of voltage instability.	1
3.0	**STATIC SERIES COMPENSATORS**	
3.1	Objective of Series Compensation	1
3.2	Variable Impedance Type Static Series Compensator -TCSC,TSSC	2
3.3	Switching Converter Type Series Converters - Operation, Characteristics and Control Schemes	2
3.4	Applications: Improvement of the system stability limit	2
3.5	Enhancement of system damping	1
3.6	SSR Mitigation.	2
4.0	**PHASE ANGLE REGULATORS AND UPFC**	
4.1	Power Flow Control using TCPAR	1
4.2	UPFC – Operation	1
4.3	Transmission Control Capabilities	2
4.4	Real and Reactive Power Control Scheme	2
4.5	Applications. UPQC & IPFC	2
5.0	**MODELLING OF FACTS CONTROLLERS**	
5.1	Modelling of Shunt and Series Controllers for Power Flow and Transient stability.	3
5.2	Modelling of UPFC.	2
	Total	**40**

Course Designers:

1. Dr.S.Latha sleee@tce.edu

		Category	L	T	P	Credit
14PSPF0	**POWER SYSTEM OPTIMIZATION**	PE	3	1	0	4

Preamble

This course covers the various techniques to solve power system optimization problems such as economic load dispatch, hydro thermal coordination and multi-objective, optimization problems in power system.

Prerequisite

- Power system analysis
- Power system operation and control

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Solve the various unconstrained and constrained optimisation problems	Apply
CO2.	Apply optimisation techniques to Solve the generation scheduling problem in thermal plants	Apply
CO3.	Apply optimisation techniques to Solve hydro thermal scheduling problems	Apply
CO4.	Explain the optimisation methods to solve Multi-objective thermal dispatch problem	Understand
CO5.	Explain the stochastic methods to solve the multi-objective generation scheduling.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	M	M	M	M	L	L	L	L	L	L
CO2.	S	M	M	M	M	L	L	L	L	L	L
CO3.	S	M	M	M	M	L	L	L	L	L	L
CO4.	S	M	L	M	M	L	L	L	L	L	L
CO5.	S	M	L	M	M	L	L	L	L	L	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	30	30	30
Understand	40	40	40	40
Apply	30	30	30	30
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Distinguish between unimodal and multimodal problem.
2. Write short notes on kuhn-tucker condition.
3. Discuss about the features and interpretation of lagrangian multiplier method .
4. Minimise $f(x_1, x_2) = x_1-2x_2+3x_1^2+3x_1x_2+x_2^2$ with the starting point (0,0) by any one of the optimization method.

Course Outcome 2 (CO2):

1. State the economic dispatch problem.
2. Briefly discuss the significance of including the transmission losses in optimal dispatch problem.
3. Explain the method of solving the economic dispatch problem by any one method.
4. The incremental production cost of 2 plants are $dF_1/dP_1 = 2 + 0.01\ P_1$ Rs/MWhr and

$dF_2/dP_2 = 1.5 + 0.01\ P_2$ Rs/MWhr. The loss coeffecient in MW^{-1} are Given. Determine the optimum schedule for the total load of 75 MW.

Course Outcome 3 (CO3):

1. Define – short range hydro thermal scheduling.
2. Discuss in detail the concept of pumped storage plant.
3. Find the optimal schedule for the following hydro thermal plants.
   Steam plant : $dF/dP_s = 2.1 + 0.002\ P_s$ Rs/MWhr. 10<Ps<500 MW
   Hydro plant : $dq/dp_H = 50 + 0.02\ p_H\ ft^3$/sec/MW , 10<PH<500MW
   Load : 24 – 9 Hrs – 350 MW
   9 – 18 Hrs - 700MW
   18 – 24 Hrs – 350 MW
4. Explain the Newton Raphson method for solving hydro-thermal scheduling problem.

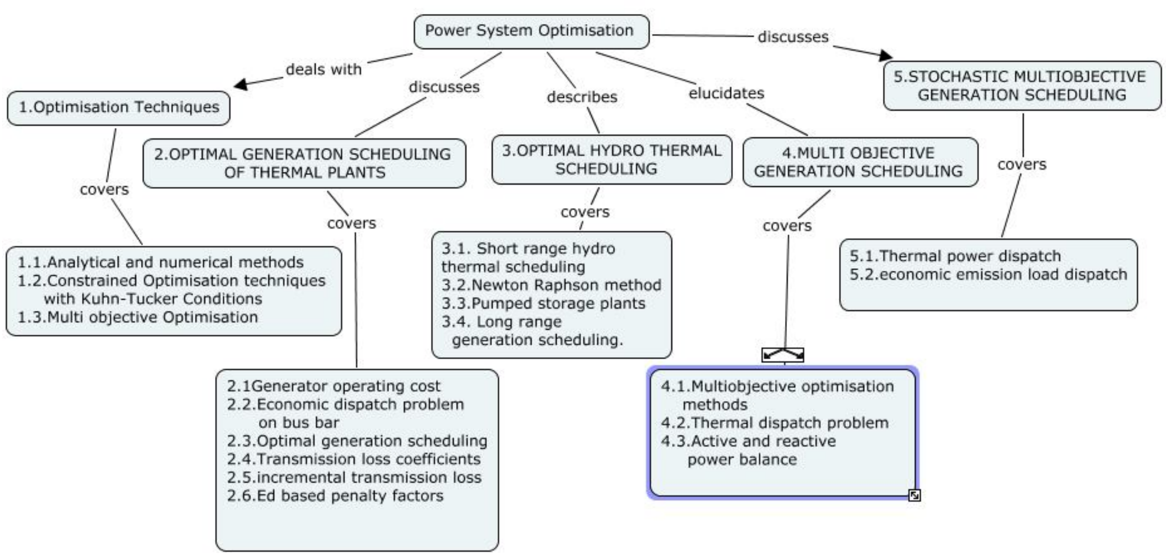
Course Outcome 4 (CO4):

1. What is emission dispatch?
2. Explain ε Constraint method to solve the Multi-objective thermal dispatch problem.
3. Explain the multi-objective dispatch for active and reactive power balance.

Course Outcome 5 (CO5):

1. Define stochastic multi objective generation scheduling.
2. Explain in detail the problem formulation of economic emission load dispatch problem.
3. Explain a suitable method to solve stochastic economic emission load dispatch problem.

Concept Map



Syllabus

OPTIMISATION TECHNIQUES

Statement of an optimization problem – One dimensional minimization- Analytical methods and numerical methods - Constrained optimization - Kuhn Tucker conditions , Lagrangian method , penalty function method , dynamic programming – Multi objective optimization.

OPTIMAL GENERATION SCHEDULING OF THERMAL PLANTS

Introduction-Generator operating cost- Economic Dispatch (ED) problem - constraints -Optimal generation scheduling-Newton Raphson method- Transmission loss coefficients-exact loss formula-incremental transmission loss-ED based on penalty factors.

OPTIMAL HYDROTHERMAL SCHEDULING
Introduction – Short range hydrothermal scheduling – Model - transmission losses – Solution using Newton Raphson method – Hydro plant modelling for long term operation-Pumped storage plants- Long range generation scheduling.

MULTI OBJECTIVE GENERATION SCHEDULING
Introduction – Multi-objective optimisation methods –Multi-objective thermal dispatch problem- ε Constraint method- Multi-objective dispatch for active and reactive power balance.

STOCHASTIC MULTIOBJECTIVE GENERATION SCHEDULING
Introduction- Multi-objective stochastic optimal thermal power dispatch - Stochastic economic emission load dispatch-Problem formulation-Solution approach.

Reference Books

1. D.P.Kothari,J.S.Dhillon ,Power System Optimization , PHI, 2004.
2. Allen J.wood and Bruce F.Wollenberg ,Power Generation , Operation and Control, John Wiley and sons , 2003
3. Nagarath and Kothari, Modern Power system analysis, Tata McGraw Hill, 1998.
4. Hadi Saadat, Power system analysis, WCB/McGraw hill ,1999.
5. S.R.Rao, Engineering optimization theory and practice, New age international Ltd, 1996.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**OPTIMISATION TECHNIQUES**	
1.1	Statement of an optimization problem – One dimensional minimization- Analytical methods and numerical methods	2
1.2	Constrained optimization - Kuhn Tucker conditions , Lagrangian method , penalty function method	2
1.3	dynamic programming – Multi objective optimization	2
2.0	**OPTIMAL GENERATION SCHEDULING OF THERMAL PLANTS**	
2.1	Introduction-Generator operating cost	2
2.2	Economic dispatch problem -constraints	2
2.3	Optimal generation scheduling-Newton Raphson method	3
2.4	Transmission loss coefficients-exact loss formula	2
2.5	Incremental transmission loss	2
2.6	ED based on penalty factors	2
3.0	**OPTIMAL HYDROTHERMAL SCHEDULING**	
3.1	Introduction – Short range hydrothermal scheduling- Model	2
3.2	Transmission losses- Solution using Newton Raphson method	3
3.3	Hydro plant modelling for long term operation -Pumped storage plants	2
3.4	Long range generation scheduling	3
4.0	**MULTI OBJECTIVE GENERATION SCHEDULING**	
4.1	Multi-objective optimisation methods	3
4.2	Multi-objective thermal dispatch problem- ε Constraint method	2
4.3	Multi-objective dispatch for active and reactive power balance	2
5.0	**STOCHASTIC MULTIOBJECTIVE GENERATION SCHEDULING**	

5.1	Multi-objective stochastic optimal thermal power dispatch	2
5.2	Stochastic economic emission load dispatch-Problem formulation-Solution approach	2
	Total	**40**

Course Designers:

1. Dr.K.Selvi kseee@tce.edu
2. Mr.R.Medeswaran rmedes@tce.edu

14PSPGO /14CIP0	**POWER PLANT INSTRUMENTATION AND CONTROL**	Category	L	T	P	Credit
		PE	4	0	0	4

Preamble

This course aims to give the fundamental concepts and practical aspects of power plant instrumentation and control. A power station is a complex entity. It involves a wide range of engineering disciplines. The basic principles of steam and water cycles, fuel, air and flue gas circuits are discussed. Also the steam generator, boiler drum and circulation, water treatment and various types of controls in a steam power plant has been discussed. It includes compression and draught control, feed water control, steam temperature control and control equipment have been discussed. The updated information on combined cycle generation is also provided.

Prerequisite

- Measurements & Instrumentation

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain the basic principles of power system instrumentation and control	Understand
CO2.	Illustrate the boiler operation and its control in a thermal power plant.	Understand
CO3.	Determine the performance of various power plant instrumentation and control systems.	Apply
CO4.	Choose from currently commercially available power plant instrumentation and control systems for a given application.	Analyse

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S			L		L		M	M		
CO2.	S					L	L	M		M	
CO3.	S	S		M			L	M	M	M	
CO4.	S	S		M			M	M	M	M	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	20	20
Apply	20	20	40	40
Analyse	20	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Name the different methods of conventional power generation.
2. Explain the importance of instrumentation.
3. Explain the basic principles of power system control.

Course Outcome 2 (CO2):

1. Explain the nature of steam and the uses of steam.
2. Define the term thermal efficiency.
3. Explain the operation of Gas turbine and combined cycle plants.
4. List the different modules of boiler control mechanism.

Course Outcome 3 (CO3):

1. Describe how the demand setting in power station is done.
2. Discuss briefly about waste to energy plants.

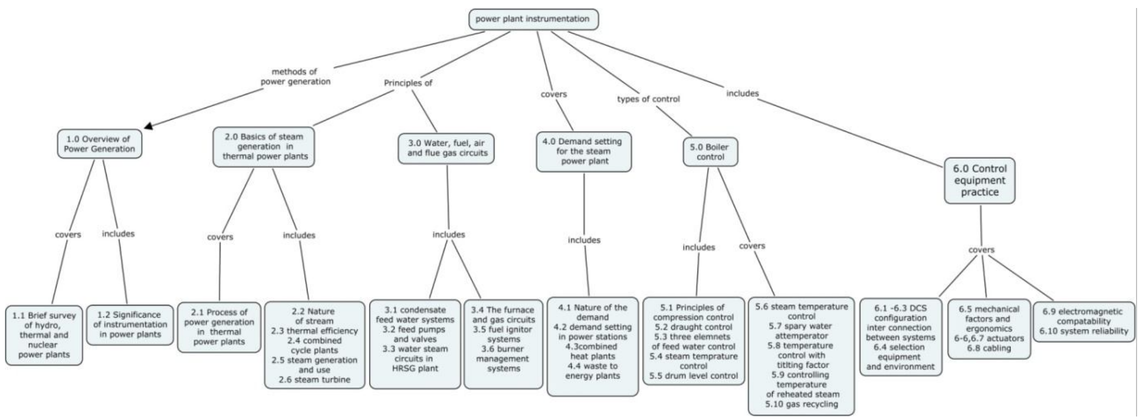
3. Explain how temperature is controlled with tilting burners.
4. List any two types of attemperator.

Compare the operation of two element and three element control used for feed water pumping.

Course Outcome 4 (CO4):

1. Organise the steps involved in compression control.
2. Compare and contrast between an oxygen analyser and a flue gas analyser.
3. Define DCS.
4. State any two advantages of electrical actuators.

Concept Map



Syllabus

Overview of Power Generating Stations: Brief survey of different methods of conventional power generation (hydro, thermal and nuclear)-Importance of instrumentation in power generating stations.

Basics of steam generation in thermal power plants: Process of power generation in coal-fired and oil fired in thermal power plants-Nature of steam-Thermal efficiency-Gas turbine and combined cycle plants-Steam turbine and use-Steam turbine

Water, fuel, air and flue gas circuits: The condensate and feed water system

Feed pumps and valves-The water and steam circuits in HRSC plant

Setting the demand for the steam generator: Nature of the demand-Setting the demand in power stations applications-Master demand in power station applications-Load demand in combined heat and power plants-Waste to energy plants

Boiler control: The principles of compression control-Draught control-The principles of feed water control-One, two and three elements feed water control

Drum level control-Steam temperature control-Spray-water at temperature-Temperature control with tilting burners-controlling temperature of reheated steam-Gas Recycling

Control Equipment Practice: DCS configuration in power plant-A Typical DCS configuration-Interconnections between systems-Equipment selection and environment-Mechanical factors and ergonomics-Electrical actuators-Hydraulic actuators-Cabling-Electromagnetic compatibility-Reliability of systems

Reference Books

1. David Lindsley, “Power Plant Control & Instrumentation ”,IEE Publications, London, UK (2001).
2. Sam G.Dukelow, The control of Boilers, Instrument Society of America, 1991.
3. Elonka, S.M. and Kohal A.L. Standard Boiler Operators, McGraw Hill, New Delhi, 1994.

4. Doebelin, “Measurement Systems”, 5th edition, Tata McGraw-Hill, 2007
5. P.K.Nag, ”Power Plant Engineering” Tata McGraw-Hill, New Delhi, 2005.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**OVERVIEW OF POWER GENERATING STATIONS**	
1.1	Brief survey of different methods of conventional power generation (hydro, thermal and nuclear)	1
1.2	Importance of instrumentation in power generating stations	1
2.0	**Basics of steam generation in thermal power plants**	
2.1	Process of power generation in coal-fired and oil fired in thermal power plants	1
2.2	Nature of steam	1
2.3	Thermal efficiency	1
2.4	Gas turbine and combined cycle plants	1
2.5	Steam generation and use	1
2.6	Steam turbine	1
3.0	**Water, fuel, air and flue gas circuits**	
3.1	The condensate and feed water system	1
3.2	Feed pumps and valves	1
3.3	The water and steam circuits in HRSG plant	1
3.4	The air and gas circuits	1
3.5	Fuel and Igniter systems	1
3.6	Burner- management systems	1
4.0	**Setting the demand for the steam generator**	
4.1	Nature of the demand	1
4.2	Setting the demand in power station applications	1
4.3	Master demand in power station applications	1
4.5	Load demand in combined heat and power plants	1
4.6	Waste to energy plants	1
5.0	**Boiler control**	
5.1	The principles of compression control	1
5.2	Draught control	1
5.3	The principles of feed water control	1
5.4	One, two and three elements feed water control	1
5.5	Drum level control	2
5.6	Steam temperature control	1
5.7	Spray-water at temperature	1
5.8	Temperature control with tilting burners,	1
5.9	controlling temperature of reheated steam	1
5.10	Gas Recycling	1
6.0	**Control Equipment Practice**	
6.1	DCS configuration in power plant	1
6.2	A Typical DCS configuration	1
6.3	Interconnections between systems	1
6.4	Equipment selection and environment	1
6.5	mechanical factors and ergonomics	1
6.6	Electrical actuators	1
6.7	Hydraulic actuators	1
6.8	Cabling,	1
6.9	Electromagnetic compatibility	1
6.10	Reliability of systems	1

		Total	**40**

Course Designers:

1.	Dr.M.Geethanjali	mgeee@tce.edu
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		Category	L	T	P	Credit
14PSPH0	**POWER SYSTEM RELIABILITY**	PE	3	1	0	4

Preamble

Electric power networks are prime examples of systems where a high degree of reliability is expected. Reliability is one of the major factors in the planning, design, operation, and maintenance of electric power system. The reliability of electric power supply system has been defined as the probability of providing the users with continuous service of satisfactory quality.
Power system reliability assessment is divided into two basic aspects: System Adequacy and System Security. Adequacy relates to the existence of sufficient facilities within the system to satisfy the consumer load demand with system operational constraints. This subject concerns with Adequacy Assessment of Electric Power System. In this subject Loss Of Load Expected (LOLE) method of Electric power generation system reliability assessment is explained for both single area system and interconnected system. Frequency and Duration (F &D) method of Electric power system reliability assessment is explained for generation and transmission system.

Prerequisite

- Power System analysis
- Power System operation and control

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain the basic reliability concepts and measures.	Understand
CO2.	Familiar with the different types of reliability indices evaluation methods for generating systems	Apply
CO3.	Explain different types of reliability indices evaluation methods for transmission systems	Apply
CO4.	Describe the different types of reliability indices evaluation methods used in composite systems and interconnected systems.	Apply
CO5.	Explain different types of reliability indices evaluation methods for HVDC systems.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	M	M								
CO2.	S	M	M								
CO3.	S		M								
CO4.	S	M	M								
CO5.	S	M	S	M	M	M					

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	20	20	20	20
Apply	70	70	70	70
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

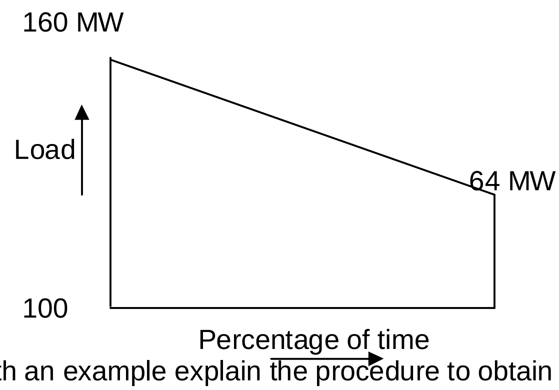
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Obtain the system reliability when 'n' components connected in series.
2. Derive the general reliability function.
3. Define the term FOR.

Course Outcome 2 (CO2):

1. If ‘i’ and ‘j’ are two identical capacity states and ‘k’ designated as the merged state, for C_k, write the values P_k, and F_k.
2. Describe recursive technique used in reliability studies
3. Give step by step procedure to obtain expected load loss, for a system containing 5-40 MW units with a forced outage rate of 0.01 and the load model is given below



4. With an example explain the procedure to obtain capacity outage probability table

Course Outcome 3 (CO3):

1. What is the difference between capacity outage and loss of load?
2. Give the advantages and disadvantages of average interruption rate method.
3. Evaluate the equivalent model parameters λ and r for two components in series.
4. Give the advantages and disadvantages of average interruption rate method
5. Draw schematic diagram of two plant single load system and give the procedure for reliability evaluation of system failure.

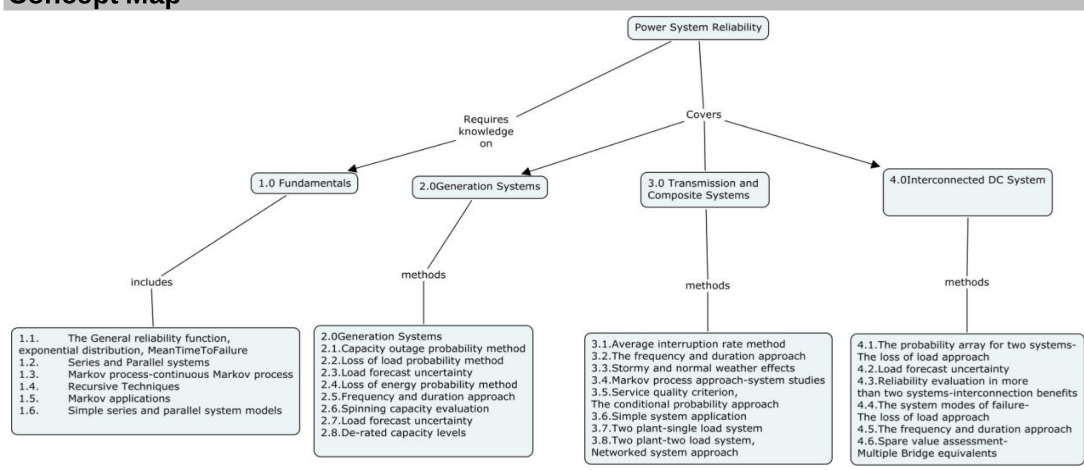
Course Outcome 4 (CO4):

1. Discuss the methods used to evaluate de-rated capacity levels
2. Interconnection between systems improves the overall level of system reliability. By loss of load approach, prove the above statement using three areas.
3. Write the benefits of interconnection.

Course Outcome 5 (CO5):

1. Draw the state space diagram for a single bridge.
2. “Determination of a reliability index based upon service quality involves more effort” why?
3. Illustrate the step by step procedure to obtain multiple bridge equivalents

Concept Map



Syllabus

Fundamentals

The General reliability function – The exponential distribution – Mean time to failure – series and parallel systems – Markov processes – continuous Markov processes – Recursive Techniques, Markov applications – Simple series and parallel system models

Generation Systems

Evaluation of Power Generation systems reliability indices – LOLP, LOLE, EENS, Power Interruption Frequency and Duration & System minutes.

Capacity outage probability method - Loss of load probability method-Load forecast uncertainty, Loss of energy probability method – frequency and duration approach – conclusion spinning capacity evaluation – Load forecast uncertainty – De-rated capacity levels.

Transmission and Composite Systems

Average interruption rate method – The frequency and duration method – stormy and normal weather effects – The Markov process approach – system studies-Service quality criterion – The conditional probability approach – simple system application, Two plant-single load system, Two plant – two load system - networked system approach.

Interconnected System and HVDC System

The Probability array for two systems – The loss of load approach – Load forecast uncertainty – Reliability evaluation in more than two systems-interconnection benefits- The system modes of failure – The loss of load approach – The frequency and duration approach – spare value assessment – Multiple Bridge equivalents.

Reference Books

1. Roy Billinton, "Power System Reliability Evaluation", Gordon and Breach Science Publishers, Newyork,1970 Edition.
2. X.Wang and J.R.McDonald, "Modern Power System Planning", Mc Graw Hill book Company. 1994 Edition
3. Roy Billinton and R.N.Allan, "Reliability Evaluation of Power Systems, Pitman", London, 1984 Edition.
4. J.Endrenyi, "Reliability modelling in Electric Power System", John wiley & Sons, Newyork
5. U.G.Knight, "Power System Engineering Mathematics", Pergamon Press – Gofard 1972
6. B.R.Gupta, "Generation of Electrical Energy" – Chand & Co Ltd., 1996 Third Edition.
7. Roy Billinton, Ronald N.Allan, "Reliability Evaluation of Engineering Systems", Pitman Books Limited, London. 1983

Course Contents and Lecture Schedule

Module No	Topics	No. of Lecture Hours
1.0	**Fundamentals**	
1.1.	The General reliability function, exponential distribution, Mean Time To Failure	3
1.2.	Series and Parallel systems	1
1.3.	Markov process-continuous Markov process	3
1.4.	Recursive Techniques	2
1.5.	Markov applications	2
1.6.	Simple series and parallel system models	2
2.0	**Generation Systems**	
2.1.	Evaluation of Power Generation systems reliability indices – LOLP, LOLE, EENS, Power Interruption Frequency and Duration & System minutes.	2
2.2.	Capacity outage probability method	2
2.3.	Loss of load probability method	2
2.4.	Load forecast uncertainty	1
2.5.	Loss of energy probability method	2

2.6.	Frequency and duration approach	2
2.7.	Spinning capacity evaluation	2
2.8.	Load forecast uncertainty	1
2.9.	De-rated capacity levels	2
3.0	**Transmission and Composite Systems**	
3.1.	Average interruption rate method	1
3.2.	The frequency and duration approach	2
3.3.	Stormy and normal weather effects	1
3.4.	Markov process approach-system studies	1
3.5.	Service quality criterion, The conditional probability approach	1
3.6.	Simple system application	1
3.7.	Two plant-single load system	1
3.8.	Two plant-two load system, Networked system approach	1
4.0	**Interconnected System and HVDC System**	
4.1.	The probability array for two systems-The loss of load approach	1
4.2.	Load forecast uncertainty	1
4.3.	Reliability evaluation in more than two systems-interconnection benefits	2
4.4.	The system modes of failure-The loss of load approach	1
4.5.	The frequency and duration approach	1
4.6.	Spare value assessment-Multiple Bridge equivalents	1
	Total	**45**

Course Designer:

1. Dr.P.Renuga preee@tce.edu

14PSPJ0/ 14CIP0	**SCADA**	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Knowledge of basic control theory is essential for studying this course. This course is designed to impart the knowledge of industrial SCADA system implementation. Emphasis is also given to modems and trouble shooting.

Prerequisite

- Measurements & Instrumentation.

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain the basic building blocks of SCADA system	Understand
CO2.	Illustrate the role of PLC as RTU in SCADA system	Understand
CO3.	Describe the hardware and firmware requirements of SCADA Systems	Understand
CO4.	Explain the communication protocols of SCADA system	Understand
CO5.	Outline the troubleshooting mechanisms of SCADA System	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S	M								
CO2.	S	M	M		M						
CO3.	S	M	M	M	M						
CO4.	S	M	M		M						
CO5.	S	M	M		M						

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	30	30	30
Understand	70	70	70	70
Apply	0	0	0	0
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Outline the hierarchy of a typical SCADA system.
2. Explain about SCADA system hardware and firmware
3. List the Key features of SCADA software.

Course Outcome (CO2):

1. State the need for RTU in SCADA system.
2. Explain the role of multiplexers in Signal conditioning stage.
3. Explain about the possible power supply requirement for RTU.

Course Outcome (CO3):

1. List any three hardware used in SCADA system.
2. Explain the need for software in information exchange between RTU's.
3. State the role of application programs for RTU.

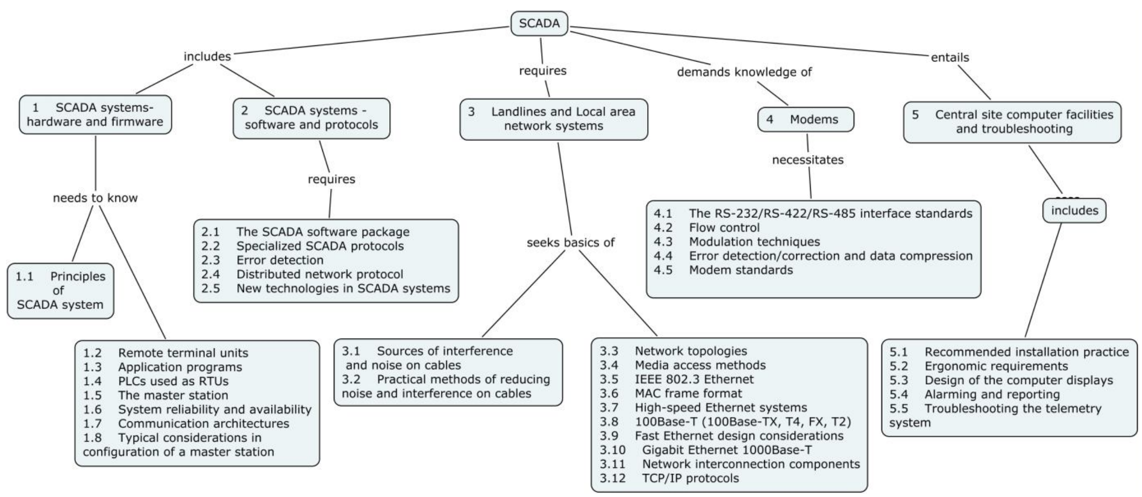
Course Outcome (CO4):

1. Describe the role of communication protocols in SCADA system.
2. List any three advantages of LAN in SCADA system
3. State the merits of point to point communication in SCADA system.

Course Outcome (CO5):

1. List the two methods of representing a data.
2. Describe the procedures for troubleshooting RTU.
3. List any three key ideas for effective maintenance of system program.

Concept Map



Syllabus

Syllabus

SCADA systems- hardware and firmware

Principles of SCADA system - Remote terminal units - Application programs- PLCs used as RTUs - The master station - System reliability and availability - Communication architectures - Typical considerations in configuration of a master station

SCADA systems - software and protocols

The SCADA software package - Specialized SCADA protocols - Error detection - Distributed network protocol - New technologies in SCADA systems

Landlines and Local area network systems

Sources of interference and noise on cables - Practical methods of reducing noise and interference on cables - Network topologies - Media access methods - IEEE 802.3 Ethernet - MAC frame format - High-speed Ethernet systems - 100Base-T (100Base-TX, T4, FX, T2) - Fast Ethernet design considerations - Gigabit Ethernet 1000Base-T - Network interconnection components - TCP/IP protocols

Modems

The RS-232/RS-422/RS-485 interface standards - Flow control - Modulation techniques - Error detection/correction and data compression - Modem standards

Central site computer facilities and troubleshooting

Recommended installation practice - Ergonomic requirements - Design of the computer displays - Alarming and reporting - Troubleshooting the telemetry system

Reference Books

1. David Bailey, Edwin Wright, "Practical SCADA for Industry", Newnes, An imprint of Elsevier 2006.

2. Gordon Clarke, Deon Reynders, Edwin Wright "Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems", Newnes, An imprint of Elsevier 2004.

Course contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**SCADA systems- hardware and firmware**	
1.1	Principles of SCADA system	1
1.2	Remote terminal units	1
1.3	Application programs	1
1.4	PLCs used as RTUs	2
1.5	The master station	1
1.6	System reliability and availability	1
1.7	Communication architectures	2
1.8	Typical considerations in configuration of a master station	1
2	**SCADA systems - software and protocols**	
2.1	The SCADA software package	1
2.2	Specialized SCADA protocols	2
2.3	Error detection	2
2.4	Distributed network protocol	1
2.5	New technologies in SCADA systems	1
3	**Landlines and Local area network systems**	
3.1	Sources of interference and noise on cables	1
3.2	Practical methods of reducing noise and interference on cables	1
3.3	Network topologies	2
3.4	Media access methods	1
3.5	IEEE 802.3 Ethernet	1
3.6	MAC frame format	1
3.7	High-speed Ethernet systems	1
3.8	100Base-T (100Base-TX, T4, FX, T2)	1
3.9	Fast Ethernet design considerations	1
3.10	Gigabit Ethernet 1000Base-T	1
3.11	Network interconnection components	1
3.12	TCP/IP protocols	1
4	**Modems**	
4.1	The RS-232/RS-422/RS-485 interface standards	1
4.2	Flow control	1
4.3	Modulation techniques	1
4.4	Error detection/correction and data compression	1
4.5	Modem standards	1
5	**Central site computer facilities and troubleshooting**	
5.1	Recommended installation practice	1
5.2	Ergonomic requirements	1
5.3	Design of the computer displays	1
5.4	Alarming and reporting	1
5.5	Troubleshooting the telemetry system	1
	Total	**40**

Course Designers

1. Mr.S.Sivakumar siva@tce.edu

2. Dr.D.Kavitha dkavitha@tce.edu
3. Mr.B.Ashok Kumar ashokudt@tce.edu

		Category	L	T	P	Credit
14PSPK0	**SMART GRID**	PE	3	1	0	4

Preamble

This course covers the fundamentals of smart power grids technologies and different smart meters and advanced metering infrastructure. The automation and computational techniques needed to ensure that the Smart Grid guarantees adaptability and capability of handling new systems and components are discussed. The course offers an introduction of power systems smart elements with computational intelligence, communication technology and decision support system.

Prerequisite

Power Converters for Distributed Generation Systems

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain the fundamentals of smart power grids.	Understand
CO2.	Describe the operation of smart grid components.	Understand
CO3.	Explain the advanced metering infrastructure.	Understand
CO4.	Perform various analyses for smart grid design.	Apply
CO5.	Explain the communication and information used in smart grid.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S										
CO2.	S		L	M				M		L	
CO3.	S								L	M	
CO4.	S	M	M	M	M	M		M			
CO5.	S					S			L		

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	60	60	60	60
Apply	20	20	20	20
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define - Smart grid.
2. Explain the difference between conventional & Smart Grid.
3. Write short notes on Self Healing Grid.

Course Outcome 2 (CO2):

1. List the requirements of Phasor Measurement Unit.
2. Explain various methods used for optimal placement of PMU.
3. Describe the steps needed for Substation Automation.

Course Outcome 3 (CO3):

1. Explain the role of advanced metering in smart grid.
2. Describe the AMI protocols used in smart grid.
3. Compare Microgrid and Smart Grid concepts.

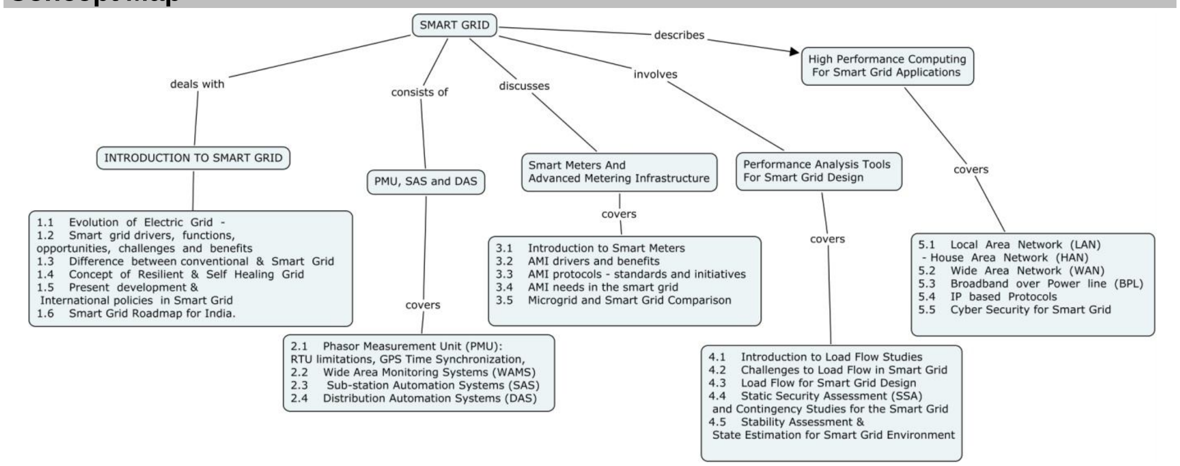
Course Outcome 4 (CO4):

1. Perform state estimation for a given smart grid application.
2. Describe the modification involved in using load flow analysis in smart grid.
3. Compare Contingency Studies used for conventional grids and Smart Grid.

Course Outcome 4 (CO4):

1. List the advantages of cloud Computing techniques.
2. Describe about IP based Protocols.
3. Discuss in detail the Neighborhood Area Communications and Home Area Network topology.
4. Discuss the different network topologies in smart grid.

Concept Map



Syllabus

INTRODUCTION TO SMART GRID

Evolution of Electric Grid - Concept, Definitions and Need for Smart Grid - Smart grid drivers, functions, opportunities, challenges and benefits - Difference between conventional & Smart Grid - Concept of Resilient & Self Healing Grid - Present development & International policies in Smart Grid - Smart Grid Roadmap for India.

PMU, SAS and DAS

Phasor Measurement Unit (PMU): Requirements, RTU limitations, GPS Time Synchronization, Location & Placement, Features - Wide Area Monitoring Systems (WAMS) - Sub-station Automation Systems (SAS) - Distribution Automation Systems (DAS)

SMART METERS AND ADVANCED METERING INFRASTRUCTURE

Introduction to Smart Meters - Advanced Metering infrastructure (AMI) drivers and benefits - AMI protocols - standards and initiatives - AMI needs in the smart grid - Microgrid and Smart Grid Comparison.

PERFORMANCE ANALYSIS TOOLS FOR SMART GRID DESIGN

Introduction to Load Flow Studies - Challenges to Load Flow in Smart Grid - Load Flow for Smart Grid Design - Static Security Assessment (SSA) and Contingency Studies for the Smart Grid - Stability Assessment & State Estimation for Smart Grid Environment.

HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS

Local Area Network (LAN) - House Area Network (HAN) - Wide Area Network (WAN) - Broadband over Power line (BPL) - IP based Protocols - Basics of Web Service and CLOUD Computing to make Smart Grids smarter - Cyber Security for Smart Grid.

Reference Books

1. Stuart Borlase, “Smart Grid: Infrastructure, Technology and Solutions”, CRC Press 2012.
2. James Momoh, “Smart Grid Fundamentals of Design and Analysis”, IEEE Press, 2012.
3. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley & Sons Ltd., February 2012.
4. Ali Keyhani and Muhammad Marwali, “Smart Power Grids 2011”, Springer Publications, 2011.
5. Christine Hertzog, “Smart Grid Dictionary”, Springer publications, 2009.
6. Tony Flick, Justin morehouse, “Securing the smart grid: Next generation power grid security”, Elsevier, 2010.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Introduction To Smart Grid**	
1.1	Evolution of Electric Grid - Concept, Definitions and Need for Smart Grid	2
1.2	Smart grid drivers, functions, opportunities, challenges and benefits	2
1.3	Difference between conventional & Smart Grid	1
1.4	Concept of Resilient & Self Healing Grid	1
1.5	Present development & International policies in Smart Grid	1
1.6	Smart Grid Roadmap for India.	1
2.0	**PMU, SAS and DAS**	
2.1	Phasor Measurement Unit (PMU): Requirements, RTU limitations, GPS Time Synchronization, Location & Placement, Features	2
2.2	Wide Area Monitoring Systems (WAMS)	2
2.3	Sub-station Automation Systems (SAS)	2
2.4	Distribution Automation Systems (DAS)	2
3.0	**Smart Meters And Advanced Metering Infrastructure**	
3.1	Introduction to Smart Meters	1
3.2	Advanced Metering infrastructure (AMI) drivers and benefits	2
3.3	AMI protocols - standards and initiatives	2
3.4	AMI needs in the smart grid	1
3.5	Microgrid and Smart Grid Comparison	1
4.0	**Performance Analysis Tools For Smart Grid Design**	
4.1	Introduction to Load Flow Studies	1
4.2	Challenges to Load Flow in Smart Grid	2
4.3	Load Flow for Smart Grid Design	2
4.4	Static Security Assessment (SSA) and Contingency Studies for the Smart Grid	2
4.5	Stability Assessment & State Estimation for Smart Grid Environment	2
5.0	**High Performance Computing For Smart Grid Applications**	
5.1	Local Area Network (LAN) - House Area Network (HAN)	2
5.2	Wide Area Network (WAN)	1
5.3	Broadband over Power line (BPL)	1
5.4	IP based Protocols - Basics of Web Service and CLOUD Computing to make Smart Grids smarter	2
5.5	Cyber Security for Smart Grid	2
	Total	**40**

Course Designers:

1.	Dr.V.Saravanan	vseee@tce.edu
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14PSPL0	HVDC TRANSMISSION	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

High voltage direct current transmission has advantages over ac transmission in special situations. With the advent of thyristor valve converters, HVDC transmission became even more attractive. This course deals with the operation, modeling and control of HVDC link in power system. Also, steady state analysis of AC/DC system and various HVDC simulations are discussed in this course.

Prerequisite

- High voltage engineering
- Transmission and distribution

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain the modern technology used in HVDC.	Understand
CO2.	Describe control strategies used in HVDC system with HVDC converters and multi terminal dc system .	Understand
CO3.	Apply suitable method for power flow analysis in AC/DC systems.	Apply
CO4.	Simulate simple HVDC system for the given specifications.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S										
CO2.	S										
CO3.	S	M	M	M	L						
CO4.	S	M	M	M	S						

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	50	50	50	50
Apply	30	30	30	30
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Differentiate AC and DC transmission systems.
2. Explain modern trends in DC transmission system.
3. Explain the specifications and concepts used DC transmission system.
4. List the advantages of DC transmission.

Course Outcome 2 (CO2):

1. Define pulse number.
2. Explain the types of MTDC systems.
3. Explain the characteristics of a twelve pulse converter used in HVDC.
4. Explain about current and extinction angle control

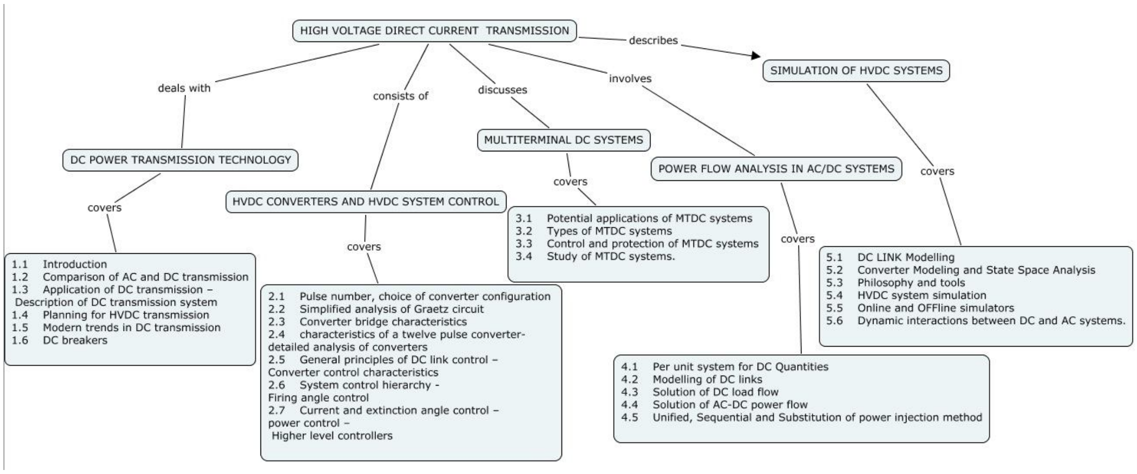
Course Outcome 3 (CO3):

1. List the advantages of per unit quantities in DC system.
2. Compare the solution of DC power flow over AC power flow in DC system.
3. Perform power flow analysis using substitution of power injection method.

Course Outcome 4 (CO4):

1. Model DC LINK in a power system.
2. Simulate a simple DC system using any one OFF line simulator tool.
3. Explain the dynamic interactions between DC and AC systems.

Concept Map



Syllabus

DC POWER TRANSMISSION TECHNOLOGY

Introduction - Comparison of AC and DC transmission – Application of DC transmission – Description of DC transmission system - Planning for HVDC transmission – Modern trends in DC transmission – DC breakers.

HVDC CONVERTERS AND HVDC SYSTEM CONTROL

Pulse number, choice of converter configuration – Simplified analysis of Graetz circuit - Converter bridge characteristics – characteristics of a twelve pulse converter- detailed analysis of converters- General principles of DC link control – Converter control characteristics – System control hierarchy - Firing angle control – Current and extinction angle control – power control – Higher level controllers.

MULTI TERMINAL DC SYSTEMS

Introduction – Potential applications of MTDC systems - Types of MTDC systems - Control and protection of MTDC systems - Study of MTDC systems.

POWER FLOW ANALYSIS IN AC/DC SYSTEMS

Per unit system for DC Quantities - Modelling of DC links - Solution of DC load flow - Solution of AC-DC power flow – Unified, Sequential and Substitution of power injection method.

SIMULATION OF HVDC SYSTEMS

Introduction – DC LINK Modelling, Converter Modelling and State Space Analysis, Philosophy and tools – HVDC system simulation, Online and OFF line simulators – Dynamic interactions between DC and AC systems.

Reference Books

1. P. Kundur, “Power System Stability and Control”, McGraw-Hill, 1993
2. K.R.Padiyar, “HVDC Power Transmission Systems”, New Age International (P) Ltd., New Delhi, 2002.
3. J.Arrillaga, “High Voltage Direct Current Transmission”, Peter Pregrinus, London, 1983.
4. Erich Uhlmann, “Power Transmission by Direct Current”, BS Publications, 2004.
5. V.K.Sood, “HVDC and FACTS controllers – Applications of Static Converters in Power System”, APRIL 2004, Kluwer Academic Publishers.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture hours
1.0 DC POWER TRANSMISSION TECHNOLOGY		
1.1	Introduction	1
1.2	Comparison of AC and DC transmission	1
1.3	Application of DC transmission – Description of DC transmission system	2
1.4	Planning for HVDC transmission	1
1.5	Modern trends in DC transmission	2
1.6	DC breakers	1
2.0 HVDC CONVERTERS AND HVDC SYSTEM CONTROL		
2.1	Pulse number, choice of converter configuration	1
2.2	Simplified analysis of Graetz circuit	1
2.3	Converter bridge characteristics	1
2.4	characteristics of a twelve pulse converter- detailed analysis of converters	2
2.5	General principles of DC link control – Converter control characteristics	2
2.6	System control hierarchy - Firing angle control	1
2.7	Current and extinction angle control – power control – Higher level controllers	2
3.0 MULTI TERMINAL DC SYSTEMS		
3.1	Potential applications of MTDC systems	2
3.2	Types of MTDC systems	2
3.3	Control and protection of MTDC systems	2
3.4	Study of MTDC systems.	2
4.0 POWER FLOW ANALYSIS IN AC/DC SYSTEMS		
4.1	Per unit system for DC Quantities	1
4.2	Modelling of DC links	2
4.3	Solution of DC load flow	2
4.4	Solution of AC-DC power flow	2
4.5	Unified, Sequential and Substitution of power injection method	3
5.0 SIMULATION OF HVDC SYSTEMS		
5.1	DC LINK Modelling	1
5.2	Converter Modelling and State Space Analysis	2
5.3	Philosophy and tools	1
5.4	HVDC system simulation	2
5.5	Online and OFF line simulators	2
5.6	Dynamic interactions between DC and AC systems.	1
	Total	**45**

Course Designer:

1. Dr. S.Charles Raja charlesrajas@tce.edu

14PSPM0 RENEWABLE ENERGY SOURCES

Category	L	T	P	Credit
PE	4	0	0	4

Preamble

Renewable energy sources are gaining importance to minimize the global warming. Presently around 5% of total energy usage is met by Renewable Energy Sources. The renewable energy usage may be met up to 50% level in the end of this century to make the world green. Energy has become an important and one of the basic infrastructures required for the economic development of a country. Energy security is imperative for sustained growth of economy. The importance and role of renewable energy sources is stressed on the aspects of growing energy demand. The harnessing of energy through renewable resources, using efficient technologies is expected to play an important role of serving a clean energy source for mankind and for the mother earth.

The mission of the Renewable Energy Sources Course is to prepare students for the challenges of designing, promoting and implementing renewable energy solutions. Graduates will have a fundamental understanding of energy engineering and a sense of social responsibility for the implementation of sustainable energy solutions.

Prerequisite

- Fundamentals of Electrical Energy Consumption and Energy Calculation
- Basics of Power Generation and Energy resources

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Describe the challenges and problems associated with the use of various energy sources, including fossil fuels, with regard to future supply and the environment.	Understand
CO2.	Discuss remedies/potential solutions to the supply and environmental issues associated with fossil fuels and other energy resources.	Apply
CO3.	Selection, Design, Operation and Operation of Solar PV System for different types of applications	Create
CO4.	Selection, Design and Operation of Wind Turbine System	Create
CO5.	Small Scale Hydroelectric Plant Selection and Design	Apply
CO6.	Biomass Power Generation Types, Applicability and Limitations	Apply
CO7.	Collect and organize information on renewable energy technologies as a basis for further analysis and evaluation.	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S								S	S	
CO2.	S									S	
CO3.	S	S	S	S		M					
CO4.	S	S	S	S		M					
CO5.	S	S	S	S							
CO6.	S					L					
CO7.	S	S	L						S		

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	10	10
Understand	50	50	40	40
Apply	30	30	30	30
Analyse	0	0	10	10
Evaluate	0	0	0	0
Create	0	0	10	10

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define the term per capita Energy consumption.
2. What is meant by Global Warming? What are the various reasons for Global Warming?
3. State the objective of Kyoto Protocol.
4. Discuss the Impacts of fossil fuel usage on Environmental. Also suggest methods to overcome

Course Outcome 2 (CO2):

1. List the non-commercial energy sources as on date on earth? Also explain the strategy to make the non-commercial energy sources into viable commercial energy sources?
2. Give an outline of energy reserves of India. Also discuss the methods to bridge the gap between Demand and Supply in India by the short-term method.
3. Explain the concept of Clean Development Mechanism to save the earth and meet the sustainable energy development.

Course Outcome 3 (CO3):

1. List the three types of solar cell based on manufacturing technique.
2. With a block diagram, explain the operation of Grid-Tie Solar PV System. Also mention its advantages and limitations.
3. Explain the principle of direct solar energy to Electrical energy conversion? Specify its limitations?
4. Calculate the number of PV modules required to produce 240kW rated power Solar array operating at voltage output of 480Volts DC Supply. A solar cell gives a voltage and power output of 0.5Volts and 1.5Watts respectively. A 300Watts 24Volts rated Solar PV Modules are used. Also specify the number of modules to be connected in parallel and series to produce the rated power of 240kW Solar PV array.
5. Design a Solar PV System to meet the energy requirement of a Cafe located at remote tourist spot and operates during Daytime needs 3600Watts of AC power for 8hours a day supplied by 14% Efficient Poly-crystalline type solar PV cell along with a battery back-up system. The operating voltage of the battery storage system is 24Volts DC Supply. The solar radiation falling on that location is equivalent to 820Wattts per square meter area. An average basis, the sun is available for 4hours daily. Design the battery size to meet the 50% energy requirement during dull sun period of every day.

Course Outcome 4 (CO4):

1. State the advantages of slow speed synchronous generator over Induction generator for wind turbine applications.
2. List the various types of Electric generator used for energy conversion in Wind turbine. Also explain the recent development in Electric generator for the above applications, along with its advantages.
3. State the various issues raised against wind turbine installation across the world. Suggest the ways and means to minimize/solving these issues.
4. Explain the need of Yaw and Pitch control in Wind turbine and specify the wind parameters to be measured to perform the above control.
5. Calculate the generated electric power, when the wind speed is 8.4 meters per second for a horizontal axis three blade wind turbine machine having rotor blade diameter of 75meter. The co-efficient of power activated in the wind turbine is 0.56. The Gear and Coupling

Efficiency is 90%. The conversion efficiency of the generator is 93%. Also calculate the power generated, when the wind speed rise by 25% more than the previous case.

6. Design a suitable size electric generator for a wind turbine, where the rated wind Speed is 14 Meter/Second and Co-efficient of Power Activation is 0.52. The suggested rotor blade diameter of the wind turbine is 75meter. Assume suitable relevant data for the design.

Course Outcome 5 (CO5):

1. Discuss the specific application of pumped storage hydro electric power plants. Mention its limitations.
2. A Run-off river plant with small pond is installed in a site, where the water stream flow rate is 90 cubic meter per second during daytime 12 Hours & 45 Cubic meter per second during night time 12 Hours and head availability is 45 meter. A Turbo jet turbine having 63% conversion efficiency is installed. The generator efficiency is 92%. Calculate the Energy produced form the hydro electric power plant in a day?
3. A pumped storage power plant operates for 4Hours daily to supply 90MW of power to the grid during peak hours at 94% overall plant efficiency . The net head availability is 210Meter. The same power plant operate in pump mode to pump back the water in 4Hours daily from the lower bay to upper bay during off-peak hours at 92% efficiency. The cost of power during peak hours and off-peak hours is Rs.4.50/kWh and Rs.2.50/kWh respectively. Calculate the cost saved per day. Also calculate the water discharge during power generation and quantity of water pumped back.

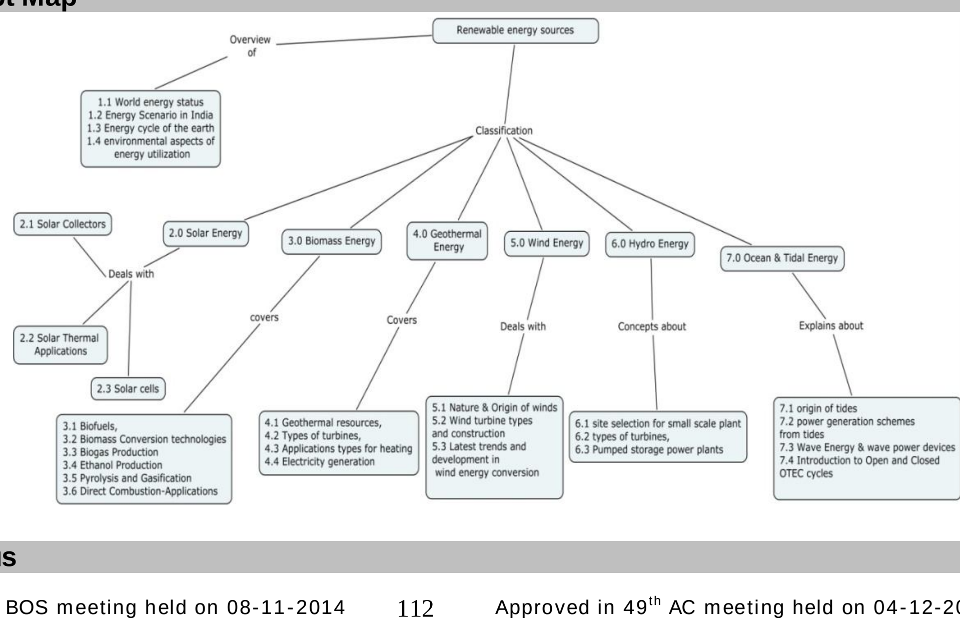
Course Outcome 6 (CO6):

1. What is meant by Energy Plantation?
2. List the various methods of producing power by biomass direct combustion. Also specify the limitations and method to overcome.
3. Explain the method of producing gas from Biomass using Thermo chemical process.
4. What are the advantages of biomass gasification, when compared to biomass direct combustion? Also specify the limitations of biomass gasification.

Course Outcome 7 (CO7):

1. Analyze the impact of harnessing Biomass and Hydro energy on Environment & related issues?
2. Discuss the benefits of green energy, when compare to fossil type energy. Also mention the limitations of green energy.
3. Explain the principle of energy conversion from wave energy with the help of Tapered channel systems and float systems?
4. Compare the contrast between the Dry & Flash Steam type Geo-thermal power plant with a block diagram.

Concept Map



Syllabus

Energy Overview: Classification of Energy Resources, World energy status, Energy Scenario in India-energy cycle of the earth-environmental aspects of energy utilization-renewable energy resources and their importance, Carbon credit.
Solar Energy: Solar cells types, Characteristics, Insolation, MPPT, Standalone & Grid Connected Solar PV System Selection, Grid-Tie Inverter, Design, Operation and Maintenance.
Biomass Energy: Bio-fuels, Biomass Conversion technologies, Biogas Production-Ethanol Production-Pyrolysis and Gasification-Direct Combustion-Biomass power generation status, Applications.
Geothermal Energy: Geothermal resources, basic theory-types of turbines-applications types, applications for heating and electricity generation
Wind Energy: Nature & Origin of winds, Wind Potential Estimation, Wind Power Calculation, Wind turbine types and construction, Wind Turbine Ratings, Selection, Latest trends and development in wind energy conversion.
Hydro Energy: Basic concepts site selection and types of turbines for small scale hydropower, Run-off River plant, Role of Pumped storage power plants in Power system for the Voltage and Frequency control, Estimation of Power in Small Scale and Pumped Storage Power plants.
Ocean & Tidal Energy: origin of tides-power generation schemes-Wave Energy, wave power devices, Introduction to Open and Closed OTEC cycles
Environmental Aspects: Energy Payback period & Environmental Payback period, Potential impacts of harnessing the different renewable energy resources.

Reference Books

1. B.H. Khan, “Non-Conventional Energy Resources” Tata McGraw-Hill Publishing Company Limited, 1st Edition, 2006.
2. Abbasi S.A, Abbasi Naseema, Renewable Energy Resources & Their Environmental Impact, Prentice Hall of India, 2001
3. G.D.Roy, Non-conventional Energy Sources, Khanna Publications, New Delhi, 2001
4. Ghosh.B.Saha, S.K.Basu, Sujay, Towards Clean Energy, Tata McGraw Hill, New Delhi, 1996
5. Garg.H.P, Prakash.J, Solar Energy, Tata McGraw Hill, New Delhi, 2000

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Energy Overview**	
1.1	Classification of Energy Resources, World energy status, Energy Scenario in India	1
1.2	Energy cycle of the earth, Environmental aspects of energy utilization	1
1.3	Renewable energy resources and their importance	1
2.0	**Solar Energy**	
2.1	Solar cells types, Characteristics, Insolation, MPPT	2
2.2	Standalone & Grid Connected Solar PV System Selection, Grid-Tie Inverter	2
2.3	Solar PV System Design	2
2.4	Operation and Maintenance	2
3.0	**Biomass Energy**	
3.1	Biofuels	1
3.2	Biomass Conversion technologies	1
3.3	Biogas Production	1
3.4	Ethanol Production	1
3.5	Pyrolysis and Gasification	2
3.6	Direct Combustion-Applications	1
4.0	**Geothermal Energy**	

4.1	Geothermal resources & basic theory	1
4.2	Types of turbines, Electric Power Generation	1
5.0	**Wind Energy**	
5.1	Nature & Origin of winds, Wind Potential Estimation,	1
5.2	Wind Power Calculation	2
5.3	Wind turbine types and construction,	1
5.3	Wind Turbine Ratings, Selection,	2
5.4	Latest trends and development in wind energy conversion	1
6.0	**Hydro Energy**	
6.1	Site selection for Small Scale Hydropower Plant, Run-off river plant	2
6.2	Turbines for Small Scale Hydro Plants	2
6.3	Role of Pumped storage power plants in Power System for Voltage and Frequency control	2
6.4	Problems in Small Scale and Pumped Storage Power Plant	1
7.0	**Ocean & Tidal Energy**	
7.1	origin of tides	1
7.2	power generation schemes from tides	2
7.3	Wave Energy & wave power devices	1
7.4	Introduction to Open and Closed OTEC cycles	1
8.0	**Environmental Aspects**	
8.1	Energy Payback period & Environmental Payback period, Potential impacts of harnessing the different renewable energy resources	2
	Total	**40**

Course Designers:

1. Dr. V.Saravanan vseee@tce.edu

14PSPN0	POWER QUALITY	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Power quality is the set of limits of electrical properties that allows electrical systems to function in their intended manner without significant loss of performance or life. The term is used to describe the electric power that drives an electrical load and the load's ability to function properly with that electric power.

The course will concentrate on:

a. Electrical power quality issues and power quality standards
b. Analysis of various PQ issues
c. Reduction of PQ problems using custom power devices and harmonic filters.

Prerequisite

- Power system modelling and analysis
- Power Electronics

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Describe the causes and effects of power quality problems and categorize the various electrical power quality issues in power systems	Understand
CO2.	Analyze the various PQ problems	Analyze
CO3.	Explain the conventional mitigation methods for PQ issues	Understand
CO4.	Design harmonic filter and custom power devices like DVR, D-STATCOM, UPQC for mitigating power quality problems	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S										
CO2.	S	M									
CO3.		L									
CO4.	S	S									

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	15	15
Understand	20	20	15	15
Apply	0	0	0	0
Analyse	30	30	40	40
Evaluate	30	30	30	30
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1)

1. Distinguish voltage imbalance and voltage fluctuations.
2. Explain the various PQ standards
3. Describe the effects of loads on the quality of power.
4. Explain the different types of transient over voltages.
5. What are the causes for voltage sag?

Course Outcome 2 (CO2)

1. Analyze the power outage using SAIFI for the following scenario: 30000 customers are served at a bus and 15000 customers are affected for 2 hours due to interruption.
2. Explain the analysis of voltage unbalance using instantaneous symmetrical components and instantaneous real and reactive powers.
3. Describe the extraction of fundamental sequence components from the samples of distorted voltage waveform.
4. A sag occurred in a three phase voltage waveform. The instant of the occurrence of the sag in the three phase is not the same. The peak values of the voltages in the three phases are 0.72pu, 0.9pu and 0.65pu respectively. Analyze the sag with suitable assumptions.

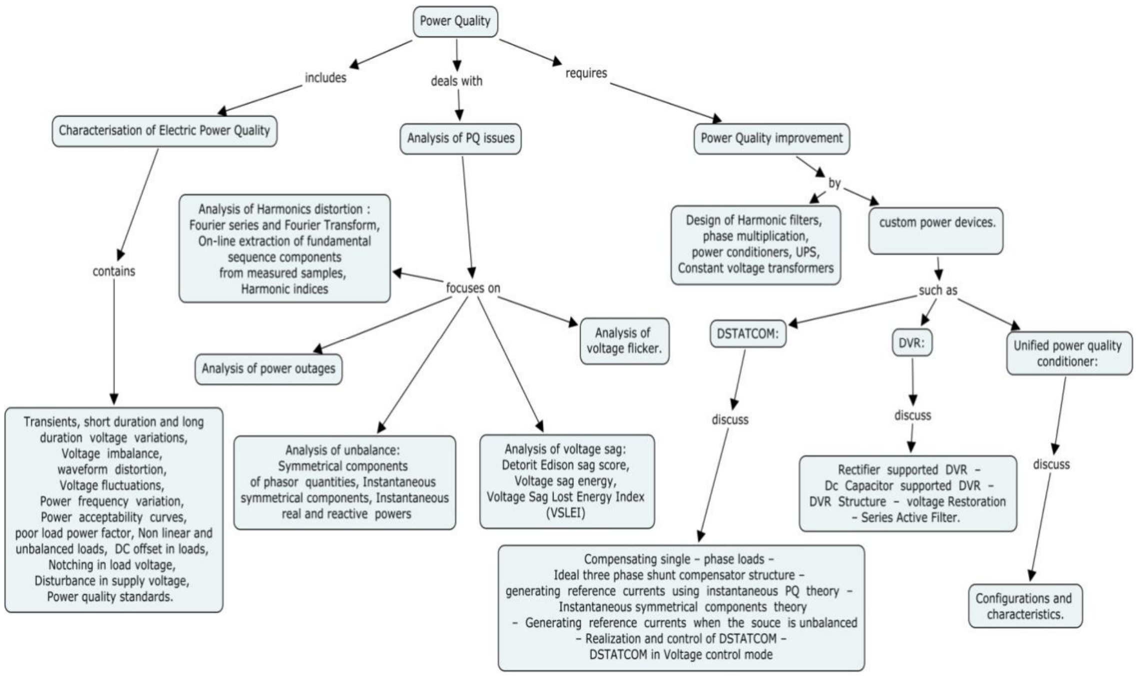
Course Outcome 3 (CO3)

1. Differentiate active and passive filters.
2. Explain the working of UPS .
3. Describe the mitigation of PQ issues using constant voltage transformers.
4. What is the role of custom power devices?

Course Outcome 4 (CO4)

1. Design a filter to attenuate the 5th, 7th, and 11th harmonics. Also design such that each filter section is tuned 4 percent below the filtered harmonic.
2. Design a filter to attenuate harmonic currents drawn from the line to comply with IEEE-519, Where the source is 277 V, line-to-neutral. The fundamental load current at 60 Hz is *IL* _ 100 A. This load also draws fifth-harmonic current I_5 _ 20 A and seventh-harmonic current I_7 _ 15 A.
3. Explain working principle and construction of D-STATCOM and also discuss how it is used for load compensation and voltage regulation in power system.
4. Discuss the issues related to voltage, current, power, energy and power factor measurements.
5. Describe the operation of UPQC and DVR. Also discuss how UPQC and DVR are used to mitigate power quality problems.

Concept Map



Syllabus

Characterisation of Electric Power Quality: Transients, short duration and long duration voltage variations, Voltage imbalance, Voltage fluctuations, Power frequency variation, Harmonics, Non linear and unbalanced loads, DC offset in loads, Notching in load voltage, Power acceptability curves, Power quality standards. **Analysis of PQ issues:** Analysis of Harmonics distortion: Fourier series and Fourier Transform, Harmonic indices, Analysis of power outages, Analysis of voltage sag: Detorit Edison sag score, Voltage sag energy, Voltage Sag Lost Energy Index (VSLEI), Analysis of voltage flicker.

Power Quality improvement: Passive and active harmonic filters, phase multiplication, power conditioners, UPS, Constant voltage transformers, Introduction to custom power devices. **DSTATCOM:** Compensating single – phase loads – Ideal three phase shunt compensator structure – generating reference currents using instantaneous PQ theory – Instantaneous symmetrical components theory – Generating reference currents when the source is unbalanced – Realization and control of DSTATCOM – DSTATCOM in Voltage control mode **DVR:** Rectifier supported DVR – DC Capacitor supported DVR – DVR Structure – voltage Restoration – Series Active Filter. **UPQC:** Configurations and characteristics.

Reference Books

1. Arindam Ghosh “Power Quality Enhancement Using Custom Power Devices”, Kluwer Academic Publishers, 2002
2. G.T.Heydt, “Electric Power Quality”, Stars in a Circle Publications, 1994(2^{nd} edition)
3. Barry W.Kennedy: Power Quality Primer, McGraw-Hill, New York, 2000
4. Sankaran.C: Power Quality, CRC Press, Washington D.C., 2002
5. Roger C. Dugan, Mark F. McGranaghan and H.Wayne Beaty: Electrical Power System Quality, McGraw-Hill, New York, 2nd Edition, 2002
6. Math H.J.Bollen, "Understanding Power Quality Problems: Voltage Sags and Interruptions", IEEE Press, New York, 2000
7. Arrillaga.J, Watson.N.R and Chen.S, "Power System Quality Assessment", John Wiley & Sons Ltd., England, 2000

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**Characterisation of Electric Power Quality**	
1.1	Transients, short duration and long duration voltage variations,	1
1.2	Voltage imbalance, waveform distortion, Voltage fluctuations,	1
1.3	Power frequency variation, Power acceptability curves,	1
1.4	poor load power factor, Non linear and unbalanced loads,	1
1.5	DC offset in loads, Notching in load voltage, Disturbance in supply voltage	1
1.6	Power quality standards.	1
2	**Analysis of PQ issues:**	
2.1	Analysis of Harmonics distortion: Fourier series and Fourier Transform	2
2.2	Harmonic indices	1
2.3	Analysis of power outages	1
2.4	Analysis of voltage sag: Detorit Edison sag score, Voltage sag energy, Voltage Sag Lost Energy Index (VSLEI)	1
2.5	Analysis of voltage flicker	1
3	**Power Quality improvement**	
3.1	Design of Harmonic passive filters	2
3.2	Analysis of active filter	1
3.3	Phase multiplication, power conditioners	1
3.4	UPS, Constant voltage transformers	1
3.5	Introduction to custom power devices	1
4	**DSTATCOM**	
4.1	Compensating single – phase loads	2
4.2	Ideal three phase shunt compensator structure – generating reference currents using instantaneous PQ theory	2
4.3	Instantaneous symmetrical components theory – Generating reference currents when the source is unbalanced	2
4.4	Realization and control of DSTATCOM	2
4.5	DSTATCOM in Voltage control mode	2
5	**DVR**	
5.1	Rectifier supported DVR	1
5.2	DC Capacitor supported DVR	1
5.3	DVR Structure – voltage Restoration	2
5.4	Series Active Filter	1
6	**Unified power quality conditioner**	
6.1	Configurations and characteristics	2
	Total	**35**

Course Designers:

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2. Dr.D.Kavitha dkavitha@tce.edu

14PSPP0	SOFT COMPUTING TECHNIQUES	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

The objective of this course is to introduce basic concepts and applications of soft computing tools such as neural networks, fuzzy logic systems, and genetic algorithms. Also it covers soft computing based solutions for real-world power system problems.

Prerequisite

- Prior knowledge of MATLAB software is required.
- 14PS120 Power system modelling and Analysis.

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Identify and describe soft computing techniques and their roles in building intelligent systems	Understand
CO2.	Recognize the feasibility of applying a soft computing methodology for a particular problem	Apply
CO3.	Apply fuzzy logic and reasoning to handle uncertainty and solve power system control problems	Apply
CO4.	Apply neural networks to load forecasting and modelling of power system	Apply
CO5.	Apply genetic algorithm to power system economic load dispatch(ELD) problem	Apply
CO6.	Use MATLAB Fuzzy logic, Neural network and GA toolboxes effectively to solve a given power system problem	Evaluate

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	L										
CO2.	M	S									
CO3.	S	S	S	M							
CO4.	S	S	S	M							
CO5.	S	S	S	M							
CO6.	S	S	S	S	S				M		S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3*	
Remember	10	10	0	10
Understand	10	10	0	40
Apply	30	30	20	50
Analyse	0	0	30	0
Evaluate	0	0	0	0
Create	0	0	0	0

*CAT 3 should be conducted as a practical examination for evaluating the attainment of CO6

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the role of soft computing tools in building intelligent systems.
2. Outline the use of soft computing tools in any two real-world systems
3. Explain the architecture of perceptron neural network.
4. Contrast between conventional logic and fuzzy logic
5. Compare the performance of conventional optimization technique and GA in solving real-world optimization problem.

Course Outcome 2 (CO2):

1. Explain where fuzzy logic can be used with a suitable example.
2. Compare the performances of soft computing tools.
3. Contrast between conventional optimization and genetic algorithms.
4. Choose the appropriate soft computing tool to solve the following problem :
   In a washing machine it is desired to determine wash cycle, wash time, temperature and water based on dirtyness of the clothes, type of clothes and number of clothes.
5. Select the appropriate soft computing tool for computer recognition of handwritten document

Course Outcome (CO3)

1. Define fuzzification and defuzzification
2. Explain the working of fuzzy logic controller with a neat block diagram
3. List the steps involved in the design of fuzzy logic controller
4. Compare the two types of fuzzy logic controller
5. The relationship between temperature and maximum operating frequency R depends on various factors for a given electronic circuit. Let $\tilde{T}$ be a fuzzy set (in degrees Fahrenheit) and $\tilde{F}$represent a frequency fuzzy set (in MHz) on the following universes of discourse:

   $$\underset{\sim}{T} = \{-100, -50, 0, 50, 100\} \quad \text{and} \quad \underset{\sim}{F} = \{8, 16, 25, 33\}.$$

   $$\underset{\sim}{R} = \begin{array}{c} \\ 8 \\ 16 \\ 25 \\ 33 \end{array} \begin{array}{c} \begin{array}{ccccc} -100 & -50 & 0 & 50 & 100 \end{array} \\ \begin{bmatrix} 0.2 & 0.5 & 0.7 & 1 & 0.9 \\ 0.3 & 0.5 & 0.7 & 1 & 0.8 \\ 0.4 & 0.6 & 0.8 & 0.9 & 0.4 \\ 0.9 & 1 & 0.8 & 0.6 & 0.4 \end{bmatrix} \end{array} \qquad \underset{\approx}{S} = \begin{array}{c} \\ -100 \\ -50 \\ 0 \\ 50 \\ 100 \end{array} \begin{array}{c} \begin{array}{ccccc} 1 & 2 & 4 & 8 & 16 \end{array} \\ \begin{bmatrix} 1 & 0.8 & 0.6 & 0.3 & 0.1 \\ 0.7 & 1 & 0.7 & 0.5 & 0.4 \\ 0.5 & 0.6 & 1 & 0.8 & 0.8 \\ 0.3 & 0.4 & 0.6 & 1 & 0.9 \\ 0.9 & 0.3 & 0.5 & 0.7 & 1 \end{bmatrix} \end{array}$$

   Suppose a Cartesian product between $\tilde{T}$ and $\tilde{F}$ is formed that results in the following relation$\tilde{R}$ The reliability of the electronic circuit is related to the maximum operating temperature. Such a relation $\tilde{S}$ can be expressed as a Cartesian product between the reliability index, $\widetilde{M}$ = {1, 2, 4, 8, 16} (in dimensionless units), and the temperature: Find a relationship between frequency and the reliability index, use (a) max–min composition (b) max–product composition.

6. Design a fuzzy logic based power system stabilizer (FPSS) with the generator speed deviation and its derivative, the acceleration, as the inputs and output of the controller as output gain. Take input range as [-1.2 to 1.2] and output as [-0.1 to 0.1]. Convert each input variables into seven linguistic variables of symmetrical and 50% overlap. Represent output as constant. Write all the 49 rules with the use of sample rules shown in Table 6.

Table 6. Sample fuzzy rules for FPSS

	NB	NM	NS	Z	PS	PM	PB
NB				NM			
NM				NM			
NS				NS			
Z				Z			
PS				PS			
PM				PM			
PB				PM			

Course Outcome (CO4)

1. Explain supervised and unsupervised learning
2. List the different types of activation functions used in ANN
3. Describe BPN architecture with a neat sketch and explain the steps involved in the training of the network
4. Develop a suitable perceptron neural network model to perform the following classification problem. The vectors (1,1,1,1) and (-1,1,-1,-1) for belonging to the class (target value 1) vectors (1,1,1,-1) and (1,-1,-1,1) for not belonging to the class (target value -1).
5. Develop a BPN architecture for the following short-term load forecasting problem
   A 12 hour load pattern on a particular day is given below and predict the remaining 12 hour load on that day

Hour	1	2	3	4	5	6	7	8	9	10	11	12
Load (MW)	11178	10695	12097	12161	12210	12260	12215	10427	11405	12488	12527	12383

Course Outcome (CO5)

1. List the various operators used in GA
2. Explain the importance of selection operator in GA.
3. Explain the role of reproduction operator in GA
4. Explain the various steps involved in solving ELD using GA
5. Perform two generations of simple binary coded genetic algorithm to solve the following optimization problem. Maximize $f(x) = x^2$ $0 \le x \le 31$, x is an integer.
   Use proportionate selection, single point crossover, binary mutation and population size of six.
6. Solve the given ELD problem using GA for one generation.

Three generators are having the following cost functions and power limits:

Fuel Cost($/h)	Minimum (MW)	Maximum (MW)
$F_1(P_1) = 0.0020P_1^2 + 8.72P_1 + 180$	45	350
$F_2(P_2) = 0.0082P_2^2 + 6.40P_2 + 743$	45	350
$F_3(P_3) = 0.0022P_3^2 + 6.75P_3 + 360$	47.5	450

Total load in the system is 500 MW. Assume that each of the three units is running all the time.

Course Outcome (CO6)

(For evaluating the attainment of CO6 , practical examination should be conducted)

1. Evaluate the performance of the fuzzy logic controller over PI controller for the given power system problem

2. Evaluate the performance of the Perceptron neural network for the given power system problem
   The system data for a load flow solution are given in following tables 1 and 2

Table 1 Line admittance
s

BUS Code	Admittance (p.u)
1-2	2-j8
1-3	1-j4
2-3	0.666-j2.664
2-4	1-j4
3-4	2-j8

Table 2 schedule of active and reactive powers

Bus code	P in p.u	Q in p.u	V in p.u	Remarks
1	-	-	1.06	Slack
2	0.5	0.2	1+j0	PQ
3	0.4	0.3	1+j0	PQ
4	0.3	0.1	1+J0	PQ

Determine the voltages at the end of first iteration using Gauss Seidal method. Take α=1.6.
Train the neural network for the load pattern suitably and obtain the load voltages

3. Perform simple binary coded and real coded genetic algorithm to solve the following optimization problem.
   Maximize f(x) = |x| sin(x) -5≤ x≤ 5, x is real number.
   Use proportionate selection, single point crossover, and binary mutation for simple GA and proportionate selection, Arithmetic crossover, and Gaussian mutation for RGA. Evaluate the performance of SGA and RGA after a fixed number of generations with equal population size.

4. Evaluate the performance of the GA for solving the given power system economic dispatch problem as compared to the gradient methods.

Three generators are having the following cost functions and power limits:

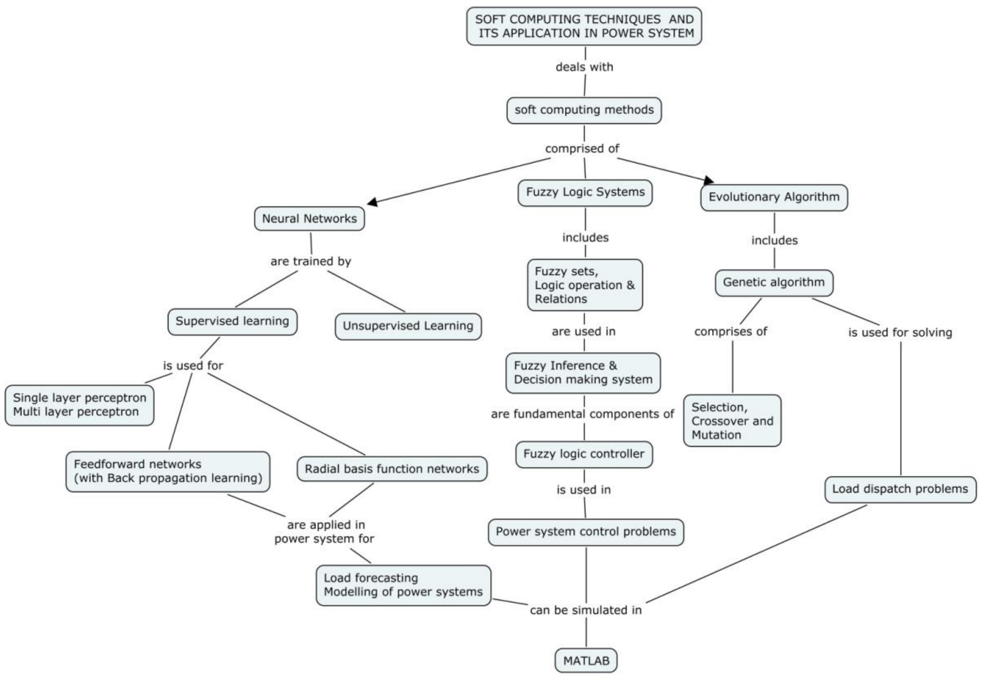
Fuel Cost($/h)	Minimum (MW)	Maximum (MW)
$F_1(P_1) = 0.00525P_1^2 + 8.66P_1 + 328$	50	250
$F_2(P_2) = 0.00608P_2^2 + 10.04P_2 + 137$	5	150
$F_3(P_3) = 0.00591P_3^2 + 9.76P_3 + 59$	15	100

The B-coefficients are given by,

$$B=\begin{bmatrix} 1.36255\,x10^{-4} & 1.753x10^{-5} & 1.8394x10^{-4} \\ 1.753\,x10^{-5} & 1.5448\,x10^{-4} & 2.82765\,x10^{-4} \\ 1.8394\,x10^{-4} & 2.82765\,x10^{-4} & 1.6147\,x10^{-3} \end{bmatrix}$$

Neglect B_0 and B_{00}. The total load in the system is 190 MW. Assume that each of the three units is running all the time.

Concept Map



Syllabus

Introduction to soft computing and its role in building intelligent systems-Need of soft computing tools-Merits and demerits-Fuzzy logic, Neural network, and Genetic algorithms

Fuzzy sets, logic operations, and relations; Fuzzy decision-making; fuzzy inference systems; design steps in fuzzy logic controller; application of fuzzy logic controller in power system

Neural networks: Basic concepts and major classes of neural networks, supervised and unsupervised learning, Single-layer perceptron, Multi-layer perceptron, Back Propagation Neural network, Radial-basis function networks; Application of neural network to load forecasting and modelling of power system

Introduction to genetic algorithms; genetic algorithm steps-Selection, Crossover and Mutation; Application of GA to power system economic dispatch problem

Use of MATLAB Fuzzy logic, Neural network and GA toolboxes to solve power system problems.

Reference Books

1. George J.Klir and, Bo Yuan, Fuzzy sets and Fuzzy Logic, Second Edition, PHI,2006
2. J.M.Zurada, Introduction to artificial neural systems, Jaico Publishing House, 2006
3. D.E. Goldberg, Genetic algorithms in search, optimization, and machine learning, Addison-Wesley.1989.

4. S.N.Sivanandam, and S.N.Deepa, Principles of Soft computing, Second Edition, Wiley India Pvt. Ltd,2013

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	Introduction to soft computing and its role in building intelligent systems	1
2	Need of soft computing tools	1
3	Merits and demerits	1
4	Basics of Fuzzy logic, Neural network, and Genetic algorithms	3
5	Fuzzy sets, logic operations, and relations	2
6	Fuzzy decision-making	1
7	fuzzy inference systems	1
8	design steps in fuzzy logic controller;	1
9	application of fuzzy logic controller in power system	2
10	Neural networks: Basic concepts and major classes of neural networks,	2
11	supervised and unsupervised learning,	1
12	Single-layer perceptron, Multi-layer perceptron	2
13	Back Propagation Neural network,	2
14	Radial-basis function networks	1
15	Application of neural network to load forecasting and modelling of power system	2
16	Introduction to genetic algorithms;	1
17	genetic algorithm steps-Selection,Crossover and Mutation;	2
18	Application of GA to power system economic dispatch problem	2
19	Use of MATLAB Fuzzy logic, Neural network and GA toolboxes to solve power system problems	8
	Total	**36**

Course Designers:

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14PSPQ0 /14CIPA0	CONTROL OF ELECTRIC DRIVES	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Electrical drives play an important role as electromechanical energy converters in transportation, material handling and most production processes. The ease of controlling electrical drives is an important aspect for meeting the increasing demands by the user with respect to flexibility and precision, needed by technological progress in industry as well as the need for energy conservation. A drive may require a control of torque, acceleration, speed or Position. The field of controlled electrical drives has undergone a rapid expansion mainly due to the advances of semiconductors in the form of power electronics as well as analogue and digital signal electronics. The introduction of electronically switched solid-state power converters has created new and difficult control problems to the electric drives.

Prerequisite

- DC Machines and transformers
- AC Machines
- Electric Drives & control

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	know the operations of different types of DC, AC motors and special machines	Understand
CO2.	Explain the different speed control and braking methods of motors	Understand
CO3.	Find out the torque and speed for different loading conditions	Apply
CO4.	Explain the different converters operation with motor loads	Understand
CO5.	Explain the different digital control methods for the DC, AC motors and special machines	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	M									
CO2.	S										
CO3.	M		S	S							
CO4.	S										
CO5.	S	M			M						

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	30	30	30
Understand	40	40	40	40
Apply	30	30	30	30

Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List the advantages of variable frequency drives.
2. Name the types of stepper motor drive.
3. List the advantages of load commutated inverter fed BLDC drive.
4. Explain the different methods of speed control of DC motor

Course Outcome 2 (CO2):

1. Name the various blocks in closed loop drives.
2. What is meant by v/f control?
3. Draw a simple circuit of speed control by current limit control to illustrate the closed loop performance of dc drive.
4. Explain the different types of braking of DC and AC motor.

Course Outcome 3 (CO3):

1. A 3-phase, 50KW, 1470rpm, 400V, 50Hz, 4 pole Y-connected induction motor has the following data : R_s =0.42 Ω, R_r =0.23Ω, X_s =0.95 Ω, X_r =0.85 Ω and X_m =28Ω, all the quantities being referred to the stator side. The motor is operated with frequency control. If the slip for maximum torque at the given supply frequency 0.12, determine a) supply frequency b) breakdown torque c) The speed at maximum torque.
2. A 460 V, 60Hz, 6 pole, 1180 rpm, Y-connected squirrel cage induction motor has the following parameters per phase referred to the stator: R_s =0.19 Ω, R_r' =0.07Ω, X_s =0.75 Ω, X_r' =0.67 Ω and X_m =20Ω. The motor is fed by a 6-step inverter, which in turn is fed by a 6-pulse fully controlled rectifier and the motor is operated at constant v/f ratio , calculate the inverter frequency and the stator current at half the rated torque and 500 rpm. Neglect derating due to harmonics.

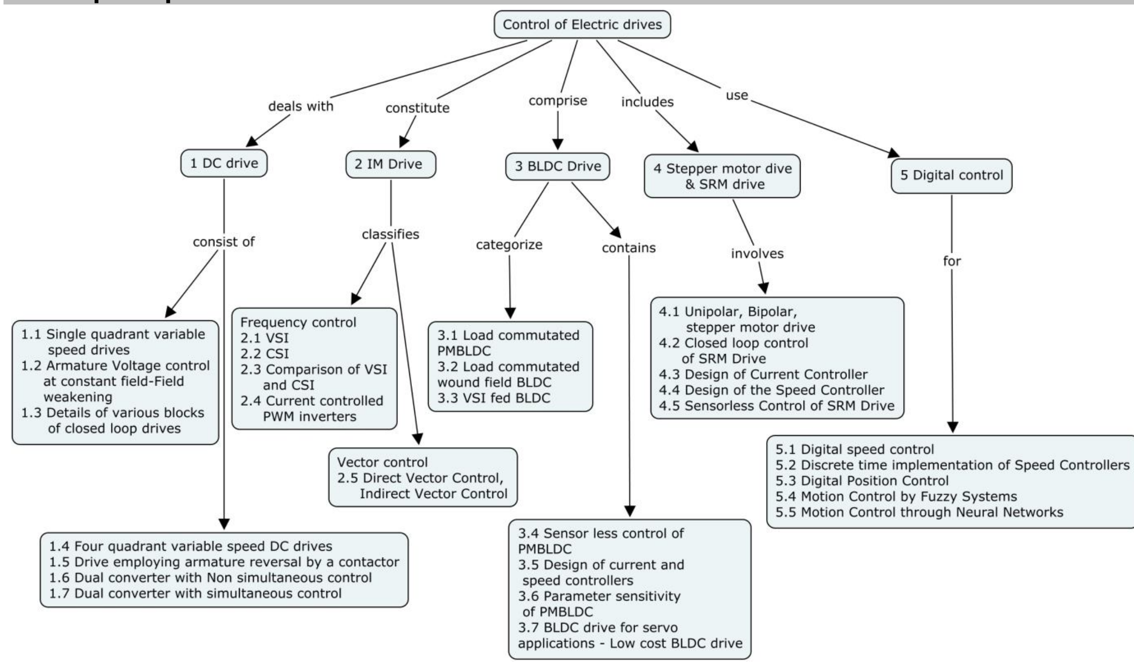
Course Outcome 4 (CO4):

1. With the neat block diagram explain the operation of closed loop speed control with inner current loop and field weakening.
2. Explain how four quadrant operation is achieved by dual converters, each of 3-phase full wave configuration, for a dc motor.
3. With neat block diagram explain the operation of closed loop variable frequency drive using current controlled PWM inverter.
4. Describe the operation of wound field BLDC motor drive with constant margin angle control.

Course Outcome 5 (CO5):

1. Implement the digital speed controllers in a closed loop operation of drive system.
2. Identify the blocks in digital position control.
3. Explain the different digital control methods for motor control.

Concept Map



Syllabus

CONTROL OF DC DRIVES

Single quadrant variable speed drives-Armature Voltage control at constant field- Field weakening- Details of various blocks of closed-loop drives - Four quadrant variable speed DC drives- Drive employing armature reversal by a contactor, Drive employing a Dual converter with Non simultaneous control, Drive employing a Dual converter with simultaneous control.

CONTROL OF INDUCTION MOTOR DRIVES

Voltage Source Inverter fed Variable frequency drives - Current Source Inverter fed Variable frequency drives – Comparison of Voltage source and Current source inverter drives-Closed loop variable frequency drive using Current controlled PWM inverters - Vector controlled Induction Motor drives- Direct Vector Control, Indirect Vector Control.

CONTROL OF BLDC DRIVES

Load commutated Permanent Magnet brushless dc motor drive- Load commutated wound field brushless dc motor drive - Voltage source inverter fed BLDC motor drive- Sensor less control of PMBLDC drive- Design of current and speed controllers - Parameter sensitivity of PMBLDC drive – BLDC drive for servo applications - Low cost BLDC drive.

STEPPER MOTOR DRIVE AND SRM DRIVE

Stepper Motor Drive- Unipolar drive, Bipolar drive - Control of SRM Drive - Closed-Loop, Speed Controlled SRM Drive - Design of Current Controller - Design of the Speed Controller- Sensorless Control of SRM Drive.

DIGITAL CONTROL OF DRIVES

Digital Speed Control- Discrete time implementation of Speed Controllers- Digital Position Control- Motion Control by Fuzzy Systems- Motion Control through Neural Networks.

Reference Books

1. G.K. Dubey, 'Power Semiconductor Controlled Drives', Prentice Hall, N. Jersey, 1989.
2. R.Krishnan, 'Electric Motor Drives', PHI Learning Pvt. Ltd., 2001.

3. G.K. Dubey, 'Fundamentals of Electrical Drives', Narosa Publishing House, Second Edition, 2001.
4. Slobodan N. Vukosavic, 'Digital Control of Electrical Drives', Springer, 2007.
5. Ion Boldea, Syed A. Nasar, 'Electric Drives', Second Edition, CRC Press, 1999
6. R. Krishnan 'Switched Reluctance Motor drives', CRC Press , 2001.
7. Jacek F Gieras , 'Permanent Magnet Motor Technology Design and Applications', Third Edition, CRC Press, 2010.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**CONTROL OF DC DRIVES**	
1.1	Single quadrant variable speed drives	2
1.2	Armature Voltage control at constant field-Field weakening	2
1.3	Details of various blocks of closed-loop drives	2
1.4	Four quadrant variable speed DC drives	1
1.5	Drive employing armature reversal by a contactor	1
1.6	Drive employing a Dual converter with Non simultaneous control	1
1.7	Drive employing a Dual converter with simultaneous control	1
2	**CONTROL OF INDUCTION MOTOR DRIVES**	
2.1	Voltage Source Inverter fed Variable frequency drives	1
2.2	Current Source Inverter fed Variable frequency drives	1
2.3	Comparison of Voltage source and Current source inverter drives	1
2.4	Closed loop variable frequency drive using Current controlled PWM inverters	2
2.5	Vector controlled Induction Motor drives- Direct Vector Control, Indirect Vector Control	2
3	**CONTROL OF BLDC DRIVES**	
3.1	Load commutated Permanent Magnet brushless dc motor drive	1
3.2	Load commutated wound field brushless dc motor drive	1
3.3	Voltage source inverter fed BLDC motor drive	1
3.4	Sensor less control of PMBLDC drive	2
3.5	Design of current and speed controllers	1
3.6	Parameter sensitivity of PMBLDC drive	1
3.7	BLDC drive for servo applications - Low cost BLDC drive	2
4	**STEPPER MOTOR DRIVE AND SRM DRIVE**	
4.1	Stepper Motor Drive- Unipolar drive, Bipolar drive	2
4.2	Control of SRM Drive - Closed-Loop, Speed Controlled SRM Drive	2
4.3	Design of Current Controller	1
4.4	Design of the Speed Controller	1
4.5	Sensorless Control of SRM Drive	1
5	**DIGITAL CONTROL OF DRIVES**	
5.1	Digital Speed Control	1
5.2	Discrete time implementation of Speed Controllers	1
5.3	Digital Position Control	1
5.4	Motion Control by Fuzzy Systems	2
5.5	Motion Control through Neural Networks	2
	Total	**40**

Course Designer:

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